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Interaction and Interdependency of Software Engineering Methods and Visual Programming

Robert A. Touchton
University of North Florida

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Interaction and Interdependency of Software Engineering Methods and Visual Programming Languages/Tools

by

Robert A. Touchton

A thesis submitted to the Department of Computer and Information Sciences in partial fulfillment of the requirements for the degree of

Master of Science in Computer and Information Sciences

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DEPARTMENT OF COMPUTER AND INFORMATION SCIENCES

April, 1995
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I especially must thank Ken Wilson, Maureen Page, and Ray Schafer for the hours they spent with me as Peer Reviewers. They each added a real-world flavor to this effort along with a sense that the results can be of benefit to fellow software engineering practitioners.

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ABSTRACT

Visual Programming Languages and Visual Programming Tools incorporate non-procedural coding mechanisms that may duplicate, or perhaps even conflict with, the analysis and design mechanisms promulgated by the mainstream Software Engineering methodologies. By better understanding such duplication and conflict, software engineers can take proactive measures to accommodate and, ideally, eliminate them. Better still, there may be opportunities for synergy that can be exploited if one is looking for them.

This research explored, documented and classified the interactions and interdependencies, both positive (synergies) and negative (conflicts), between two closely related and rapidly evolving Computer Science subdisciplines: software engineering and visual programming. A literature search was conducted to surface, evaluate, and build upon (where appropriate) recent and ongoing research in this area. A mechanism was created to capture observations of conflicts and synergies. This capture mechanism was applied to an experimentation test bed that was established to provide concrete examples of gaps, overlaps, conflicts, and synergies. In this regard, two relatively simple applications, one data-base oriented
and one algorithm oriented, were designed and implemented using multiple software engineering methods and multiple visual tools/languages.

A software prototype, which bridges one of the gaps discovered during the research, was built to underscore the importance of eventually merging Computer Aided Software Engineering and visual development tools. The overall results as well as anticipated trends and developments in the area of software engineering and visual programming were summarized. The synergy/conflict observations, in conjunction with the literature search results, were used to develop strategies and guidelines for successfully using visual programming languages and tools in concert with sound software engineering methods.
Chapter 1

INTRODUCTION

Visual Programming Languages (VPLs), such as Visual Basic and Visual C++, and Visual Programming Tools (VPTs), such as ObjectVision and PowerBuilder, incorporate non-procedural coding mechanisms. Some of these mechanisms may duplicate, or perhaps even conflict with, the analysis and design mechanisms promulgated by the mainstream Software Engineering methodologies, such as Gane & Sarson or Coad/Yourdon [Pressman92]. By better understanding such duplication and conflict, software engineers can take proactive measures to accommodate and, ideally, eliminate them. Better still, there may be opportunities for synergy which can be exploited if one is looking for them.

VPLs and VPTs have been made possible by the maturation of Object-Oriented Programming constructs, leading to a strong correlation between the use of these new tools and OOP. Indeed, every one of the languages and tools studied rely strongly upon OOP for their internal design and operation (although they may differ in the degree to which they make OOP constructs available to application developers) [West92]. Therefore, this work was conducted with a
backdrop of object-orientation. However, the focus is on identifying and resolving gaps, conflicts and synergies between the use of structured, formal Software Engineering methods and the use of VPLs and VPTs.

1.1 Statement of Problem

The importance and use of VPLs and VPTs is growing at a rapid pace both locally and nationally. A recent issue of Computer Magazine devoted over 50 pages to visual programming [IEEE95]. In the past 36 months, the number of Jacksonville-based companies seriously using visual development software has climbed from perhaps one or two to dozens (based on a non-scientific review of Florida Times-Union classified ads which mention one or more of the recognized visual programming tools/languages). Similarly, a casual search of the internet for job postings which mention such languages and tools returns hundreds of hits (just looking at the IEEE Careers, Career Mosaic and the "Monster" Board on the world wide web). At the same time, more and more companies are adopting formal software engineering methodologies, usually in the form of a commercially offered CASE (Computer Aided Software Engineering) tool. Personal experience gained in the author's work environment has increased his awareness of inconsistencies between these two Computer Science
subdisciplines. He also became convinced that positive steps can and should be taken to ensure that the benefits from both of these technological advancements are realized. This conviction forms the basis of this research.

The need for substantial advances was foreshadowed in Lowry’s 1992 article in AI Magazine where he suggested that current CASE tools were shallow, that the latest programming environments were good for prototyping but lacked the ability to produce efficient, production-quality code and that perhaps the use of artificial intelligence could close the gap [Lowry92]. More recently, the gap between CASE tools and implementation tools have been editorialized in software engineering trade journals. For example, in one issue of Software Development magazine, Larry Constantine emphasizes the importance of one day being able to program by drawing models of the target application[Constantine94] and Larry O’Brien points how event-driven architectures, visual programming aids and the like have seriously challenged the traditional CASE tools[O’Brien94].

Inconsistencies may manifest themselves as conflicts, gaps, or overlaps in screen layout, process diagrams, Entity-Relationship Diagrams, or Data Dictionaries. Synergies take shape as opportunities for direct program generation.
and rapid prototyping, as well as improved communication with end users; the day may come where end-users can use a VPT to build their own prototype as a starting point for implementation by a central IS group.

An example of a conflict would be writing a traditional Program Flow Chart only to find out that the VPT must approach the flow of control in a completely different way. Consider the fact that ObjectVision relies on two event-driven program flow mechanisms, neither of which have a direct mapping from a traditional flow chart: "when-changed" methods attached to data elements and "logic trees" for responding to user- and application-generated messages. The flow chart, while useful for communicating desired program behavior, will provide little or no insight about how to implement that behavior. A similar case can be built for pseudocode. To turn the example into one of synergy, imagine that the designer had been able to access a tree-like representation to devise and communicate the program flow of control. This would provide insight into its implementation in addition to its desired behavior. Perhaps the software engineering method could be modified to actually embrace the visual event trees of ObjectVision as its program flow representation.
1.2 Research Plan

During the formative stages of this research, the author proposed a definitive series of steps aimed at ensuring that the effort would be of graduate-level quality and content and that the objectives of the effort would be achieved. Upon consultation with the Thesis Committee, a final research plan was established, as reflected in the following steps:

1. Devise a problem classification scheme and mechanism for capturing and documenting conflicts (e.g., gaps or overlaps) and synergies (smooth transitions and cooperation) between software engineering methods and implementation languages and tools

2. Review and evaluate modern software engineering methodologies

3. Review and evaluate visual programming languages and tools

4. Create a controlled experimentation test bed to provide concrete, working examples of interactions and interdependencies in the form of gaps, overlaps, conflicts, and synergies
5. Develop a prototypical bridge for generating Graphic User Interface Screens in the "native tongue" of a visual programming language based on screens designed in a CASE tool.

6. Evaluate and Document Results, including a summary of major trends and guidelines for avoiding problems and ensuring synergies.

The objective of this research was to explore, document and classify the interactions and interdependencies, both positive (synergies) and negative (conflicts), between two closely related and rapidly evolving Computer Science subdisciplines: software engineering and visual programming.

1.3 Literature Search

One element of the research effort was conduct of a literature search to surface, evaluate, and build upon (where appropriate) recent and ongoing research in this area. Much of the fruit of that search is embodied in this thesis. Most of the remainder of the information found was of general or bibliographic value, but not suitable for direct reference.
The literature search included Journals, such as the Journal of Visual Languages and Computing and IEEE Transactions on Software Engineering, Transactions/Proceedings, such as ACM Transactions on Programming Languages and Systems, Texts, such as Object Oriented Design with Applications by Booch [Booch91], and Code Complete, by McConnell [McConnel1993]. The effort also included a search of the internet, using archie.

1.4 Summary of Results

Chapter 2 describes the problem classification scheme and observation collection mechanism called for in the first Step. Problem groupings, as well as areas of cooperation, arising between the software engineering methods and the visual programming languages and tools are identified. A data base tool to facilitate the capturing of conflict and synergy observations is also described.

The results of the second step of the Research Plan are presented in Chapter 3. The treatment briefly discusses those traditional and object-oriented software engineering methods used in this study, along with a summary of their notation and use. A section on the CASE tool used for portions of this effort is also provided.
The results of step 3 are included in Chapter 4, which provides a synopsis of the visual programming languages and tools evaluated along with an overview of visual programming. The treatment briefly compares and contrasts the various tools and languages and, for ones not used in the test bed, provides specific examples of areas which make these software packages unique. Since the maturity of the desired guidance required immersion in the selected language/tools, attention was paid to the mechanics and details of their operation. Generalizations could then be drawn from the specific experiences in their use.

During step 4, two test applications were defined: one database-oriented and one algorithmic in nature. Then, two software engineering methods were selected, one used for each application (see Table 1). Finally, one visual programming language and two visual programming tools were selected and each application was implemented using the VPL and one VPT (see Table 1). As the applications were designed and implemented, the capture mechanism from step 1 was applied. Table 1 summarizes the test bed resulting from step 4 of the Research Plan, while Chapter 5 and Appendices A through F present it in detail.

The software bridge between the System Architect CASE tool and Visual Basic, resulting from step 5, are presented in
Chapter 6 and Appendix G. The bridge points to the importance of eventually merging Computer Aided Software Engineering and visual development tools.

The results of step 6 are presented in Chapter 7 and Appendices H and I. Because of the impact on this research of the rapidly changing software development environment, a treatment on current trends and developments was compiled. The synergy/conflict observations, in conjunction with the literature search results, were used to develop strategies and guidelines for successfully using visual programming languages and tools in concert with sound software engineering methods. The guidelines were segmented based on type of problem being addressed. Finally, the overall effort and its contribution to future efforts are summarized.

<table>
<thead>
<tr>
<th>Application Type</th>
<th>Application Name</th>
<th>Software Engineering Methodology</th>
<th>Implementation Language</th>
<th>Implementation Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Base - Oriented</td>
<td>Customer Problem Tracking System</td>
<td>Gane &amp; Sarson DFDs plus ERDs</td>
<td>Visual Basic</td>
<td>ObjectVision</td>
</tr>
<tr>
<td>Algorithm - Oriented</td>
<td>Tic-Tac-Toe</td>
<td>Coad/Yourdon</td>
<td>Visual Basic</td>
<td>Smart Elements</td>
</tr>
</tbody>
</table>

Table 1: Experimentation Test Bed Matrix
Chapter 2

Conflict/Synergy Capture Mechanism

During the planning stages of the research, it was recognized that there needed to be a formal mechanism in place to assist the author in capturing and distilling the examples of conflict and synergy that were to be sought ("self observations"). Therefore, the premise that conflict and synergy should be detectable was carried to more specific categories, as discussed in Section 2.1. These classifications would then be used to create a data base which would serve both as a repository of experiment observations and as a prompting device to elicit a consistent slate of information about each observation (Section 2.2). As the research moved into the experimentation phase, it was further decided that the observation data base would be altered slightly to enable it to be used to elicit information from working practitioners using similar combinations of CASE tools and VPTs ("peer observations").
2.1 Conflict/Synergy Classifications

The issues that might be encountered during visual development were classified into two major categories, Structural and Behavioral, each with three subcategories. As shown in Table 2, types of conflicts and synergies were identified for each subcategory (where applicable) and specific examples given.

<table>
<thead>
<tr>
<th>Category</th>
<th>Conflict</th>
<th>Synergy</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STRUCTURAL:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Interface Layout</td>
<td>Duplication of Effort</td>
<td>Automation of Effort</td>
<td>(-) Sketch in CASE (or on paper), then re-sketch in the tool or language &lt;br&gt; (+) Sketch in CASE with generation of screens in the tool or language</td>
</tr>
<tr>
<td>DB Schema Design</td>
<td>Tool/Language Does Not Support the Schema</td>
<td>Automation of Effort</td>
<td>(+) Design Schema in CASE with generation DB structures in the tool or language &lt;br&gt; (-) Relational Design, but tool or language only supports &quot;flat&quot;</td>
</tr>
<tr>
<td>Object Representation</td>
<td>Tool/Language Does Not (fully) Support</td>
<td>Full Object-Oriented Environment</td>
<td>(+) Developer-definable objects/attributes with multiple inheritance, such as C++ &lt;br&gt; (-) Limited ability to create/use objects, such as Visual Basic</td>
</tr>
<tr>
<td><strong>BEHAVIORAL:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service/Utility Modules</td>
<td>Designing Modules that are already &quot;Built-In&quot; to the Tool/Language</td>
<td>Utilizing Them</td>
<td>(+/-) File Browser; Print Setup</td>
</tr>
<tr>
<td>Function/Routine Design</td>
<td>Tool/Language Does Not Support the Concept</td>
<td>Tool/Language Strongly Supports the Concept</td>
<td>(+) Time Object in VB &lt;br&gt; (+) Dealing with time in OV</td>
</tr>
<tr>
<td>Event-Based Design</td>
<td>SE Methods are limited</td>
<td>Strong Support from Modern Tools and Languages</td>
<td>(+/-) See Pressman's Watch example on [Pressman92, pp. 495-497]</td>
</tr>
</tbody>
</table>

Table 2: Visual Development Conflicts/Synergy Matrix
2.2 Conflict/Synergy Observation Data Forms

The content of the classification scheme was used to derive a series of data elements and types of textual information that ought to be collected for each observation of a conflict or synergy. These elements were used in turn to create a data base and corresponding GUI. Figure 1 shows a typical data form as it looks in the GUI. ObjectVision, which was used to create the application, has the ability to print out the data base as a series of sheets that look like the data entry form. The possible or likely values of the data elements were used to populate pull-down menus and to create the check boxes seen in the figure.
During the completion of the experimentation test bed (see next Chapter), the "self observation" forms were filled out soon after each conflict or synergy was encountered. The "peer observation" version of the forms were used in an interview setting. The author described the premise and nature of the study, presented the preliminary results, and then encouraged the participant to fill out a data form for each memorable example of a conflict or synergy within the scope of the research. A "Quick Reference Guide," shown in Figure 2, was developed to help peers when filling out the forms.
<table>
<thead>
<tr>
<th><strong>Synergy/Conflict Observation Quick Reference Guide</strong></th>
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<tbody>
<tr>
<td><strong>Observation Type:</strong></td>
</tr>
<tr>
<td><strong>Project:</strong></td>
</tr>
<tr>
<td><strong>Category:</strong></td>
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<tr>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
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<tr>
<td><strong>Number of Times Observed:</strong></td>
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<td><strong>SE Application:</strong></td>
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<td><strong>SE Method:</strong></td>
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<tr>
<td><strong>Visual Tool:</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
</tr>
<tr>
<td><strong>Circumstances:</strong></td>
</tr>
<tr>
<td><strong>Guidance Ideas:</strong></td>
</tr>
</tbody>
</table>

*Figure 2: Peer Observation Handout*
Chapter 3

Software Engineering Methodologies and CASE Tools

Software Engineering can be defined as "the establishment and use of sound engineering principles in order to obtain economically software that is reliable and works efficiently on real machines," and comprises three key elements: methods, tools, and procedures [Pressman92, pp. 23-24]. There is a wide variety of Software Engineering techniques and methodologies in current use by Computer Scientists in both academic and commercial settings. These techniques and methodologies address a wide range of issues, including project planning, management and estimation, software quality and testing and detailed software design and implementation. However, the focus of this investigation is the areas of requirements analysis and high-level design. Some methods are very formal and structured, while others are more heuristic in nature, providing good practice guidelines.

The sections that follow highlight the software engineering methods and tools used in conducting the research for this thesis. Section 3.1 provides a general synopsis of the various methods and tools evaluated. Section 3.2 addresses
the more traditional techniques used to support the data base applications. Section 3.3 looks at the object-oriented/event-based techniques used for the algorithmic applications. Section 3.4 explores the CASE tool used for portions of the work.

3.1 Synopsis of Software Engineering Methodologies and CASE Tools Evaluated

Each method has associated with it a set of tools, whether applied manually, automatically, or both, which manifests a special language or graphical notation. The more widely used methods have been integrated with one another and incorporated into Computer Aided Software Engineering (CASE) tools. Two of the most widely used methods, Data Flow Diagrams and Entity-Relationship Diagrams, are described in section 3.2. Several other mainstream methods were evaluated for use in the data base-oriented application but were eliminated based on either unnecessary complexity for the target problem or focus upon areas irrelevant to the target problem. For example, a State Transition Diagram (STD) can be developed to identify the possible states of each data entity and the allowed transitional events that can cause the state to change. However, an STD for the Customer Support Tracking System would have been trivial and of little value to the research. Likewise, a Ward and Mellor real-time analysis
can be conducted to identify time-based processes and interfaces to physical devices. However, the intended system exhibited no complex real-time behaviors, rendering a Ward and Mellor analysis useless.

Several object-oriented software engineering methods were also evaluated. Coad/Yourdon, the one selected for the Tic Tac Toe game, is described in section 3.3. Two other methods, Rumbaugh and Booch, were investigated. Each of the three has its own style and approach to object-oriented analysis and design, with no one method appearing stronger than the others. Therefore, the selection of Coad/Yourdon was primarily based on the author’s prior exposure to it.

Commercial-grade CASE tools are now widely available, with a wide range in both capabilities and price. High-end tools, such as IEF by Texas Instruments and HPS by SEER, are extremely robust and powerful within the framework of their intent (e.g., legacy or mainframe data bases), and typically include a high degree of support for team programming and automation of production tasks. Such tools also bring with them a high per-developer price tag, typically above $10,000. Unfortunately, the high-end tools having any significant market share have their roots in mainstream, conventional programming environments with little to no support for object-oriented programming.
environments, event-based programming, Graphic User Interfaces or 4GLs (exceptions to this statement are discussed in Section 7.2)

Smaller, more specialized or single-purpose tools are also becoming more widely used, such as VisSim by Visual Solutions Inc. VisSim, a tool that sells for under $200, allows engineers to create on-screen diagrams that model and simulate physical processes. In between is a class of tools whose members are priced in the $1000 - $2000 per-developer range and provide an assortment of the more popular Software Engineering methods. Tools in this category include ERWin, EasyCASE and System Architect. The capabilities of System Architect will be discussed further in Section 3.4 since it was used during the course of this research. Another category of CASE tools encompasses those provided by data base vendors. For example, ORACLE now provides an excellent suite of software engineering tools as add-on products to their popular relational data base product.

3.2 Gane & Sarson Data Flow Diagrams and Entity Relationship Diagrams

The primary method used for analyzing and designing the Data Base Management System (DBMS) aspects of the test bed was the creation of Data Flow Diagrams (DFDs). The
specific DFD notation style of Gane & Sarson was adopted. The use of DFDs for analysis and design of information systems is well documented in a number of software engineering texts [Pressman 92, Chapters 7 and 11]. For purposes of this thesis, it is sufficient to summarize that DFDs provide a structured methodology for representing external sources and sinks of data, the processes that manipulate the data, stores of data, and the specific data that must flow to and from each process. Figure 3 shows the graphical notation for each of these items. The methodology relies heavily on levels of abstraction, such that a process modeled in general at one level can be examined in greater detail at another level. The zeroeth (most abstract) level is referred to as the "context" diagram, showing only one process: the software application under study. The level 1 DFD breaks the application down into its major modules, level 2 divides those modules into smaller components, and so it goes until the modeler is satisfied that the processes shown on the diagram are sufficiently atomic to be implemented. Although highly subjective, the dividing line between analysis and design is often set between level 2 and level 3 DFDs.

The second software engineering method used in the test bed was that of data modeling, using a powerful modeling tool known as the Entity-Relationship Diagram (ERD) [Pressman 92,
Figure 3 Gane & Sarson DFD Notation [Pressman92, page 210]

section 8.3]. ERDs pick up where DFDs leave off in terms of detailing the form, content and structure of the relevant data elements. Specifically, ERDs identify each data entity, its attributes, and how it relates to other entities in terms of cardinality and function. ERDs are especially useful when the design calls for a relational data base: the entities become tables, the attributes become column names, and the relationships become cues to the required referential keys. Figure 4 shows the ERD graphical notation used for this effort.
The transition from DFD to ERD takes place at the DFD Data Store. In other words, the next level of abstraction for a DFD Data Store is not another (higher level) DFD, but rather, is an ERD. In this fashion, the DFDs govern the DBMS (with emphasis on "management system") while the ERDs govern the Data Definitions (or structures) to be manifested in the data base.
3.3 Coad/Yourdon

Object-Oriented Analysis and Design (OOA/D) was the primary method used for the algorithmic portion of the test bed (i.e., the Tic Tac Toe game). The specific method and notation style of Coad/Yourdon was adopted [Coad/Yourdon90 and Coad/Yourdon91]. OOA/D was considered well-suited as one component of the test bed because the visual tools targeted for implementation were known to be object-oriented and event-based in nature. For purposes of this thesis, it is sufficient to summarize that OOA/D provides a structured methodology for representing classes and objects, their interconnecting structure, their attributes, the services they provide and the message connections that communicate the need for services. Figure 5 summarizes the graphical and semantic notation used in the Coad/Yourdon approach to OOA/D. Note that the abstraction tool referred to as "subject" was not required for this effort.

The Service Chart notation was also extrapolated to model the overall behavior of the application. Thus, the notation was used to provide a flow chart style representation of an event-based design.

The procedural aspects of the OOA/D effort followed Coad/Yourdon's OOA Strategy Summary and OOD Strategy Summary [Coad/Yourdon91, pp. 164-181 (Appendix B and
Appendix C)]. Although some of the strategy elements were not relevant to the simple test bed application, the sequence and content of the remainder were found to be quite useful.
3.4 System Architect CASE (Computer Aided Software Engineering) Tool

The System Architect CASE tool (version 3.0) was used to implement the software engineering methodologies discussed in Section 3.2 [SysArch94A]. (The OOD/A methods were applied manually.) Like most mid-range CASE products, System Architect is a desktop workstation-based suite of tools aimed at helping software developers provide higher quality, more efficient work products. It maintains an integrated, team-oriented repository (data base) of results, referred to as an "encyclopedia," which contains project-wide Data Definitions, Diagrams, etc. System Architect provides diagramming/modeling support and rules checking for a wide variety of popular software engineering methods, including all of the ones discussed in this thesis (the Object-Oriented methods are obtained via an optional upgrade module). It also provides, as upgrade options, a project report generator, a data base schema generator, a PowerBuilder bridge, and a reverse engineering tool.

Another optional module which was used in this effort is the Screen Painter, which is a screen design and layout tool with a Windows Dialog generator (see Chapter 6).

The mechanics of using System Architect are straightforward. First, one must select the software engineering method to be used. The tool then provides an on-screen
template of graphic icons relevant to that method which can be "dragged" and "dropped" onto the diagram under construction. Connection icons are further enabled to allow the developer to click on the icons to which they are connected with knowledge of directional flow (i.e., "from" the first icon clicked "to" the second one). Each icon can then be further refined by opening a series of "behind the scenes" dialog boxes (using a right-click to pop up a menu of options). These refinement dialogs handle duties from the routine, such as names and labels, to the advanced, such as cardinality and composite data definition statements.

System Architect also supports levels of abstraction by allowing each icon to link to a Child Diagram, which represents a more detailed breakdown of its parent. One of the rule-checking features of the tool is to verify that the inputs and outputs of a Child Diagram are consistent with those of the Parent (so-called "balancing").
Chapter 4

Visual Programming Languages and Tools.

"Visual Programming" has been defined as "the use of meaningful graphic representations in the process of programming" [Shu88, page 9]. Shu further defines a visual programming language as one "which uses some visual representations (in addition to or in place of words and numbers) to accomplish what would otherwise have to be written in a traditional one-dimensional programming language" [Shu88, page 138]. A visual programming tool can be thought of as a higher-level development environment, incorporating a 4GL or scripting language and perhaps project management aids, interpretive testing (i.e., without compilation) or team development aids.

Visual programming (at least in a commercial setting) is tightly connected to object-oriented programming in that all of the tools and languages evaluated were themselves object-oriented and most allowed developers to enjoy the benefits of object-oriented programming to some degree. Further, visual programming enables object-oriented practitioners "to build applications from simple, reusable
parts...by providing palettes of compatible parts in easily accessible formats ready for use by developers” [Jicha94]. Classification as a visual programming language or tool is not absolute, but is by degree. The Gartner Group suggests a continuum ranging from “Visual GUI with Text Scripts” (e.g., Visual Basic) to “Visual with Minor Text Required” (e.g., Smart Elements) to “Visual with Text Optional” (e.g., ObjectVision) to “Visual Only” (e.g., Layout) [West92]. Shu further decomposes the “Visual Only” category into “Diagrammatic systems” which use as their programming paradigm “flow charts and diagrams that are already in use on paper” (e.g., Layout), “Iconic systems” wherein “graphical symbols are deliberately designed to play the central role in programming” (e.g., G2) and “Form systems” which employ graphical software representations of physical tables and forms which “are designed as an integral part of a language” (e.g., Visual Basic) [Shu88, pp. 12-16].

4.1 Synopsis of Visual Languages and Tools Evaluated

Because of the variety and depth of visual programming languages and tools available, one task of this research was to evaluate a reasonable sampling of them and select the ones to be used in the experimentation test bed. This section provides a brief synopsis of each language/tool
evaluated. The sections that follow elaborate on the ones actually used. It is important to note that the languages and tools evaluated as part of this research are representative of the class of visual programming languages and tools; thus allowing one to reasonably generalize the results of this study.

Visual Basic is a Microsoft product which provides a WYSIWYG layout tool for quickly constructing functional Windows front ends. It is somewhat object-oriented in that each visual element has self-contained attributes and behaviors; events which occur at run-time can trigger BASIC functions and procedures. However, programmers cannot define their own classes/objects or inheritance schemes. The visual nature of Visual Basic is laying out of the user interface and using the interface objects to organize and contain much of the behavior of the application. Visual Basic is an economical development language suitable for small to medium applications and is supplemented by a large catalog of third-party add-on tools and utilities. Section 4.2 elaborates on Visual Basic and how it was used to support this effort.

ObjectVision is a Borland product which offers a form-oriented WYSIWYG user interface layout tool, a tree-like visual language for processing logic, a spreadsheet-like
macro language for manipulating data and a user-friendly "point and click" tool for linking data base files/tables with ObjectVision objects. If an application's requirements align with such features, ObjectVision can be an extremely powerful tool; conversely, attempting to build an application for which a form-style user interface is not appropriate, or one which requires procedural algorithms, can prove to be frustrating and non-productive. Like Visual Basic, it is somewhat object-oriented in that each visual element has self-contained attributes and behaviors, and events which occur at run-time can trigger ObjectVision functions and procedures; however, programmers cannot define their own classes or objects. ObjectVision offered an extremely economical price point, but is now being phased out by Borland. Therefore, it should not be used for any production-grade application where upgrades or support would be required. Section 4.3 elaborates on ObjectVision and how it was used to support this effort.

Smart Elements, by Neuron Data, originated as an expert system development tool named Nexpert Object (circa 1987). Later, they added a GUI development tool named Open Interface (circa 1991). Most recently, they bundled and integrated these two tools to form Smart Elements. Smart Elements is completely object-oriented in both its own implementation and its use by developers. It is also one
of the most portable development environments available today in that even the most graphical application developed on one platform can be immediately recompiled on another (e.g., develop on DOS/MSWindows and deploy on Unix/Motif without touching the source). Smart Elements is visual in several ways. First, its GUI editor provides much the same functionality as discussed for Visual Basic, with the added benefit of extendibility and full object-orientation (e.g., one can create new widget classes and inherit from them). Next, much of the behavior of the application is implemented by filling out "point and click" and "fill in the blank" dialog boxes. Last, class/object/attribute/method hierarchies (as well as rule-bases) can be visualized as graphical tree structures. Smart Elements provides its own scripting language for high-level users (analogous to BASIC for Visual Basic), while allowing full-fledged software engineers to implement module details in C (analogous to Visual C++). This tool is moderately-priced. Section 4.4 elaborates on Smart Elements and how it was used to support this effort.

Visual C++ is a Microsoft product which provides a very robust class library for handling such diverse tasks as OLE support, graphical drawing, printing services. It also has the "Class Wizard" which handles the details of creating subclasses and instances, such as inserting the correct
properties and behaviors and adding comments like "//ADD APPLICATION SPECIFIC CODE HERE." Visual C++ is by far the most powerful and robust of the tools evaluated. It is unfortunately the least visual; for example, it has a limited WYSIWYG layout tool when compared to Visual Basic.

PowerBuilder is a tool from PowerSoft for application developers who are creating the "client" end of client/server applications. It is geared towards MSWindows applications networked to a SQL data base server. PowerBuilder provides a WYSIWYG user interface layout tool, a non-standard scripting language, automatic or manual generation of SQL statements to put/get/manipulate server data and hooks into the C language. Although not fully open to programmers, its flexibility and power go well beyond that of Visual Basic and ObjectVision but at about 30 times the price. SQLWindows by Gupta serves much the same audience and provides much the same functionality as PowerBuilder. However, SQLWindows is considerably more open and extensible, probably due to the fact that is more object-oriented. SQLWindows has a slightly more attractive price point than PowerBuilder. Both tools offer team development add-ons and are well-suited for large-scale, production-grade development projects.
G2 by Gensym, Inc. is a real-time expert system development shell which has a strong visual-programming component, especially for modeling and simulating physical systems such as process plants and factories. It supports Model-Based Reasoning in conjunction with visually laying out and connecting the components of the physical system. Each class of physical object is manifested in a G2 class object, including its visual icon, its connection ports, its possible states and its behaviors (usually in the form of an equation). Thus, the class, PUMPS, might have the icon depicted in Figure 6 with a suction port, a discharge port and a power port; states of pumping, available and out-of-service, and a behavior of "If the POWER SUPPLY object connected to the power port is energized, AND If the FLOW LINE object connected to the suction port is open, AND If the FLOW LINE object connected to the discharge port is open, Then the state of this PUMP is pumping."
Such class objects can then be instantiated, dragged, dropped, named and interconnected on a workspace using the mouse. G2 is very object-oriented and open (considering that it is a tool and not a language) but is very expensive ($50,000 to $100,000, depending on hardware platform and options selected).

The most visual tool examined was VisualAge by IBM. Because of the high price tag (and the fact that the author's place of work has not yet purchased a copy), the examination was at IBM at the hand of an IBM demonstrator. Nonetheless, it was obvious that VisualAge is a fully-functional visual programming tool. It is completely object-oriented in both its implementation and its use. It is built in Smalltalk and is extensible using Smalltalk. VisualAge was originally introduced in OS/2, but is now available in Windows as well. The tool has a GUI layout scheme much like the other tools, but carries forward the visual programming paradigm to include flow of information and control. The behavior of the application is programmed by dragging, dropping and connecting functional components and then adding any necessary conditionals or parameters. Were it not for the economic barrier involved, this author would have included VisualAge as one of the VPTs used in the experimentation test bed.
Layout from Objects, Inc., is the most unique of the VPTs considered. It uses the flow-charting concept to visually construct a working (and compilable) application. "Flow charts" are made up of user-connected "black boxes," each designed to provide a specific function (such as opening a window, displaying information, accessing a file, etc.). The basic program comes with over 200 pre-defined black boxes and allows users to assemble black box abstractions (called "procedures"), plus Layout allows a professional programmer to build additional ones in C/C++, Turbo Pascal and QuickBASIC. It claims that its compilation process uses an expert system to generate optimized final source code (in C/C++, Pascal or BASIC), rather than blindly append code fragments based solely on how the developer laid out the flow chart of black boxes. Objects Inc. purports that "Layout is probably the ultimate CASE tool...a full life-cycle CASE tool, able to assist you in diagramming and designing your program, prototyping it, fleshing it out, testing it, and then, when you're done, create the finished program for you." [Layout92] Layout is relatively inexpensive and supports DOS and MSWindows. Layout was originally targeted for use in the test bed; however, it turned out to be unsuitable for building an algorithmic application under Windows. However, Section 4.5 shows an example of how recursion is implemented in a visual programming tool.
There are other excellent visual programming languages and tools in commercial use, such as Forte' (Forte' Software), ObjectView (KnowledgeWare), VisualWorks (ParcPlace) and several offerings from Computer Associates [Hanna94]. There are numerous experimental and developmental ones as well, such as PFG (U. of Maryland), PT (U. Of Kansas), and HI-VISUAL (Hiroshima University) [Chang90] [Ichikawa90].

The omission of any tool or language from this treatment is not an indication of its value, but only a necessary limitation of the scope of this research effort. The sections that follow provide additional details for those tools actually used to support this thesis.

4.2 Visual Basic

Microsoft Visual Basic (version. 3.0), Standard Edition, was used on both of the applications in the experimentation test bed [Microsoft93]. The Standard Edition is the entry-level version of the product (the Professional Edition provides a larger suite of tools and controls).

Visual Basic uses "forms" as its primary layout and organization metaphor. That is, a form module is both the visual manifestation of the Graphic User Interface window and its components, and a programmatic artifact which the developer can access to establish the look and feel and the
behavior of the application. One form is established as
the master and is opened whenever the resulting program is
executed. Each additional window, whether modal or
modeless (referred to as a Multiple-Document Interface, or
MDI, child), is manifested as a form. Forms have
properties which are set by the developer and which can be
altered programmatically during execution. Forms also may
have behaviors which respond to pre-defined user-generated
or system events, such as “Load,” “Click,” “Unload,” etc.
Each form is stored as a file with an extension of “.FRM”.

The visual elements are referred to as controls. Common
examples include push buttons, radio buttons, text boxes,
combo and pop-up menus, static text and graphics. Each
control type is shown as an icon on a toolbox window such
that an instance of the control can be dragged from the
toolbox and dropped onto a previously painted form. Once
on the form, the control can be sized by either grabbing it
with the mouse or by setting its left, top, height and
width properties to the desired values. Other properties
may be set, including aesthetics (e.g., colors, borders and
fonts) and behaviors (e.g., whether visible or what happens
to the mouse icon whenever it is over the control). Some
controls include a special “Tag” property which can be used
by the developer to add a customized attribute when needed.
Like forms, controls also may have behaviors which respond to pre-defined user-generated or system events, such as "Change," "Click," "GotFocus," etc.

Visual Basic also provides a suite of tools. There is a Menu Design tool for setting up the menu bar and accelerator keys. There is a Data Manager for creating data bases (in Access). There is a Setup Wizard for creating distribution disks for stand-alone executables.

As touched on above, Visual Basic is an event-based environment. Events can be spawned by the user, for example, by moving or clicking the mouse or by keyboard actions. The system can also programmatically generate events, such as when a control changes value or it loses focus. Events can also be used as a way of sending a message to the degree that one can include in code the ability to generate any registered event (including ones normally reserved for users). The event handler also keeps track of which object spawned the event and, if the control was part of a control array (a group of identical instances of the same control and its options), it passes the index to the calling member of the array. This allows the receiver of the message to alter its response according to who was the sender.
The "methods" themselves (i.e., the receivers of the event messages) are in fact subroutines written in BASIC, associated with a control and attached to the form which holds it. Each control has its own built-in set of events to which it will respond (advanced developers can also create and register their own additional ones). If the design calls for a certain behavior given a certain event, then that behavior is implemented as a BASIC subroutine whose name is the object name joined to the event name by an underscore (e.g., Sub btnQuit_Click). If the control is implemented as an array, then the subroutine would also set up the indexing (e.g., Sub txtCell_Change (Index As Integer)). However, this indexing scheme stops short of allowing the code to be self-aware (the concept of the "SELF" keyword will be discussed in Section 4.4).

The features and functionality of Visual Basic can be significantly extended by buying add-on widgets from Microsoft or third-parties and by writing your own custom controls (so-called VBX's) in C. There is currently a booming market for add-on custom controls for such diverse areas as improved GUI widgets, communication utilities, and image viewing tools.

To build an application in Visual Basic, start by creating and naming an empty form. Then set its properties, such as
whether it will be sizable by users and the caption that should be displayed in the title bar. Next, drag, drop, name, and size each control and set its properties, such as whether it is initially enabled or whether it is reachable by user "tabbing."

For data base applications, special data controls must be set up for each data base connection. The data control enables the application to navigate, filter, and manipulate the attached data base, using SQL-like commands (e.g., WHERE, GROUP BY, etc.) supplemented by a set of API-like methods (e.g., MoveLast, MoveNext, etc.). The data control also enables certain visual controls, such as Text Boxes, to be directly linked to the data base such that their current value is automatically updated when the associated data base value changes and vice versa.

Next, for each relevant event of each form and control, add GUI-specific code. When the developer double-clicks on the object, the source code editor is opened with a default event subroutine already sketched in (e.g., _Change for Text Boxes and _Click for Buttons). The application-specific code is then added there, if that is the intended event, otherwise, a pull-down menu can be accessed to bring up any other event that is meaningful to that object.
Any general purpose code (i.e., routines that are not tied to the behavior of specific user interface control objects) is implemented in a BASIC module associated with the application under development (".BAS" file). Whether in a ".FRM" or a ".BAS" file, the general syntax, variable definition/scoping and data structures of the BASIC language apply.

4.3 Object Vision

Borland's ObjectVision (version 2.1) was used as the second implementation vehicle for the data base application of the experimentation test bed [Borland91A]. Like Visual Basic, ObjectVision uses the "form" as the metaphor for the GUI. Conceptually, the construction of the forms and the visual elements contained on them, referred to as objects, is very similar to that described in Section 4.2. Unlike Visual Basic, ObjectVision has only one file for the entire application, stored with the extension ".OBV". Forms are used to implement Windows and Dialog Boxes, and are individually named. ObjectVision also provides support for creating menus and accelerator keys and runtime deployment.

The visual objects are quite similar in form and function to those discussed for Visual Basic. However, several of them are more powerful (i.e., require less programming to
accomplish the same goal). For example, in Visual Basic, one must programmatically populate the contents of a pop-up menu; in ObjectVision, the developer can provide the contents, or the application can dynamically populate the menu itself based on data base values at runtime. Another more advanced feature is support for data restriction via the concept of content “pictures” (e.g., a local phone number would have a picture of ###-####).

ObjectVision’s capability for linking to data bases is superior. The “links” tool allows one to create and modify data base schema in several popular PC-based formats, including Xbase, Paradox, B-trieve and even comma-delimited ASCII flat files. More importantly, the links tool examines objects on the forms that have built up to that point and attempts to match them up to the data base. Likewise, in data base creation mode, the schema is created based on the data types and lengths found on the forms.

Another data base related area where ObjectVision excels is in managing relational designs. Even though they are manifested in traditionally non-relational data base formats, ObjectVision itself establishes and maintains the contents as relational tables. This includes understanding of foreign keys and automation of developer-selected
referential integrity rules. This tool also recognizes likely joins and automatically establishes them.

ObjectVision is also an event-driven tool, responding to both user-generated and system-generated events. Events can also be invoked programmatically, but such usage is less powerful since they cannot contain arguments or report which object spawned them.

The primary means of implementing application behaviors is by creating logic trees. These trees are constructed in a visual editor that provides developmental support, such as menus of available objects and guidance on legal maneuvers. Such trees are the closest equivalent to methods available in ObjectVision, and are one of two types. "Value Trees" are used primarily to provide derived data values (when the visual object to which it is attached remains null) and to perform data validation (when the visual object to which it is attached receives a value from the user). "Event Trees" are used for performing more general event-based duties and are created for specific events for specific object. For example, the "Quit" button object would likely have an Event Tree attached to it to instruct the application on how to respond to a "Click" event. The action to be taken when a leaf of the tree is reached is articulated using Lotus 1-2-3-like scripting language.
The events and script verbs can be extended by writing your own custom DLL's in C and registering them with the application at start-up.

If used correctly, and if the target application is database-oriented, ObjectVision can be a powerful tool. Otherwise, it can be a drain to productivity. The first task is to construct the GUI. The steps required include: create and name an empty form; set its properties; drag, drop, name, and size objects; set their properties.

The second task is to add the behavioral dimension to the application by constructing the Event Trees and Value Trees for each relevant event of each form and control.

The final task is to use the "link" tool to attach the GUI objects to their counterparts in the data base. If data elements in the GUI are missing from the data base, the links tool will help create them. It will also prompt for referential integrity options and other helpful options, such as filters.

4.4 Smart Elements

Smart Elements (version 2.0), by Neuron Data, was used as the second implementation vehicle for the algorithmic
application of the experimentation test bed [NeuronData94C]. Smart Elements is actually a package that integrates two independent Neuron Data products that had achieved success in the marketplace: Open Interface (version 3.0) and Nexpert Object (version 3.0). The Open Interface element can be used alone to build portable GUI front ends to C-based applications. The Nexpert Object element can be used alone to build portable Knowledge-Based Systems or object-oriented applications. Together, they form a very complete, graphical environment for building advanced, production-grade applications. Open Interface supplies the front-end processing and Nexpert Object provides the back-end processing.

On the surface, Smart Elements provides much the same set of capabilities and features as were discussed in the previous two sections. Using the "Open Editor" facility, windows and dialogs (modal or modeless) and the visual elements contained on them (referred to as "widgets") are created by dragging, dropping, sizing, and naming them and then setting their properties. The results are stored in two formats: a platform-independent ASCII resource file (".RC") and a platform-independent binary data base file (".DAT"). Push buttons, radio buttons, text edit boxes, combo and pull-down menus, text and graphics are just some
of the standard widgets provided. Advanced users can extend or alter these widgets as they see fit.

Open Interface provides tools for setting up menu bar and accelerator keys and linking to knowledge bases (in Nexpert Object). There is also a C source code generator that creates a compilable version of the application front end.

Open Interface is highly event-driven in its architecture, while the behavior of Nexpert Object is governed by a complex and highly configurable agenda mechanism and inference engine which handles both events and chaining of rules. Behavior of the GUI is governed by procedures written either in the Open Interface scripting language or in C. The scripting language is itself based on C, and C programmers will find it a familiar environment to work in. On the Nexpert Object side, behaviors are implemented either by methods, using the Method Editor, or by rules, using the Rule Editor. Both elements support creation and inheritance of very generic code which can adapt itself to the situation at run-time, including interpretation of reserved words: "@"V for knowledge base atom names, "SELF" to represent the specific widget to which a script is attached, and "EVENT" to represent the event currently being processed.
Smart Elements is fully object-oriented in both its internal design and its use by developers. Both elements allow creation and exploitation of class/subclass/object (instance) hierarchies, including multiple inheritance. In Open Interface, the class structures can be displayed graphically in the Resource Browser and instances are created and modified in Open Editor; however, creation of new classes requires significant programming. On the other hand, in Nexpert Object, objects, properties, methods and rules are all written and modified by filling out dialog boxes. Results can be visualized in a series of graphical browsers, including a Rule Network and an Object Network. The notation used for these browsers is shown in Figure 7.

The classes, objects, properties, rules and methods of a Nexpert Object application are stored as a platform-independent ASCII knowledge base file (".KB"). The knowledge base can also be stored in a platform-specific compiled (binary) format.

Another unique feature of Smart Elements is that the environment is very open. For example, features can be extended by writing your own procedures or DLL's in C. More importantly, application modules built in Smart
Elements can be embedded into other C applications using a very robust Application Programming Interface (API).

One of the most powerful features of Nexpert Object is built in support for pattern matching in rules and methods. Pattern matching allows very generic code to perform searches of properties over class/object hierarchies and return a list of the matching objects. The list persists for the duration of the current operation and can thus be used with subsequent conditionals or actions of that
operation. The list can also be passed as an argument to another operation. The value of this feature will become obvious in Section 5.2.3.

To build an application, first start up the Smart Elements Main Window. From here, one may either proceed to create the GUI in Open Interface or the back end in Nexpert Object. The tool is so robust, that there are numerous avenues to accomplish any task, so this treatment suggests merely one, starting with building the GUI. In reality, this is an interactive process, cycling among GUI widget editing, widget script writing, and editing of classes, objects, properties, methods, and rules.

First, display the Resource Browser, navigate to the “Win” resource, and double-click on it to start the Open Editor with an empty window. Use the tools, palettes and dialogs to create and name the required windows; set their properties; drag, drop, name, and size widgets; and set their properties. For each relevant event of each window, dialog and widget, add the GUI-specific script which will achieve the desired behavior (or alternatively, generate a C-source template and add C-code to implement behavior).

For knowledge-based applications, set up links between the GUI objects in Open Interface and knowledge base objects in
Nexpert Object. For data base applications, one can also set up data links, using either an add-on product named Data Elements for complex, client/server applications, or the built-in scripting calls for simple ones.

Now, implement the structural aspects of the application in Nexpert Object (i.e., classes, objects and properties) by opening and using the Class Editor, Object Editor and Property Editor, respectively. The results of this hierarchical construct can be visualized using the Object Network browser. Finally, implement the (non-GUI) behavioral aspects of the application in Nexpert Object (i.e., methods and rules) by opening and using the Method Editor and Rule Editor, respectively.

4.5 Layout

Layout, by Objects, Inc., was originally slated as the tool to be used to build the second algorithmic application in the experimentation test bed [Layout92]. Although it was ultimately abandoned for use in the test bed, it does provide an interesting insight into visual programming. In particular, a recursive version of the classic factorial algorithm was visually programmed in Layout as part of the evaluation process. Although somewhat tangential to the main thrust of this thesis, the purpose of this section is
to demonstrate how a such an abstract concept as recursion can be programmed visually.

The programming metaphor used by Layout is the flow chart. Functional code modules are represented by icons known as "Black Boxes." Cascading palettes of Black Boxes are available from which one may select and drop onto the flow chart. Black Boxes can have inputs and/or outputs, can return a value to the Black Box which called it, and can receive and send messages with arguments. Flow Charts can be broken up into callable Procedures which themselves can take arguments and return values. Woven throughout the Flow Chart and Black Box metaphor are supporting ones, such as "Filling out a Card" for opening a user dialog window.

Layout has a GUI painting tool to develop user windows and populate it with the (now) usual slate of widgets. These widgets are connected to the Flow Chart and its Black Boxes in a very restrictive fashion. (ASIDE: The lack of flexibility in the connection between the GUI and the Flow Chart became the downfall of this tool for the Tic Tac Toe game. Many hours of work-around attempts, discussions and faxes with Layout Tech Support yielded no viable solution.) User input data is collected and organized using the data card (or index card) metaphor. There is also a tool for creating/managing the variables used in the Black Boxes.
To build an application in Layout, use the Flow Chart tool to begin visually building the application. When a Black Box is chosen that requires a window, a screen painting tool will open which will allow you to create and name an empty window (or card) and set its properties. You may also drag, drop, name, and size objects and set their properties. When a Black Box is chosen that requires an equation with variables, a Variables tool will open which will allow you to create the needed data elements. The process of editing the Flow Chart and its Black Boxes, including the filling out of associated dialogs, when requested, is repeated until the desired application behavior is achieved.

With that background, the concept of visual recursion can now be presented. Of course, the impact of visual programming is significantly diminished when reduced to a paper-based portrayal, such as this. However, the point that visual programming opens new software engineering opportunities and challenges should not be lost.

The factorial application presented here provides a simple graphic user interface to accept the input value and display the output value. The application also provides input validation and feedback to the user if the input is unacceptable (i.e., not a positive integer). Last, but
certainly not least, it must calculate the factorial of the input value and place the result in the output value. It is this last step that is implemented recursively. The pseudo-code for a recursive version of the factorial algorithm is as follows ("input" and "output" are global integers):

```
factorial (input, output)
    If input > 1 Then
        input = input - 1
        output = output * input
        factorial (input, output)
    End If
End function
```

Figure 8 shows the Layout Flow Charts for the Main ("factorial") and Recursive Procedures ("factorial recur"). The main program sets up the user window; sets up the main event loop (while the user has not selected the "Done" button); lets the user enter an input value (in an data entry object named "Original Integer" on a Card named "factorial"); sets up entry validation and correction loop (while user input < 0); handles the special case for 0! (If user input = 0, result = 1) and otherwise initializes the input ("FactVal") and output ("FactRes") variables and calls the recursive procedure (the Else portion); makes a
Figure 8: Layout Flow Charts of Recursive Factorial
"beep" to acknowledge completion; closes the window and exits (once the user has clicked on "Done").

The recursive procedure tests the input value ("FactVal") to verify that it has not yet become decremented all the way to 1 (if it does equal 1, the procedure is immediately exited); if not equal to 1, the procedure decrements the input to the procedure by 1, sets the result ("FactRes") equal to the old result times the newly decremented input value and calls the recursive procedure; when control returns, the procedure is exited.

The concept of a visually programmed recursive function may be hard to imagine. However, when the Flow Chart is displayed, it only shows the current level of recursion. One can drill down to the next level in the recursion by clicking on the small icon to the left of the "Use a Procedure" Black Box and come back up back by clicking on the small icon to the left of the "Start of Procedure" Black Box. The developer may drill down as many levels as desired and Layout will keep repainting the same recursive procedure; however, it is keeping track of the levels because the icon for coming back out will have to clicked just as many times to get back to the main procedure.
Chapter 5

Experimentation Test Bed

The experimentation test bed described in this chapter was conceived to create a controlled environment in which to observe the interactions and interdependencies among the software engineering methodologies discussed in Chapter 3 and the visual programming languages and tools discussed in Chapter 4. The observation capture mechanism discussed in Chapter 2 was applied throughout the design and implementation process as noteworthy synergies and conflicts were encountered.

5.1 Customer Support Tracking System

The Customer Support Tracking System (CSTS) was inspired by a project ongoing at the author’s workplace for which the client was wanting the company to take incoming technical support calls for a fielded software system and then bill them for the time used. CSTS was conceived as a relational data base aimed at managing a group of users of a fielded software product. CSTS was designed using Gane & Sarson DFDs and ERDs using System Architect and implemented in Visual Basic and ObjectVision. The system must maintain a
data base of licensed users, including relevant data about that user and the company for which he or she works. It must also track the duration and content of technical support calls taken from licensees. The GUI must serve as both the end-user and maintenance interface.

5.1.1 CSTS Design

The CSTS Design Package is provided as Appendix A. The package consists of a System Requirements Definition statement, the Gane & Sarson DFDs and associated Process Definitions, the ERD and associated Data Definitions.

The design was created using the System Architect CASE tool. The tool is not only responsible for producing high-quality printouts of the various diagrams and definitions, but also maintains an association between the symbols on the diagrams and the contents of the definitions data base. Thus, System Architect was not used simply as a drawing tool, but rather, was used as a repository of design information, both symbolic and definitive. It also helped reveal the need to normalize the data. The original requirements did not specify a separate table for the licensee (person) and the company for which they worked. It turns out that one company may have multiple licensees and as such the company data ought to be stored and
maintained separately. Therefore, the design divided the CUSTOMER table that was specified into separate LICENSEE and COMPANY tables.

5.1.2 CSTS Implementation in Visual Basic

The listings and screens for the Visual Basic version of CSTS are provided as Appendix B. There are four sections in the appendix, one for each of the major modules. Each module consists of a printout of the GUI screen, the definitions of that screen and the visual objects it contains, and a listing of the Visual Basic source code for the object behaviors. The main module, CSTSMain, provides the "Customer Support Tracking System" window and is saved under the name CSTS.FRM. The company information maintenance module, ChangeCompany, provides the "Change Company Information" window and is saved under the name CHANGECO.FRM. The technical support module, SupportCall, provides the "Support Calls" window and is saved under the name SUPPORTC.FRM. A module for deleting companies, CSTSMnt, provides the "CSTS Company Maintenance" window and is saved under the name CSTSMNT.FRM. This application has no generic (.BAS) module files.

To use the Visual Basic version of CSTS:

- Start Visual Basic
• Load the CSTS Project (CSTS.MAK)
• Run the application and the CSTS main window will open
• You may exit the application either by first selecting the "File" item from the menu bar or by double-clicking on the system icon (the bar in the upper left corner of the window)
• You may browse existing licensees using the navigation icons (they are similar to VCR buttons) to go to the first, previous, next and last record.
• You may edit the licensee information (the company information cannot be edited from this screen)
• You may type a value in the Licensee ID box; if that ID already exists, that record will be displayed, otherwise, a new licensee record will be created and the "Change Company Information" window will be opened (since every licensee must have a company associated with it)
• You may Click on the "Change Company Info" Button to open the "Change Company Information" window
• On the "Change Company Information" window, you may edit the data, browse the existing company records (using the navigation icons), select an existing company record directly (using the pull-down menu) or create a new company record by typing in a new name; you may either "Accept" the changes or "Cancel" them, either of which will return you to the main CSTS screen
• From the main CSTS screen, you may Click on the "Support Calls" button to open the "Support Calls" window

• On the "Support Calls" window, you may type in a description of the call of any length into the scrollable text box; you may browse the past support calls to that licensee using the navigation icons; you may either "Accept" the support call information or "Cancel" it, either of which will return you to the main CSTS screen

• From the main CSTS screen, you may delete a company record or a licensee record by first selecting "Maintenance" item from the menu bar (NOTE: cascading deletion of the related data is not automatically provided by Visual Basic and was not programmatically implemented)

During the implementation, several interesting things occurred. One positive experience had to do with a powerful data base connection device built in to Visual Basic (known as the "data control"). It allows visual objects to be directly linked to fields in a data table and also automatically provides the data base browser feature.

A disappointing experience was discovering that the pull down menus (e.g., combo boxes) are not populated automatically at run time, but rather must be populated
programmatically. Other tools, such as ObjectVision, are able to scan the contents of the data base at run time and populate the menu without the need to write a single line of code.

5.1.3 CSTS Implementation in ObjectVision

The listings and screens for the ObjectVision version of CSTS are provided as Appendix C. There are three sections, one containing printouts of the three screens, one containing printouts of the behavioral event trees and scripts, and one containing sample screen shots from the ObjectVision development environment. The three screens are: the "Customer Support Tracking System" window, the "Change Company Information" window, and the "Support Call" window. Since this application was constructed in a visual programming tool, it has no source code listing, per se. Instead, event tree diagrams with their "mini-scripts" are provided for: the "Change Licensee ID" (text edit) Event, the "Open Change Company Information" (form) Event, the "Click New Company" (button) Event, the "Click Return" (button) Event (on "Change Company Information"), the "Click Cancel" (button) Event (on "Change Company Information"), the "Open Support Call" (form) Event, the "Click Accept" (button) Event (on "Support Call"), and the "Click Cancel" (button) Event (on "Support Call"). The
screen shots portraying typical parameters that were set for various dimensions of the application are: combo box setup (attribute menu, Field Type selection, Expected List dialog for combo box showing “Automatic”), date field setup (attribute menu, Field Type selection, Date Type selection dialog), non-editable text edit box setup (attribute menu, Protection choices dialog), constrained data entry text box setup (attribute menu, Field Type selection, Picture String dialog), data base table creation (Data Links dialog, Paradox Link Creation dialog, Data Base Table Creation dialog), and data base filter setup (Data Links dialog, Paradox Link Creation dialog, Optional Link Capabilities dialog, Link Filters dialog).

To use the ObjectVision version of CSTS:

- Start ObjectVision
- File|Open CSTS.OVD (the CSTS main window will open)
- You may exit the application either by double-clicking on the system icon (the bar in the upper left corner of the window)
- You may browse existing licensees using the navigation icons (they are similar to VCR buttons) to go to the first, previous, next and last record.
- You may edit the licensee information (the company information cannot be edited from this screen)
You may select an existing licensee record directly from the Licensee ID box (using the pull-down menu)
You may type a value in the Licensee ID box; if that ID already exists, that record will be displayed, otherwise, a new licensee record will be created and the "Change Company Information" window will be opened (since every licensee must have a company associated with it)
You may Click on the "Change Company Info" Button to open the "Change Company Information" window
On the "Change Company Information" window, you may edit the data, browse the existing company records (using the navigation icons), create a new company record by clicking "New Company" and typing in the new name, or deleting the current company record by clicking on "Delete"; you may either accept the changes by clicking "Return" or "Cancel" them, either of which will return you to the main CSTS screen
From the main CSTS screen, you may Click on the "Support Call" button to open the "Support Call" window
On the "Support Call" window, you may type in a description of the call of any length into the scrollable text box; you may browse the past support calls to that licensee using the navigation icons; you may either "Accept" the support call information or
"Cancel" it, either of which will return you to the main CSTS screen

- From the main CSTS screen, you may delete a licensee record by clicking on "Axe".

The primary negative impression during the development process was the nearly impossible task of documenting the object attribute selections. There is no direct way to do this. Taking screen shots (as was done for the few samples in Appendix C) would be prohibitively time consuming on even a medium-size project.

On the positive side, the data base connection (link tool) was most impressive. ObjectVision successfully generated "straw man" data tables based on visual objects, automatically setup referential integrity constraints, automatically setup joins at run time, and automatically populated the combo box menus. At first, the fact that the System Architect Schema Generator tool did not offer support for any of the data base formats supported was disappointing. However, the schemas for all three data tables were ghosted in based on the GUI objects and polished up in a matter of minutes.
5.2 Tic Tac Toe

The Tic-Tac-Toe game was inspired by an assignment in the Software Tools class. It provides at straightforward application that is both visual and does not entail a database. It does, however, require (simple) logical and numeric algorithms. Tic Tac Toe was designed using the Coad/Yourdon methodology and implemented in Visual Basic and Smart Elements.

5.2.1 Tic Tac Toe Design

The Tic Tac Toe Design Package is provided as Appendix D. The package consists of a System Requirements Definition Statement, the Coad/Yourdon Analysis and Design step results, and the Coad/Yourdon Object State Transition diagrams.

The design was not created using a CASE tool, but rather was performed and documented manually. The analysis and design process was nonetheless a productive exercise. The information spelled out during completion of the OOA/D steps did indeed lay out a course for direct implementation. The mapping from the design to the programming environment was considerably better for Smart Elements than for Visual Basic, as would be expected.
considering that the former is a fully object-oriented tool.

The original design did not include the Object State Transition Diagrams. During the Visual Basic implementation, the need to understand the cascading sequence of events became evident (the author kept getting lost in a not-so-visible web of events causing side-effects causing more events and so on). At that point, effort was directed back to the design phase and the states and the events which could cause a change in state were laid out in a manageable and understandable fashion.

The design calls for nine identical cell objects to represent the nine locations of play on a Tic Tac Toe board. There are also eight conceptual summation objects to represent the state of the three rows, three columns and two diagonals which are possible on a Tic Tac Toe board. The object representation scheme is rounded out by a game state object that contains the current state of play.

The key to the algorithms used by the gaming engine is to represent the player's "X" with the integer "1", the game's "O" with the integer "-1", and an unused cell with "0". This allows the state of each row, column and diagonal to be unambiguously discerned by simply adding up the values
of its three cells: +3 means the user has won, -2 means the
game will take the (necessarily) remaining empty space for
the win, and +2 means the game will take the (necessarily)
remaining empty space for the block. The sums are also
used to help discern several special cases having to do
with the user attempting to get the game into a double-bind
(where there are two rows/columns/diagonals that must be
blocked, referred to as a "wedge").

The strategy devised for the gaming engine is, in order of
priority:

1. Test for user win (any sum = +3) ==> Game Over

2. Test for game win (any sum = -2) ==> Find and Pick Empty
   Cell and Game Over

3. Test for block (any sum = +2) ==> Find and Pick Empty
   Cell

4. Test for diagonal wedge (sum of the sums of both
diagonals = 0) ==> Pick Center or Top Edge

5. Test for edge wedge (the only one of concern is when the
   sum of the sums of the bottom row and the right column =
   2) ==> Pick the Lower Right Corner Cell
6. Pick the next empty cell according to the following "search pattern":

```
  2 6 3
  7 1 8
  4 9 5
```

5.2.2 Tic Tac Toe Implementation in Visual Basic

The listings and screens for the Visual Basic version of Tic Tac Toe are provided as Appendix E. There are four parts in the appendix, one for each type of information. The first part is simply the GUI screen for the application. The second part contains the definitions of that screen and the visual objects it contains (saved as MAIN.FRM). The third part provides the a listing of the Visual Basic source code for the object behaviors (also in MAIN.FRM). The fourth part is the Visual Basic source code for the generic functions used by the application (saved as TTT.BAS)

To use the Visual Basic version of Tic Tac Toe:

- Start Visual Basic
- Load the Tic Tac Toe Project (TTT.MAK)
- Run the application and the Tic Tac Toe window will open
• You may exit the application at any time either by clicking on the “Quit” button or by double-clicking on the system icon (the bar in the upper left corner of the window).
• You may click on any cell to make your first move, or click on the “You Go First” button if you want the game to make the first move.
• You will always be "X" and the game will always be "0".
• Notice that the mouse cursor icon changes whenever it is placed over a mouse-sensitive region of the game board.
• After each move by the game, you may select another empty cell for your move.
• Notice that the game will not allow you to make two simultaneous moves or put your "X" in an already occupied cell.
• The game will notify you of the final result when there is “three in a row” or when there are no more moves.
• Warning: the game cannot be defeated, so do not spend more than two or three hours trying.

Since design of the Tic Tac Toe game required both a symbolic and numeric representation of each cell on the board, the “Tag” property of Visual Basic TextBox object was put into service. Whenever the Text value of a cell changed to an "X", a "_change" method was invoked which set the Tag value of that cell to +1. Likewise, when the game
decided its move, it set the Text value to "0" and let the change method set the Tag value to -1. This technique allowed the human to see the symbolic values and the game to apply its algorithms to the numeric values of the same objects.

The Visual Basic’s capability to allow creation of an indexed array of identical visual objects was exploited in the implementation. Specifically, the "object_Change" method (mentioned earlier) was implemented as a completely generic subroutine. This routine was then attached to the first cell that was created for the game board. The other eight cells were added as indexed “clones” of the first one. In this fashion, all nine of the individual (indexed) text cells on the game board shared the same (identical) subroutine for handling changes in the value of a text cell. Thus, the code fragment shown below was written once and reused eight times with no additional programming required:

```
Sub txtCell_Change (Index As Integer)
    If txtCell(Index).Text = "X" Then
        txtCell(Index).Tag = 1
    ElseIf txtCell(Index).Text = "O" Then
        txtCell(Index).Tag = -1
    End If
```

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5.2.3 Tic Tac Toe Implementation in Smart Elements

The listings and screens for the Smart Elements version of Tic Tac Toe are provided as Appendix F. There are four parts in the appendix, one for each type of information. The first part is simply a printout of the GUI screen for the application. The second part contains the Open Interface definitions of that screen and the visual objects it contains (saved as TTT.RC). Since the Open Interface scripts are formatted in an unfriendly manner in the "RC" file, a manually edited listing of the scripts is also included. The third part presents the Nexpert Object "source code" for the Knowledge Representation Scheme (i.e., the Classes, Objects and Properties and how they are connected to one another). This part is a combination of screen printouts from the browsers and editors of the development environment plus a textual listing of the Knowledge Base (saved as TTT.KB). The fourth part is the Nexpert Object "source code" for the rules and methods used to provide the behavior of the application. Once again, this part is a combination of screen printouts from the browsers and editors of the development environment plus a textual listing.
To use the Smart Elements version of Tic Tac Toe:

- Start Smart Elements (this requires a security key)
- Load the Tic Tac Toe Knowledge Base (TTT.KB); this establishes the gaming engine in Nexpert Object
- Load the Tic Tac Toe compiled resource file (TTT.DAT); this establishes the GUI engine in Open Interface
- Navigate to the Open Editor main dialog (first, display the Resource Browser, navigate to the "Win" resource, and double-click on it to start Open Editor, which will display the Tic Tac Toe window in development mode
- Run the application by clicking on the "Test" button
- You may exit the application at any time either by clicking on the "Quit" button or by double-clicking on the system icon (the bar in the upper left corner of the window)
- You may click on any cell to make your first move, or Click on the "You Go First" button if you want the game to make the first move
- You will always be "X" and the game will always be "O"
- Notice that the mouse cursor icon changes whenever it is placed over a mouse-sensitive region of the game board.
- After each move by the game, you may select another empty cell for your move
- Notice that the game will not allow you to make two simultaneous moves or put your "X" in an occupied cell
• The game will notify you of the final result when there is "three in a row" or when there are no more moves.

• The current state of the game is displayed for information purposes and to give you something to do besides fume over the fact that the game cannot be defeated.

Implementing Tic Tac Toe in Smart Elements was a truly enjoyable experience. Although several dead ends and need for work-arounds were encountered, all in all, the environment delivered on the productivity and visualization benefits touted for a high-end visual programming tool. There was perhaps a factor of more than 5 times on productivity over the Visual Basic implementation.

Incremental development in an object oriented tool environment also paid rewards. The most dramatic example was development of the part of the gaming engine that manages the state of the game board (i.e., the sums of the eight rows, columns and diagonals). Once the prototype (one row of game board) was operating correctly, it took less than 15 minutes to create a fully operational game board. This rapid scalability was due to the self-maintaining quality of the board objects achieved through inheritance of generic methods. All that was required was to clone the other six cells, clone the other seven...
"summation" objects and connect the appropriate three cells to the corresponding summation object. It worked on the very first try, requiring not one line of new code and not one session of debugging.

The concept of Pattern Matching in Nexpert Object was used extensively in the generic methods mentioned above. For example, the conditional (IF clause) of one of the rules was:

\[
(= (\langle|Sums|\rangle . Sum) 2)
\]

This says “If the .Sum property of any child of the Sums Class equals 2 (i.e., two "X"’s), then put the name of that object in a list.” That list can then be used in subsequent operations in that rule and can be passed as an argument to a method, as seen in the action (THEN clause) of that same rule:

\[
\text{(SendMessage ("mthdPickLastCell") (\@TO=|Cells|.Val;\@ARG1=\langle|Sums|\rangle;))}
\]

This says “Send a message to the .Val property of all children of the Cells class, and invoke the PickLastCell method, with the previously generated list, locally known as \langle|Sums|\rangle, as an argument.” The method, expecting as an
argument a list of objects with one member whose .Val property is 0, then sets off to identify its name (remember that for a summation to have been equal to 2, two of the cells in that row, column or diagonal must have been filled with a 1, leading the knowledge that the third must still be empty). Note that the same method is used by the rule seeking a row, column, or diagonal equaling -2 (i.e., two "O"s) to identify the empty cell.

One of the challenges of implementing Tic Tac Toe in Smart Elements involved the need to mold the (tool-independent) design into a distributed processing architecture. This rethinking was required because the GUI engine (in Open Interface) and the gaming engine (in Nexpert Object) are completely independent processes communicating through a software bridge. Thus, the design had to be augmented to flesh which jobs should be done inside which process and how the necessary inputs and outputs of each process should be communicated to the other.
Chapter 6

System Architect to Visual Basic Bridge Prototype

One of the current trends (discussed in Section 7.2) has to do with the merging of CASE tools and VPTs. This trend embraces the concept of automatic programming. Indeed, System Architect today can automatically generate SQL database schema from a data model built in the tool. However, many other implementation aspects remain a manual process in all but the most advanced tools. One such aspect is that of graphic screen design and implementation. System Architect provides a component for "painting" a Graphic User Interface screen and then automatically generating a generic MSWindows dialog file (which is characterized by a "DLG" extension). Unfortunately, Visual Basic does not recognize such dialog files, but rather, uses its own file format for storing user interface data (characterized by a "FRM" extension). Therefore, the author created a prototypical bridge program, named SA2VB.EXE, which automatically generates Visual Basic Forms (*.FRM) from screens (*.DLG) generated using System Architect. The purpose of this effort was to demonstrate that such bridges are possible, are practical and should be pursued as part of the maturation process of these tools.
6.1 SA2VB.EXE Design and Scope

To design a GUI translator, one must first understand the syntax, coordinate system, and naming conventions used on both sides of the translation (i.e., source and target). Several reference documents were digested in order to pin down these topics on the Windows Dialog side [Microsoft92] [Petzoid92] [SysArch94B]. On the Visual Basic side, these topics primarily were discovered by "reverse engineering" example Forms, with some help from the Programmer's Guide [Microsoft93]. For example, one can populate a form (window) with an assortment of controls (widgets) each having an assortment of options selected and then examine the ".FRM" file for that form to discover the representation scheme.

Because of the difference in coordinate systems between System Architect and Visual Basic, the size and location parameters had to be converted. The algorithms for doing this were applied as each parameter was handled. In Windows dialog files, x-coordinates and width parameters are based on 1/4 of an average character width while y-coordinates and height parameters are based on 1/8 of an average character height [Petzoid92]. For standard Windows GUI applications, a character is 8 units wide and 16 units high, thus making the coordinate system symmetrical in both axes. In Visual Basic, the default coordinate system uses
“twips,” which are defined in terms of size at 1440 twips per logical inch [Microsoft93, pp. 353-354]. Visual Basic on-line help, under “ScaleMode Property,” further explains that a standard character is 120 twips wide and 240 twips tall. For most situations, the conversion algorithm was simply the parameter’s dialog-value times 30, which is a good approximation for converting character height and width fractions to twips (i.e., 120 twips/char width + 4 dialog units/char width or 240 twips/char height + 8 dialog units/char height). The main window was the exception, requiring the height and width to be offset by an additional 360 and 60 twips, respectively, to account for a slight difference in representing the origin of the window.

Since there are an enormous number of controls and options, the scope of the translator was limited to the window itself and three fundamental control types: Text Edit Boxes, Pushbuttons and Static Text. The recognized options for the main window and these three controls are summarized in Table 3. Other design decisions were to implement the bridge as a DOS-based utility program using Borland Turbo C++, Version 1.01 [Borland91B], to accept the source file name as a command line argument and to output the resulting Visual Basic file with the name “out.frm”.

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<table>
<thead>
<tr>
<th>Dialog Items</th>
<th>Recognized Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Window</td>
<td>Size/location&lt;br&gt;No Border&lt;br&gt;Fixed Single Border&lt;br&gt;Thick (sizable) Border&lt;br&gt;Control Box (the menu box in upper left corner)&lt;br&gt;Maximize Button&lt;br&gt;Minimize Button&lt;br&gt;Caption text</td>
</tr>
<tr>
<td>Text Edit Box</td>
<td>Size/location&lt;br&gt;Default text&lt;br&gt;Vertical Scroll Bar&lt;br&gt;Horizontal Scroll Bar&lt;br&gt;Both Scroll Bars&lt;br&gt;Multiline&lt;br&gt;Right Justified&lt;br&gt;Left Justified&lt;br&gt;Centered&lt;br&gt;Border Box</td>
</tr>
<tr>
<td>Pushbutton</td>
<td>Size/location&lt;br&gt;Caption text&lt;br&gt;Default button</td>
</tr>
<tr>
<td>Label (Static Text)</td>
<td>Size/location&lt;br&gt;Label text&lt;br&gt;Right Justified&lt;br&gt;Left Justified&lt;br&gt;Centered</td>
</tr>
</tbody>
</table>

Table 3: SA2VB Scope Matrix

6.2 SA2VB.EXE Implementation and Testing

The source listings for SA2VB.EXE can be found in Appendix G. The program opens the source file (using fopen) and scans it word by word (using fscanf) to identify and test each token. Because the possible tokens are well constrained, the program was written using statically defined variables (up to 256 characters) to represent each word. When an in-scope item is encountered, the program
appends its Visual Basic equivalent to the output file (using fprint). The program is written such that it harmlessly ignores out-of-scope tokens.

The program first sets up the window and its options, and then recursively seeks out and handles the controls and their options. The coordinate algorithm discussed earlier is applied as each control is handled; however, a defined constant, FACTOR, is used in case a non-standard video configuration creates a need for a different conversion factor. When the end token is encountered, the program wraps up out.frm and closes out the input and output files.

The program was tested using several cases designed to exercise its various features. In addition, randomly selected System Architect screen files developed by various employees of PathTech Software Solutions, Inc., were converted to ensure that the program could handle "real world" conditions.

6.3 SA2VB.EXE Application

To use SA2VB.EXE, one must first go into System Architect and use its "Graphic Screen" module to define a user interface. This is done by dragging, dropping and shaping the window and its components and by filling in the details
for each component in "behind the scenes" dialog boxes. These dialog boxes, called up by either double-clicking on the graphic component or by clicking the right mouse button on it, are where the various options are selected. Once the screen image and its properties are satisfactory, one must then invoke the System Architect "Generate Dialog" feature. This causes System Architect to automatically create a Windows standard compliant "*.DLG" file containing the appropriate control parameters and definitions.

Once a valid "*.DLG" file is available, one must shell out to DOS and execute SA2VB.EXE with the dialog file as a command line argument, as follows:

```
SA2VB TEST.DLG
```

Next, one must launch Visual Basic and add the file named "OUT.FRM" (this is found under the "File|Add File" menu). Finally, the newly created user interface can be displayed and examined (and later saved under a meaningful name) by double-clicking on "OUT.FRM" in the Project Window.

This process was carried out for numerous test files, as discussed earlier. One example, showing the image and file listing before and after conversion, is included as part of Appendix G.
Conclusions

The conclusions which can be drawn from this research effort have been divided into four areas of discussion. The first points to the observations collected during construction of the test bed. The second examines the current trends in the literature as they relate to this effort. The third section offers a series of guidelines aimed at bridging the gap between the subject technologies. The last summarizes the results and findings of the overall effort.

7.1 Observation Results

As expected, a variety of instances occurred where subject technologies worked in concert or in conflict. The self observation forms which capture these instances are collected in Appendix H. In addition, three colleagues who regularly deal in the subject technologies were interviewed to verify that the specific findings based on the test bed could be reasonable generalized. The peer observation forms are collected in Appendix I.
7.2 Anticipated Trends and Developments

Lowry forecasts the emergence of "knowledge-based software engineering" where CASE tools will evolve to include semantic content and where "software engineers will be delivering the knowledge for generating software rather than the software itself" [Lowry92]. Although well out of this author's price range, Intellitect's Object Management Workbench (OMW) is well on its way to fulfilling that forecast [Hanna94]. Based on a fully object-oriented methodology known as Martin-Odell, OMW allows software engineers to create analysis and design diagrams which are directly executable and from which C++ source can be generated and compiled when the time is right.

In early 1994, O'Brien expressed his concern that CASE tool vendors were not keeping up with the rapid adoption of event-based architecture, object-orientation, component-based development and points to the need for a new generation of CASE tools [O'Brien94]. If this is indeed the case, the market need for new tools will draw them out of the vendors, if not the current ones, then new ones who crop up to fill the void [Linthicum94, Constantine95]. One researcher, pondering how difficult it was to avoid methodology obsolescence, envisioned a marriage of formal software engineering techniques and visual programming which he called Visual Software Engineering [Chang94].
The forerunner of such a marriage is automatic program generation. This is a relatively mature technology for non-visual settings. However, automation of conceptual models, often best candidates for visualization, is in its infancy. Blum reinforces this belief as he classifies software engineering methodologies according to whether they are more concerned with conceptual modeling or formalization, and then points to a gap between the two [Blum94]. Indeed, it was the gap between GUI design and implementation that spawned the idea for the SA2VB bridge prototype that was discussed in Chapter 6. The (hopefully interim) need for such utilities was underscored by Keuffel as he described the techniques he used to narrow the gap between Evergreen’s EasyCASE and Microsoft FoxPro [Keuffel94]. The off-loading of routine programming tasks to end-users via “Wizards” is another concept that could be carried into the software engineering domain (today’s Wizards are targeted at helping office workers create custom charts, forms, layouts, etc.) and is a trend that bodes well for the proposed marriage [Kiyooka95].

From the visual programming point of view, tools with more and more power and flexibility are reaching the marketplace. The most visual, such as IBM’s VisualAge, are empowered by full object orientation, an intuitive 4GL, and support for relational data base concepts. VisualAge,
implemented in a combination of Smalltalk and itself (making it both a tool and a language), offers visual design and development of client/server applications, including SQL schema generation and application partitioning [Hanna94, Harding95].

The rapid growth in the use of visual programming tools is being driven by their ability to deliver reasonably transparent access to object-oriented programming and an easier transition to event-based architectures, GUI front ends, component-based development and the like [Jicha94, Schmidt95]. However, it is unlikely that even the best visual programming environment can achieve its full potential if it is not also delivering a sharable, understandable, reusable, printable, widely accepted software engineering methodology.

7.3 Guidelines for Development

This section of the thesis presents a collection of guidelines for finding synergy and avoiding conflicts between software engineering methodologies and visual programming tools and languages. The guidelines that follow are presented as a bridge to the day when CASE tools and visual development tools are truly one in the same. The guidelines are divided into the four major categories
of User Interface, DB Schema, Event-Based and/or Object-Oriented Design, and Function Design.

7.3.1 User Interface

Look for CASE tools that can automatically generate the Graphic User Interface "code" in the native tongue of the Visual language/tool, thus avoiding duplication of effort.

If such a CASE tool is not available, or if a CASE tool is not being used on the project, then consider using the layout mode of the implementation language/tool as the design tool. Most Visual Programming languages and tools provide the capability to quickly sketch out a screen, including titles, labels, and graphics, data presentation and edit areas, and user control devices (e.g., pull-down menus and buttons).

Look beyond the obvious in stretching the features of the tool to make it meet the specifications. For example, the design may call for a text edit object with certain behaviors regarding clicks or changes, but the tool may not provide all of the desired behaviors for a text edit object. However, a 1 x 1 spreadsheet or grid object looks exactly like a text edit object and may provide enhanced behaviors needed in the design. This guidance comes with
one caution, however. The benefit of stretching a tool may reach a point of diminishing return, leading to excessive labor costs and lost productivity.

Many languages/tools provide the ability to create custom classes, objects or widgets. Doing such would provide the ability to incorporate whatever "generic" attributes and behaviors the object should have (e.g., a BoardCell in the Tic-Tac-Toe application) and then create instances of it in the User Interface. If the development team includes strong computer science capability, then major extensions can sometimes be coded using the underlying language of the visual tool. For example, one can significantly alter the features and behavior of IBM's Visual Age using its underlying language, Smalltalk. Similarly, one can extend Visual Basic by writing their own so-called "custom controls" (identified by a ".VBX" extension) using C.

Establish a GUI object naming convention which expresses the type of object, whether it is native or derived and which options apply. Some object types are pervasive enough to now be considered generic, such as a text edit object or a combo box object. If the implementation tool is known, then the naming convention can be more explicit in how it represents the tool's objects and their options. An example is shown in Table 4.
<table>
<thead>
<tr>
<th>GUI Object</th>
<th>Naming Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple text edit</td>
<td>tedObjectName</td>
</tr>
<tr>
<td>Specialized (i.e., derived) text edit</td>
<td>projXtedObjectName</td>
</tr>
<tr>
<td>Delete Record Button</td>
<td>delbtnObjectName</td>
</tr>
<tr>
<td>Delete Record Button, with &quot;Are You Sure?&quot; flag</td>
<td>delbtn?ObjectName</td>
</tr>
</tbody>
</table>

Table 4: Example Object Naming Convention

7.3.2 DB Schema

When selecting the data base engine and CASE tool for a project, the compatibility of one with the other should be an explicit selection criterion. However, this may spawn a debate regarding whether a CASE tool should influence the data base to be selected. Ironically, the CASE tool is often selected before the data base engine is selected, since some level of design must be completed in order to specify the data base requirements. This problem can be circumvented by using a CASE tool whose schema generator supports a wide variety of data base products and technologies. Chances are, there will be a match between the "best" data base engine based on the design requirements and those which are compatible with the CASE tool. If such good fortune fails to arise, then
consideration should be given to switching to a CASE tool that does support the database of choice, since the project will still be early in its life cycle and the cost of switching CASE tools may be less than that of finishing the project with mismatched tools. (Of course, if the database has been cast before the project begins, then select a CASE tool that provides a schema generator for it.) For example, Visual Basic now supports Microsoft Access 2.0 and the System Architect CASE tool can generate a "vanilla" SQL that can be used with minor editing to automatically create the database structures.

Incremental development (a.k.a. Spiral Model and Software Accretion) is becoming a common strategy, especially when using modern tools and languages such as those under investigation. One challenge of this strategy is frequent design changes based on "lessons learned" from the prior increment. This, in turn, creates difficulties in keeping the design synchronized with the current version of the software. For synchronizing the design representation with the "as-built" application during incremental development, several approaches are suggested:

1. Settle on design conformity/leniency rules (i.e., how far can the programmer deviate from the design without invoking a redesign cycle) and design update
frequencies for manually synchronizing the design (this approach applies whether or not a CASE tool is being used).

2. This problem may be mitigated by deciding to carry a minimum of detail in the design, leaving a great deal of leeway for the programmer during implementation. However, this approach adds a significant design and documentation burden on the programmer. The programming staff must be good at designing code modules and be religious in the documentation of their as-built code.

3. Select the CASE tool and data base such that reverse engineering can be used to convey changes implemented in the development tool back to the CASE tool.

Know your tool's presumptions about how an application will be developed and go with the flow. By simply understanding the expected sequence of development, one can streamline the development process. Conversely, bucking the system can easily cripple an otherwise useful tool. This is not to say that one should use risky or unsatisfactory development practices. And, of course, never, never, never would I suggest that one change the problem to suit the tool. However, if one approach is about the same as
another, then let the expected synergy with the development
tool make the decision. (This, in turn, means that someone
on the development team must know, or be able to find out,
how the tool expects the problem to be tackled.) For
example, ObjectVision assumes the sequence of development
will be: 1) Layout the User Interface, 2) Program the
Operational Behaviors, and 3) Create/Connect the Data
Base(s). When this pattern is followed, the data base
back-end practically "writes itself" since ObjectVision
drafts a "straw man" version of the data base schema based
on the existing GUI objects. It even suggests data types
and length based on how its associated GUI object has been
laid out. Thus, the developer must merely remove or edit
the schema elements. If one begins by laying out the data
base, every element will have to be put in by hand. This
example should be contrasted with PowerBuilder, which
presumes that a data base already exists and attempts to
aid the developer in building the front end and which can't
do much more than sketch out user screens unless an
underlying data base is actually available.

7.3.3 Event-Based and/or Object-Oriented Design

All of the visual programming tools and languages
investigated for this effort employed event-based
processing and object-oriented programming at least to some
degree. Some just scratch the surface of these non-
traditional programming paradigms (e.g., Visual Basic) 
while others are quite mature (e.g., Smart Elements).
Thus, it is necessary to discuss potential conflicts and 
synergies which arise not because of the visual nature of 
the tool or language, but due to the intrinsic use of these 
emerging programming paradigms. Further, if the 
implementation tool/language is in fact known at design-
time, avoid fighting the language; it is better to adapt 
(limit) the design methodology to take advantage of 
whatever advanced features are available (e.g., object-
orientation, or event-based processing) and use procedural 
or conventional approaches for the balance. Two examples 
of such prudence follow:

1. When Visual Basic is known to be the implementation 
language, the design should be geared to have only one 
property per object causing event-based behaviors to 
execute, since the “Tag” property does not spawn 
events and no other value-properties can be added. 
(This example presumes that the developer is not a C 
programmer capable of constructing a custom control.)

2. When Visual Basic is known to be the implementation 
language, one should avoid the use of objects other 
than those destined for the User Interface, since
Visual Basic does not support OOP in the general sense. Another approach (not tested) is to create a Virtual Form to hold objects which will be used internally but never actually displayed to the User; this would in essence "trick" Visual Basic into having a collection of objects for use (literally) "behind the scenes."

If you are going to use an object-oriented tool to implement an application, Go For The Gold in the design process. Craft Methods that are as generic as possible. Apply them as high in the hierarchy as possible. Take full advantage of classification structures and let the benefits of OOP shine through.

For fully equipped OOP environments, it may be preferable to keep (reasonably related) communication links between major system modules simple (like a "pinch point"). A single, simple message from one module to the other is easy to follow and debug if problems do arise. The target method can then spawn however complex a set of processes as are required (see Figure 9). This advice may also be useful in designing communications between modules in a distributed application using a client/server architecture.
Smart Elements does not provide a vehicle to explicitly notify user interface objects when they to be updated. Note that for objects having a one-to-one correlation between the knowledge base and user interface, it does provide a linking mechanism; however, it is often the case that one would want to send a message from one Knowledge Base object to a non-correlated GUI object. This type of messaging is provided in the other direction. In the Tic-Tac-Toe application, the Knowledge Base and GUI objects could not be linked because the object value in the GUI was symbolic (X, 0 or <space>), whereas in the Knowledge Base, the value was numeric (+1,-1 or 0).] The workaround used in the Tic-Tac-Toe application causes a great deal of extra work, since every interface object must be "pulsed" after each call to the Engine to see if they need to "do anything." Other tools suffer from similar front-end/back-end communication gaps, such as opportunistically advising a User Interface when a stored procedure has placed new
data into the data base. In a full strength application, where performance could be in jeopardy, a more focused (i.e., intelligent rather than exhaustive) messaging system would have to be crafted. For example, one could add a "black board" table into which the data base "engine" could place a list of updated data objects and which an Interface method could use to update just those Interface objects whose data values had changed. Of course in the Smart Elements application, the built-in linking mechanism could have been used "as is" and then have an Interface method convert the numeric value into its symbolic equivalent.

7.3.4 Function Design

Consider the use of a tool that provides an explicit rule-based paradigm, even if the application is not an expert system or does not require inferencing. The rules can be used to expedite control strategy/logic or to explicitly represent the business rules to be followed. The visualization of such rules can be a powerful communication tool for use with the internal customer how the program will behave. Visualization of processing logic can also accelerate the validation of the program by a testing or design review group.
To accommodate nuances and/or unknowns of the implementation tool, the design must be kept generic (tool-free) down to a point. Then, if the tool and its special needs are known, a layer of specialization can be added. (Note that the Gane & Sarson process modeling technique uses a drill-down approach to specificity, thus making it suitable for this approach.)

For applications which include an underlying data base (probably relational), consider using a hybrid of software modeling methodologies. In particular, Gane & Sarson Data Flow Diagrams for high-level context and major processes, Entity-Relationship Diagrams for detailed data schema, and Coad/Yourdon Event Diagrams for events make a good combination.

7.4 Summary of Findings

Table 5 is a matrix which presents the observation results (from Section 7.1 and appendices H and I) mapped into the functional categories developed in Section 7.3. Thus, the table presents the observation frequency of conflicts and synergies as a function of Application and Category. The table indicates that, in general, the current state of the technology provides more instances of conflict than of synergy. Also note that the most advanced tool, Smart
Elements, provided more instances of synergy than conflict. Perhaps this is an indication that these technologies are indeed beginning to mature.

Applying a software engineering methodology provided benefits during the design and implementation of the test bed applications. The design process surfaced data structure and behavioral issues that would have not otherwise have been discovered until the debugging stage had begun. As such, there seemed to be considerably fewer hours spent writing and debugging code compared to other programming projects undertaken by this author. When implementation problems did occur, reference back to the design documents usually helped solve them. Although not formally studied, the author also believes that the
conclusions of the research would have been the same no matter which of the mainstream software engineering methodologies had been chosen. Thus, the decision to use a software engineering methodology is more critical than the choice of which one or whether to use a CASE tool to implement it.

Using a visual programming language or tool provided benefits during the development of the test bed applications. It would seem that this would always be the case if the application has a visual component (e.g., a GUI) or is such that visualization of its design and/or operation is important (e.g., model-based reasoning or simulation). Productivity was higher when using the tools than when using Visual Basic. However, not all tools offer the same flexibility. For example, for ObjectVision to deliver a net benefit, the application must closely fit the expected mold. Conversely, Smart Elements can be made to look and feel more like a language than a tool when the built-in functions and features are not sufficient.

Ironically, even though it was manipulating GUI resource files, the SA2VB bridge itself had no visual dimension to it. Thus, it was implemented in a non-visual development environment. Further, since it required no complex data structures and no complex architecture, hand-marked example
input and output files and hand-sketched logic diagrams were the extent of analysis and design required to solve the problem. The lesson here is that, as powerful as CASE tools and visual development environments may be, there are still cases where the complexity of the problem does not warrant the investment required to procure and learn how to use them.

Interpolating between the test bed applications, which clearly benefited from both the application of software engineering methods and visual development tools, and bridge, which did not, leads to the possibility that there lies a class of problems which can and should be solved using the visual development environment alone. An example of such might be the bridge application with the added requirements of a GUI-based file browser and preview capability. Conversely, a "pure" data base application (perhaps CSTS without the call timer and with a simplified user interface) could be designed in a CASE tool and generated by it with little or no additional programming. However, the relative number of problems whose solution fit one of these profiles may be small, such that the best advice is to establish a development environment that provides a flexible, cooperative suite of software engineering methodologies and visual programming languages and tools. From there, standards can be developed as to
which tools and methodologies in the suite should be applied to which problems.

Guidelines and utilities fashioned along the lines of those presented in this thesis should be directly beneficial to developers charged with delivering an application using a visual language or tool while following a formal software engineering methodology. This will be especially true for projects involving a team of developers. Of more importance, such guidelines and utilities are themselves primary ingredients of the merged CASE and visual programming environments of the future. Perhaps the results presented here will facilitate the transition.
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[West92]
APPENDIX A

Customer Support Tracking System Design Package

CSTS Requirements Definition Statement

Upon startup, the system shall present to the user a form-like data entry screen, plus several options available from either menus or buttons. The main data entry screen shall be named "Customer Support Tracking System" and shall provide a place for a User ID (which the system must guarantee as unique), Company Name, Address (two lines, plus City, State, and Zip+4), Country, Telephone (with 5 digit extension) and FAX, Contact Name and Title, Date First Product Shipped and the Total Support Time rendered. Information entered using this screen shall be stored in a CUSTOMER data base using User ID as the primary key. The system shall be designed such that a Customer's primary record may be both created and maintained using this same screen. The Total Support Time area shall not be user editable, but rather shall be calculated by the system each time support is provided; the system shall provide an "Update Total Support Time" menu option under a "Maintenance" menu bar item in case it must be overridden...
by the user. The other functions under "Maintenance" shall be "Delete Company" and "Delete Licensee." The Main screen shall provide a <Support Calls> button which shall take the user to the "Customer Support" screen. The Customer Support screen shall also appear form-like and shall repeat the Licensee ID and Contact Name from the customer's primary record. It shall automatically provide the Support Date and Time for the support currently being provided, plus a scrollable, unlimited, editable text field for capturing Comments, the Elapsed Time, and a user definable Combo list of Support Types. The Customer Support screen shall provide buttons for starting and stopping a timer and for returning to the Main screen. The system shall maintain a SUPPORT database containing the data from individual support entries with the Date/Time stamp as the unique Primary Key and the User ID as the Foreign Key (to CUSTOMER). Returning to the Main screen shall also cause the system to increment the Total Support Time field by the amount of time in the Elapsed field.
Context
Customer Support Tracking System

All Users are enabled/responsible for maintenance and reporting as well as using the system during a support call.
Major Processes
Customer Support Tracking System

P1.1
Browse/Maintain Customer Data

P1.2
Browse/Handle Support Calls

P1.3
Generate Reports
(Not Implemented)

CSTS Data Stores

<table>
<thead>
<tr>
<th>D</th>
<th>Licensees</th>
<th>D</th>
<th>Support Calls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Companies</td>
<td></td>
<td>Problems</td>
</tr>
</tbody>
</table>
1.1. Browse/ Maintain Customer Data

P1.1.1 Browse/Edit Licensees
P1.1.2 Add New Licensee
P1.1.3 Browse/Edit Companies
P1.1.4 Add New Company

CSTS Data Stores
- Licensees
- Companies
1.2. Browse/Handle Support Calls

- P1.2.1: Browse/Edit Support Calls
- P1.2.2: Begin New Support Call
- P1.2.3: End New Support Call

CSTS Data Stores

Support Calls

Licensees
Process Definitions

Name: Add New Company
Purpose: This process finds the last record in Companies, reads its value for CMPY_LOC_ID, increments by 1, creates a new record with that ID, sets the current record pointer to it, and returns control to the Browse/Edit Company Information process.

Documentation:
Responsible:
Transaction Frequency: StartDt: CompDate:
Description:

Name: Add New Licensee
Purpose: This process allows the user to enter a new Licensee ID and then ensures that it is unique. If so, this process creates a new (empty) licensee record with that ID. If not, it sets the current record pointer to that licensee. Control is then returned to Browse/Edit Licensees.

Documentation:
Responsible:
Transaction Frequency: StartDt: CompDate:
Description:

Name: Begin New Support Call
Purpose: Save current time stamp. Start timer object if appropriate.

Documentation:
Responsible:
Transaction Frequency: StartDt: CompDate:
Description:

Name: Browse/Edit Companies
Purpose: The Licensee and Company tables shall be joined via Company/Location ID(CMPY_LOC_ID). Company data may be edited directly. The user shall have the ability to page up and down thru the records, go to the top or the bottom of the records. The user may invoke commands to 'Accept' (store changes), 'Cancel', or 'Add New Company'.

Documentation:
Responsible:
Transaction Frequency: StartDt: CompDate:
Description:

Name: Browse/Edit Licensees
Purpose: The Licensee and Company tables shall be joined via Company/Location ID(CMPY_LOC_ID). Licensee data may be edited directly; editing of Company data shall require the user to invoke a 'Change Company Info' command. The user shall have the ability to page up and down
thru the records, go to the top or the bottom of the records, delete a Licensee, or delete a Company. The user may invoke commands for "Add New Licensee", "Add New Company" or "Support Call".

Documentation:
Responsible:
Transaction Frequency : StartDt: CompDate:
Description:

Name: Browse/Edit Support Calls
Purpose:
Filter records based on current LICENSEE_ID in Licensees. Support data may be edited directly. The user shall have the ability to page up and down thru the records, go to the top or the bottom of the records, or delete a record. The user may invoke commands for 'New Support Call', or 'Done'.

Documentation:
Responsible:
Transaction Frequency : StartDt: CompDate:
Description:

Name: End New Support Call
Purpose:
Clock Duration of Support Call and Store its value (in minutes) in SPRT_TM of the current (new) support record. Calculate a new summation of the support time for the current licensee and store it in LIC_TOT_SPRT_TM of that licensee's master record. Close the form and return control to Browse/Edit Customers.

Documentation:
Responsible:
Transaction Frequency : StartDt: CompDate:
Description:

Name: Maintain Customer Data
Purpose:

Documentation:
Responsible:
Transaction Frequency : StartDt: CompDate:
Description:
### CSTS Data Stores

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Type</th>
<th>Width</th>
<th>Domain</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMPY_AD1</td>
<td>CHARACTER</td>
<td>40</td>
<td></td>
<td>Customer Address Part One</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMPY_AD2</td>
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<td>Customer Address Line Two</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMPY_CITY_NM</td>
<td>CHARACTER</td>
<td>25</td>
<td></td>
<td>Customer City Name</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMPY_CTRY</td>
<td>CHARACTER</td>
<td>15</td>
<td></td>
<td>Customer Country</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMPY_EXT_ZIP</td>
<td>INTEGER</td>
<td></td>
<td></td>
<td>Plus 4 Zip Extension</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMPY_LOC_ID</td>
<td>INTEGER</td>
<td>4</td>
<td></td>
<td>Unique Company/Location ID; automatically</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>incremented as new record is added;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>supports multiple users at same company</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>and location, using the same license ID.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>CMPY_NM</td>
<td>CHARACTER</td>
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<td></td>
<td></td>
</tr>
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</table>

Data Store/Entity and Field Definitions (current)

As of 3/06/95
CSTS Data Stores

Description:
Company name.

Comments:

**CMPY_ST_CD**
Type: CHARACTER
Domain:
Description:
Customer State Code

**CMPY_ZIP**
Type: CHAR
Domain:
Description:
Customer Zip Number

Data Store/Entity and Field Definitions (current)
As of 3/31/95

Page 2
CSTS Data Stores

Licensees

Volume:
Comments:

Purpose:

CMPY_LOC_ID
Type: INTEGER
Domain:
Description: Unique Company/Location ID; automatically incremented as new record is added; supports multiple users at same company and location, using the same license ID.
Comments:

LICENSEE_ID
Type: CHARACTER
Domain:
Description: Company's ID which will be assigned when the Software package is shipped. This number can be found in the runtime about box, for applications which support embedded User IDs.
Comments:

LIC_CNFC_1ST_NM
Type: CHARACTER
Domain:
Description: Customer contact first name.
Comments:

LIC_CNFC_LAST_NM
Type: CHARACTER
Domain:
Description: Customer contact last name.
Comments:

LIC_CNFC_TTL
Type: CHARACTER
Domain:
Description: Customer Contact Title Name
Comments:

LIC_FAX_NB
Type: CHARACTER
Domain:
Description: Customer FAX Telephone Number
Comments:

LIC_SHIP_DT

Data Store/Entity and Field Definitions (current)
As of 3/06/95
## CSTS Data Stores

**Shipping date for the original runtime package.**

### LIC_TLP_EXT
- **Type:** CHARACTER
- **Width:** 5
- **Domain:**
- **Description:** Customer Telephone Extension Number
- **Comments:**

### LIC_TLP_NB
- **Type:** CHARACTER
- **Width:** 14
- **Domain:**
- **Description:** Customer Telephone Number
- **Comments:**

### LIC_TOT_SPRT_TM
- **Type:** INT
- **Width:**
- **Domain:**
- **Description:** Total support time for this customer in minutes.
- **Comments:**
## CSTS Data Stores

**Problems**

**Volume**

**Comments:**

*Purpose:*

**PRBM_CD**

*Type:* CHARACTER  
*Width:* 8

*Domain:*

*Description:*  
Problem Code will contain the code for the recurring instances of support given, for example: problems with installation, or configuration.

*Comments:*

**PRBM_DESC**

*Type:* TEXT  
*Width:*

*Domain:*

*Description:*  
Description of a recurring problem.

*Comments:*
CSTS Data Stores

Support Calls

<table>
<thead>
<tr>
<th>Volume</th>
<th>Entity</th>
<th>Normalize: T</th>
</tr>
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<tbody>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
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</tbody>
</table>

Purpose:

<table>
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<tr>
<th>LICENSEE_ID</th>
<th>Type: CHARACTER</th>
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<td></td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Company's ID which will be assigned when the Software package is shipped. This number can be found in the runtime about box, for applications which support embedded User IDs.

Comments:

<table>
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<td>Length:</td>
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</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Problem Code will contain the code for the recurring instances of support given, for example: problems with installation, or configuration.

Comments:

<table>
<thead>
<tr>
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<tr>
<td>Description:</td>
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This is a memo field to contain the comment/reason for the support.

Comments:

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Contain the date of the support.

Comments:

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<td>Length:</td>
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</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Support Time will contain the duration of support time in minutes.

Comments:
Customer Support Tracking System Visual Basic Listings/Screens

Customer Support Tracking System Main Screen (Visual Basic Version)
Main Form Object Definitions (CSTS.FRM)

VERSION 2.00
Begin Form CSTSMain
  Caption = "Customer Support Tracking System"
  ClientHeight = 6735
  ClientLeft = 360
  ClientTop = 1605
  ClientWidth = 8640
  Height = 7425
  Left = 300
  LinkTopic = "Form1"
  ScaleHeight = 6735
  ScaleWidth = 8640
  Top = 975
  Width = 8760
Begin CommandButton btnSprtCall
  Caption = "Support Calls"
  Height = 495
  Left = 4440
  TabIndex = 40
  Top = 120
  Width = 1335
End
Begin Frame CMPYData
  BackColor = &H00E0E0E0&
  Caption = "Company Information"
  Height = 2895
  Left = 120
  TabIndex = 18
  Top = 3600
  Width = 7935
Begin CommandButton btnCoMaint
  Caption = "Delete Companies"
  Height = 615
  Left = 3480
  TabIndex = 9
  Top = 2160
  Width = 1935
End
Begin CommandButton btnChgCoInfo
  Caption = "Change Company Info"
  Height = 615
  Left = 5520
  TabIndex = 10
  Top = 2160
  Width = 2175
End
Begin Label Label2
  Caption = "Company Country:"
  Height = 255
  Left = 120

- 120 -
TabIndex = 38
Top = 2520
Width = 1575

End

Begin Label Label1
DataField = "CMPY_CNTRY"
DataSource = "Licensees"
Height = 255
Left = 1680
TabIndex = 39
Top = 2520
Width = 1695

End

Begin Label CompanyName
DataField = "CMPY_NM"
DataSource = "Licensees"
Height = 375
Left = 1560
TabIndex = 22
Top = 480
Width = 4815

End

Begin Label CompanyAddr1
DataField = "CMPY_AD1"
DataSource = "Licensees"
Height = 255
Left = 1800
TabIndex = 23
Top = 960
Width = 4575

End

Begin Label CompanyAddr2
DataField = "CMPY_AD2"
DataSource = "Licensees"
Height = 255
Left = 1800
TabIndex = 13
Top = 1320
Width = 4575

End

Begin Label CompanySt
DataField = "CMPY_ST_CD"
DataSource = "Licensees"
Height = 375
Left = 6000
TabIndex = 14
Top = 1680
Width = 375

End

Begin Label CompanyCity
DataField = "CMPY_CITY_NM"
DataSource = "Licensees"
Height = 375
End
Begin Label CmpyZPEXT
  DataField = "CMPY_EXT_ZIP"
  DataSource = "Licensees"
  Height = 255
  Left = 2760
  TabIndex = 36
  Top = 2160
  Width = 615
End

Begin Label lblCmpySt
  Caption = "Company State:"
  Height = 375
  Left = 4560
  TabIndex = 35
  Top = 1680
  Width = 1455
End

Begin Label lblCmpyCity
  Caption = "Company City:"
  Height = 375
  Left = 120
  TabIndex = 34
  Top = 1680
  Width = 1335
End

Begin Label lblCmpyAdl
  Caption = "Company Address:"
  Height = 615
  Left = 120
  TabIndex = 33
  Top = 960
  Width = 1695
End

Begin Line Line5
  BorderWidth = 2
  X1 = 2400
  X2 = 2520
  Y1 = 2280
  Y2 = 2280
End

Begin Label CompanyZip
  Alignment = 1 'Right Justify'
  DataField = "CMPY_ZP"
  DataSource = "Licensees"
  Height = 255
  Left = 1320
  TabIndex = 21
  Top = 2160
<table>
<thead>
<tr>
<th>Width</th>
<th>855</th>
</tr>
</thead>
</table>

**Begin Line Line4**

<table>
<thead>
<tr>
<th>BorderWidth</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>7920</td>
</tr>
<tr>
<td>X2</td>
<td>7920</td>
</tr>
<tr>
<td>Y1</td>
<td>2880</td>
</tr>
<tr>
<td>Y2</td>
<td>120</td>
</tr>
</tbody>
</table>

**End**

**Begin Line Line3**

<table>
<thead>
<tr>
<th>BorderWidth</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>0</td>
</tr>
<tr>
<td>X2</td>
<td>7920</td>
</tr>
<tr>
<td>Y1</td>
<td>2880</td>
</tr>
<tr>
<td>Y2</td>
<td>2880</td>
</tr>
</tbody>
</table>

**End**

**Begin Label lblHyph**

<table>
<thead>
<tr>
<th>Caption</th>
<th>&quot; &quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>FontBold</td>
<td>True</td>
</tr>
<tr>
<td>FontItalic</td>
<td>False</td>
</tr>
<tr>
<td>FontName</td>
<td>&quot;MS Sans Serif&quot;</td>
</tr>
<tr>
<td>FontSize</td>
<td>12</td>
</tr>
<tr>
<td>FontStrikethru</td>
<td>False</td>
</tr>
<tr>
<td>FontUnderline</td>
<td>False</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>2280</td>
</tr>
<tr>
<td>TabIndex</td>
<td>15</td>
</tr>
<tr>
<td>Top</td>
<td>2160</td>
</tr>
<tr>
<td>Width</td>
<td>375</td>
</tr>
</tbody>
</table>

**End**

**Begin Label lblCmpyName**

<table>
<thead>
<tr>
<th>Caption</th>
<th>&quot;Company Name:&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>375</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>TabIndex</td>
<td>20</td>
</tr>
<tr>
<td>Top</td>
<td>480</td>
</tr>
<tr>
<td>Width</td>
<td>1455</td>
</tr>
</tbody>
</table>

**End**

**Begin Label lblCmpyZP**

<table>
<thead>
<tr>
<th>Caption</th>
<th>&quot;Company Zip:&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>TabIndex</td>
<td>19</td>
</tr>
<tr>
<td>Top</td>
<td>2160</td>
</tr>
<tr>
<td>Width</td>
<td>1215</td>
</tr>
</tbody>
</table>

**End**

**Begin Frame LicData**

<table>
<thead>
<tr>
<th>Caption</th>
<th>&quot;Licensee Information&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>2775</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>TabIndex</td>
<td>16</td>
</tr>
<tr>
<td>Top</td>
<td>720</td>
</tr>
</tbody>
</table>
Width     = 7935
Begin TextBox LicTST
    DataField   = "LIC_TOT_SPRT_TM"
    DataSource  = "Licensees"
    Height      = 375
    Left        = 6240
    TabIndex    = 30
    TabStop     = 0 False
    Top         = 2040
    Width       = 735
End
Begin TextBox LicFAX
    DataField   = "LIC_FAX_NB"
    DataSource  = "Licensees"
    Height      = 375
    Left        = 5160
    TabIndex    = 7
    Top         = 1320
    Width       = 1695
End
Begin TextBox LicTE
    DataField   = "LIC_TLP_EXT"
    DataSource  = "Licensees"
    Height      = 375
    Left        = 5160
    TabIndex    = 6
    Top         = 840
    Width       = 735
End
Begin TextBox LicTN
    DataField   = "LIC_TLP_NB"
    DataSource  = "Licensees"
    Height      = 375
    Left        = 5160
    TabIndex    = 5
    Top         = 360
    Width       = 1695
End
Begin TextBox LicSD
    DataField   = "LIC_SHIP_DT"
    DataSource  = "Licensees"
    Height      = 375
    Left        = 1560
    TabIndex    = 4
    Top         = 2040
    Width       = 2175
End
Begin TextBox LicTtI
    DataField   = "LIC_CNTC_TTL"
    DataSource  = "Licensees"
    Height      = 615
    Left        = 1560
    MultiLine   = -1 True
End
Begin Label IblLicTN
  Caption = "Telephone:"
  Height = 255
  Left = 3960
  TabIndex = 27
  Top = 480
  Width = 1215
End
Begin Label IblLicSD
  Caption = "Ship Date:"
  Height = 255
  Left = 360
  TabIndex = 26
  Top = 2160
  Width = 1215
End
Begin Label IblLicTtl
  Caption = "Title:"
  Height = 255
  Left = 360
  TabIndex = 25
  Top = 1560
  Width = 1215
End
Begin Label IblLicLN
  Caption = "Last Name:"
  Height = 255
  Left = 360
  TabIndex = 24
  Top = 960
  Width = 1215
End
Begin Line Line2
  BorderWidth = 3
  X1 = 7920
  X2 = 7920
  Y1 = 2760
  Y2 = 120
End
Begin Line Line1
  BorderWidth = 3
  X1 = 0
  X2 = 7920
  Y1 = 2760
  Y2 = 2760
End
Begin Label IblLicFN
  Caption = "First Name:"
  Height = 255
  Left = 360
  TabIndex = 17
  Top = 480

- 126 -
Width = 1215
End
End

Begin TextBox CompanyIDFK
DataField = "Licensees.CMPY_LOC_ID"
DataSource = "Licensees"
Height = 285
Left = 8040
TabIndex = 8
Top = 1080
Width = 495
End

Begin TextBox LicenseeID
Height = 495
Left = 1440
TabIndex = 0
Top = 120
Width = 2775
End

Begin Data Licensees
Caption = "Licensees"
Connect = ""
DatabaseName = "C:\RATFILES\THESIS\TEST_BED\VB\CSTS\CSTS.MDB"
Exclusive = 0 'False
Height = 495
Left = 5880
Options = 0
ReadOnly = 0 'False
RecordSource = "select * from Licensees, Companies, Licensees INNER JOIN Companies ON Licensees.CMPY_LOC_ID = Companies.CMPY_LOC_ID order by LICENSEE_ID"
Top = 120
Width = 2175
End

Begin TextBox CompanyIDPK
DataField = "Companies.CMPY_LOC_ID"
DataSource = "Licensees"
Height = 285
Left = 8040
TabIndex = 11
Top = 5760
Width = 495
End

Begin Label lblLicID
Caption = "Licensee ID"
Height = 255
Left = 120
TabIndex = 12
Top = 240
Width = 1455
End

Begin Menu MenuFile
Caption = "&File"
Begin Menu MenuFileExit
- 127 -
Option Explicit

Sub btnChgCoInfo_Click ()
    Dim SavePlace As Variant
    'SavePlace = Licensees.Recordset.Bookmark
    'Licensees.Recordset.AddNew
    ChangeCompany.Show 1
    'If LicenseeID.Text = "" Then
    '    Licensees.Recordset.Bookmark = SavePlace
    '    Exit Sub
    'End If

    SavePlace = Licensees.Recordset("LICENSEE_ID") 'LicenseeID.Text
    On Error GoTo CheckErr

    Licensees.Recordset.Update
    Licensees.Refresh
    Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""

    Exit Sub 'No errors

CheckErr:
    Dim msg As String
    Dim Answer As Integer

    Select Case Err
        Case 3022
            msg = "That License ID already exists. Click Yes if you want to go to that record, or Click No if you want to try again."
    End Select
End Sub
Answer = MsgBox(msg, 4, "Duplicate ID Decision")
If Answer = 6 Then 'Yes, go to existing record
    SavePlace = Licensees.Recordset("LICENSEE_ID") *LicenseeID.Text
    Licensees.Recordset.FindFirst "LICENSEE_ID = '' & SavePlace & '''
    Exit Sub
Else
    'btnNewLic_Click 'No, try again
    Exit Sub
End If

Case 3058
    msg = "You must choose a Company affiliation for consistency's sake. Please try again."
    MsgBox msg
    btnChgCoInfo_Click

Case 3101
    msg = "You must choose a Company affiliation for consistency's sake. Please try again."
    MsgBox msg
    btnChgCoInfo_Click

End Select
Resume
End Sub

Sub btnCoMaincClick ()
    CSTSMnt.Show 1
End Sub

Sub btnSprtCall_Click ()
    SupportCall.Show 1
End Sub

Sub LicenseID_LostFocus ()

    Dim SavePlace As Variant
    Dim SaveAffil As Variant
    Dim SQL As String
    Dim CompID As Integer

    SavePlace = LicenseID.Text
    SaveAffil = Licensees.Recordset("Licensees.CMPY_LOC_ID")

    If SavePlace = "" Then
        Licensees.Recordset.MoveNext
        Licensees.Recordset.MoveNext
        Exit Sub
    End If
Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""

'Focus will now be on desired record IF it exists

If Licensees.Recordset.NoMatch = True Then

'Create a new LICENSEE record.
Licensees.Recordset.AddNew
Licensees.Recordset("LICENSEE_ID") = SavePlace
'Each new Licensee must have a Company Affiliation or else the JOIN will be broken
Licensees.Recordset("Licensees.CMPY_LOC_ID") = SaveAffil 'Set a Default
Licensees.Recordset.Update
'Set current record to this new one
Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""

'Automatically invoke the Company info form
btnChgCoInfo_Click

'Refresh with all the latest info
Licensees.Recordset.Update
Licensees.Refresh
Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""

End If

End Sub

Sub Licensees_Error (DataErr As Integer, response As Integer)
Dim msg As String
Dim Answer As Integer
Dim SavePlace As Variant
Select Case DataErr
Case 3022
    msg = "That License ID already exists. Click Yes if you want to go to that record, or Click No if you want to try again."
    Answer = MsgBox(msg, 4, "Duplicate ID Decision")
    If Answer = 6 Then 'Yes, go to existing record
        SavePlace = LicenseeID.Text
        Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""
    Else
        'btnNewLic_Click 'No, try again
        End If
        response = 0
End Select
End Sub

Sub Licensees_Reposition()

    On Error GoTo CheckError

    LicenseeID.Text = Licensees.Recordset("LICENSEE_ID")

End Sub
Exit Sub

CheckError:
Dim msg As String
Dim Answer As Integer
Dim SavePlace As Variant

Select Case Err
Case 3022
    msg = "That License ID already exists. Click Yes if you want to go to that record, or Click No if you want to try again."
    Answer = MsgBox(msg, 4, "Duplicate ID Decision")
    If Answer = 6 Then 'Yes, go to existing record
        SavePlace = LicenseeID.Text
        Licensees.Recordset.FindFirst "LICENSEE_ID = " & SavePlace & ""
        Exit Sub
    Else 'btnNewLic_Click 'No, try again
        Exit Sub
    End If
Case 3058
    msg = "You must choose a Company affiliation for consistency's sake. Please try again."
    MsgBox msg 'btnNewLic_Click
Case 94 'btnChgColnfo_Click
    Exit Sub
End Select
Resume
End Sub

Sub MenuFileExit_Click ()
    End
End Sub

Sub MenuMaintDelCo_Click ()
    CSTSMnt.Show 1
End Sub

Sub MenuMaintDelLic_Click ()
    Licensees.Recordset.Delete
    Licensees.Recordset.MoveNext
End Sub
Select a Company, or type in a new one (up to 50 characters).

Edit/review the rest of the information for the selected company. If there are multiple locations for a company, you can scroll through them to find the right one.

Company Address:

Make Your Changes Below:

Company City:

Company State:

Company Zip:

Company Country:

Customer Support Tracking System Company Maintenance Screen
(Visual Basic Version)

Company Maintenance Form Object Definitions (CHANGECO.FRM)

VERSION 2.00

Begin Form ChangeCompany
  Caption = "Change Company Information"
  ClientHeight = 4995
  ClientLeft = 75
  ClientTop = 2100
  ClientWidth = 10665
  Height = 5400
  Left = 15
  LinkTopic = "Form1"
  ScaleHeight = 4995
  ScaleWidth = 10665
  Top = 1755
  Width = 10785

Begin CheckBox chkBrowse
  Caption = "Browse All Companies"
  Height = 255
  Left = 480
  TabIndex = 18
  Top = 3720
  Width = 2295
End
Begin CommandButton btnCancel
  Caption = "Cancel"
  Height = 615
  Left = 1680
  TabIndex = 9
  Top = 4320
  Width = 975
End

Begin TextBox tedCompanyCntry
  DataField = "CMPY_CNTRY"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 7
  Top = 4560
  Width = 855
End

Begin TextBox CompanyZPExt
  DataField = "CMPY_EXT_ZIP"
  DataSource = "Companies"
  Height = 375
  Left = 6120
  TabIndex = 6
  Top = 3960
  Width = 735
End

Begin TextBox tedCompanySt
  DataField = "CMPY_ST_CD"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 4
  Top = 3360
  Width = 495
End

Begin TextBox tedCompanyCity
  DataField = "CMPY_CITY_NM"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 3
  Top = 2760
  Width = 3255
End

Begin TextBox tedCompanyAddr2
  DataField = "CMPY_AD2"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 2
  Top = 2160
  Width = 4815
End
End
Begin TextBox tedCompanyAddr1
  DataField = "CMPY_AD1"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 1
  Top = 1680
  Width = 4815
End

Begin TextBox CompanyZip
  DataField = "CMPY_ZP"
  DataSource = "Companies"
  Height = 375
  Left = 4680
  TabIndex = 5
  Top = 3960
  Width = 855
End

Begin ComboBox TempCoName
  Height = 300
  Left = 2880
  Sorted = -1 'True
  TabIndex = 0
  Top = 360
  Width = 7095
End

Begin CommandButton btnAccept
  Caption = "Accept"
  Height = 615
  Left = 480
  TabIndex = 8
  Top = 4320
  Width = 975
End

Begin Data Companies
  Caption = "Companies"
  Connect = ""
  DatabaseName = "C:\RA TFILES\THESIS\TEST_BED\VB\CSTS\CSTS.MDB"
  Exclusive = 0 'False
  Height = 615
  Left = 480
  Options = 0
  ReadOnly = 0 'False
  RecordSource = "Companies"
  Top = 2880
  Width = 2175
End

Begin Label lblCmpyCntry
  Caption = "Company Country:"
  Height = 255
  Left = 2880
  TabIndex = 17
Top = 4560
Width = 1575
End
Begin Line Line5
BorderWidth = 2
X1 = 5760
X2 = 5880
Y1 = 4080
Y2 = 4080
End
Begin Label lblCmpyCity
Caption = "Company City:"
Height = 375
Left = 2880
TabIndex = 14
Top = 2760
Width = 1335
End
Begin Label lblCmpyAd1
Caption = "Company Address:"
Height = 615
Left = 2880
TabIndex = 16
Top = 1680
Width = 1695
End
Begin Label lblCmpySt
Caption = "Company State:"
Height = 375
Left = 2880
TabIndex = 15
Top = 3360
Width = 1455
End
Begin Label lblNameChg
Caption = "Make Your Changes Below:"
Height = 255
Left = 5160
TabIndex = 13
Top = 720
Visible = 0 'False
Width = 2415
End
Begin Label lblCmpyZP
Caption = "Company Zip:"
Height = 255
Left = 2880
TabIndex = 12
Top = 3960
Width = 1455
End
Begin Label Label4
Caption = "Edit/review the rest of the information for the selected company. If there are
multiple locations for a company, you can scroll through them to find the right one."

Option Explicit

Dim Loading As Integer
Dim browsing As Integer

Sub btnAccept_Click()
    Dim SQL As String
    Dim CompID As Integer
    Dim SavePlace As String

    'Mustn't have a blank company name, so let the default ride
    If TempCoName.Text = "" Then
        Unload ChangeCompany
        Exit Sub
    End If

    'Update the record with the current info
    Companies.Recordset.Edit
    Companies.Recordset("CMPY_AD1") = (tedCompanyAddr1.Text)
    Companies.Recordset("CMPY_AD2") = (tedCompanyAddr2.Text)
    Companies.Recordset("CMPY_CITY_NM") = (tedCompanyCity.Text)
    Companies.Recordset("CMPY_ST_CD") = (tedCompanySt.Text)
    Companies.Recordset("CMPY_EXT_ZIP") = Val(CompanyZPExt.Text)
    Companies.Recordset("CMPY_ZP") = Val(CompanyZip.Text)
    Companies.Recordset("CMPY_CNTRY") = (tedCompanyCntry.Text)
    CSTSMain.CompanyIDFK = Companies.Recordset("CMPY_LOC_ID")
    Companies.Recordset.Update

    Unload ChangeCompany

End Sub
Sub btnCancel_Click()

Unload ChangeCompany
'NOTE: if you move the record with a button, any edits will be committed!

End Sub

Sub chkBrowser_Click()

If chkBrowser.Value = 1 Then

browsing = True
TempCoName_Click
Else

browsing = False
TempCoName_Click

End If

End Sub

Sub Companies_Reposition()

'The purpose of this procedure is to keep the company name synchronized with
'the rest of the record when browsing, since it is not directly linked to the
'table.

'If we are populating the TempCoName menu (or we know that the current
'record will be NULL), then we want to exit this procedure
If Loading Then
    Exit Sub
End If

'Otherwise, set the box to the value of the current record
TempCoName.Text = Companies.Recordset("CMPY_NM")

End Sub

Sub Form_Load()

Dim SQL As String
Dim PrevLoc As Integer
SQL = "select * from Companies order by CMPY_NM"
Companies.RecordSource = SQL
Companies.Refresh

Loading = True 'Flag for Reposition Event

'Populate the pull-down menu
TempCoName.AddItem "<Browse All Companies>"
Do While Not Companies.Recordset.EOF
    'Skip duplicate names
If TempCoName.List(TempCoName.NewIndex) <> Companies.Recordset("CMPY_NM") Then
    TempCoName.AddItem Companies.Recordset("CMPY_NM")
End If

Companies.Recordset.MoveNext
Loop
'Synchronize the Companies record with the Licensees record
PrevLoc = CSTSMain.Licensees.Recordset("Licensees.CMPY_LOC_ID")
Companies.Recordset.FindFirst "CMPY_LOC_ID = " & PrevLoc & ""
TempCoName.Text = Companies.Recordset("CMPY_NM")
'The work for the rest of the Company data is the same as for a click
TempCoName_Click
Loading = False 'Flag for Reposition Event

End Sub

Sub TempCoName_Click ()
    Dim SavePlace As Variant
    Dim SaveIndex As Variant
    Dim SQL As String
    Dim CompID As Integer

    'Hang on to the desired company name
    SavePlace = TempCoName.Text

    'If it's the same as the current record, just hang on to the ID
    If SavePlace = Companies.Recordset("CMPY_NM") Then
        CompID = Companies.Recordset("CMPY_LOC_ID")
    Else
        'Otherwise, move to the beginning of the new name, and grab the ID
        Companies.Recordset.FindFirst "CMPY_NM = " & SavePlace & ""
        CompID = Companies.Recordset("CMPY_LOC_ID")
    End If

    'Make sure that the entire table is available for the upcoming FindFirst
    'and sort it by company name, which is more meaningful to users than ID
    SQL = "select * from Companies order by CMPY_NM"
    Companies.RecordSource = SQL
    Companies.Refresh

    'Our job is done if the user is wishing to browse all companies
    If SavePlace = "<Browse All Companies>" Then
        chkBrowser.Value = 1
        browsing = True
        Exit Sub
    End If

    'Now match the User-Supplied Company Name
Companies.Recordset.FindFirst "CMPY_NM = " & SavePlace & ""

If Companies.Recordset.NoMatch = True Then
    'Since there is no match, create a new COM_LOC_ID and add a new record with new company name.
    Loading = True 'to avoid illegal null in Companies_Reposition
    'move to the highest numbered company ID
    SQL = "select * from Companies order by CMPY_LOC_ID"
    Companies.RecordSource = SQL
    Companies.Refresh
    Companies.Recordset.MoveNext
    'and increment it to set the ID for the new company
    CompID = Companies.Recordset("CMPY_LOC_ID")
    CompID = CompID + 1
    'Then create a new record with the new name and ID
    Companies.Recordset.AddNew
    Companies.Recordset("CMPY_LOC_ID") = CompID
    Companies.Recordset("CMPY_NM") = SavePlace
    Companies.Recordset.Update
    Companies.Recordset.MoveNext
    'Add the new company to the pull-down menu
    TempCoName.AddItem SavePlace 'or...
    'Finally, resort the table and put the new record in front of the user
    TempCoName.Text = Companies.Recordset("CMPY_NM")
    SQL = "select * from Companies order by CMPY_NM"
    Companies.RecordSource = SQL
    Companies.Refresh
    Companies.Recordset.FindFirst "CMPY_LOC_ID = " & CompID
    Loading = False

Else
    'Since there is a match, filter the records and go to the first one
    'Unless the user is in Browsing Mode
    If browsing Then
        Companies.Recordset.FindFirst "CMPY_LOC_ID = " & Str(CompID)
        Exit Sub
    End If

    SQL = "select * from Companies where CMPY_NM = " & TempCoName.Text & ""
    Companies.RecordSource = SQL
    Companies.Refresh
    Companies.Recordset.MoveNext
    'Move to the most recent ID
    Companies.Recordset.FindFirst "CMPY_LOC_ID = " & Str(CompID)

End If
End Sub

Sub TempCoName_LostFocus ()

    TempCoName_Click

End Sub
Support Call Form Object Definitions (SUPPORTC.FRM)

VERSION 2.00
Begin Form SupportCall
  Caption  = "Support Calls"
  ClientHeight  = 6900
  ClientLeft  = 1320
  ClientTop  = 1815
  ClientWidth  = 7365
  Height  = 7305
  Left  = 1260
  LinkTopic  = "Form1"
  ScaleHeight  = 6900
  ScaleWidth  = 7365
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>MultiLine</td>
<td>-1 'True</td>
</tr>
<tr>
<td>ScrollBars</td>
<td>2 'Vertical</td>
</tr>
<tr>
<td>TabIndex</td>
<td>0</td>
</tr>
<tr>
<td>Top</td>
<td>1560</td>
</tr>
<tr>
<td>Width</td>
<td>6975</td>
</tr>
<tr>
<td>Caption</td>
<td>&quot;Support Time:&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>3360</td>
</tr>
<tr>
<td>TabIndex</td>
<td>11</td>
</tr>
<tr>
<td>Top</td>
<td>1080</td>
</tr>
<tr>
<td>Width</td>
<td>1575</td>
</tr>
<tr>
<td>Caption</td>
<td>&quot;Start Date/Time:&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>3360</td>
</tr>
<tr>
<td>TabIndex</td>
<td>10</td>
</tr>
<tr>
<td>Top</td>
<td>480</td>
</tr>
<tr>
<td>Width</td>
<td>1575</td>
</tr>
<tr>
<td>Caption</td>
<td>&quot;Minutes&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>6240</td>
</tr>
<tr>
<td>TabIndex</td>
<td>9</td>
</tr>
<tr>
<td>Top</td>
<td>1080</td>
</tr>
<tr>
<td>Width</td>
<td>735</td>
</tr>
<tr>
<td>Caption</td>
<td>&quot;Description of Call:&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>TabIndex</td>
<td>8</td>
</tr>
<tr>
<td>Top</td>
<td>1320</td>
</tr>
<tr>
<td>Width</td>
<td>1695</td>
</tr>
<tr>
<td>Caption</td>
<td>&quot;Licensee ID:&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>255</td>
</tr>
<tr>
<td>Left</td>
<td>120</td>
</tr>
<tr>
<td>TabIndex</td>
<td>7</td>
</tr>
<tr>
<td>Top</td>
<td>1215</td>
</tr>
<tr>
<td>Width</td>
<td>1215</td>
</tr>
<tr>
<td>BorderStyle</td>
<td>1 'Fixed Single</td>
</tr>
<tr>
<td>DataField</td>
<td>&quot;SPRT_DATE&quot;</td>
</tr>
<tr>
<td>DataSource</td>
<td>&quot;SupportCalls&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>495</td>
</tr>
<tr>
<td>Left</td>
<td>5040</td>
</tr>
</tbody>
</table>
TabIndex  = 5
Top       = 360
Width     = 2055
End

Begin Label lblSprtTimeUsed
BorderStyle = 1 'Fixed Single
DataField   = "SPRT_TM"
DataSource  = "SupportCalls"
Height      = 495
Left        = 5040
TabIndex    = 4
Top         = 960
Width       = 1095
End
End

Support Call Form Object Behaviors (SUPPORTC.FRM)

Option Explicit

Dim Prevloc As String

Sub btnAccept_Click()

    Dim Duration As Integer

    'Calculate the time used for the call
    Duration = DateDiff("n", lblStartTime.Caption, Now)
    Duration = Duration / 15
    Duration = Duration * 15 + 15
    lblSprtTimeUsed.Caption = Duration

    'Put the record pointer at the new record
    SupportCalls.Recordset.MoveLast

    'Update the record with the current info
    SupportCalls.Recordset.Edit
    SupportCalls.Recordset("SPRT_CMT") = txtDescription.Text
    SupportCalls.Recordset("SPRT_TM") = Val(lblSprtTimeUsed.Caption)
    SupportCalls.Recordset.Update

    Unload SupportCall

End Sub

Sub btnCancel_Click()

    'Put the record pointer at the new record
    SupportCalls.Recordset.MoveLast

    'Delete the newly created record
SupportCalls.Recordset.Delete
SupportCalls.Recordset.MoveNext

Unload SupportCall
'NOTE: if you move the record with a button, any edits will be committed!

End Sub

Sub Form_Load()

Dim SQL As String
Static Prevloc As String

Prevloc = CSTSMain.Licensees.Recordset("Licensees.LICENSEE_ID")

'Filter the records to the selected Licensee
SQL = "select * from Support where Support.LICENSEE_ID = "
SQL = SQL & Prevloc
SQL = SQL & " order by SPRT_DATE"
SupportCalls.RecordSource = SQL
SupportCalls.Refresh

'Create a new record
SupportCalls.Recordset.AddNew

'Set the start date/time (key) and ID for the new support call
SupportCalls.Recordset("SPRT_DATE") = Now
SupportCalls.Recordset("LICENSEE_ID") = Prevloc
SupportCalls.Recordset("SPRT_TM") = 0 'For Null protection, (just in case)
SupportCalls.Recordset.Update
SupportCalls.Recordset.MoveLast

End Sub

Sub Form_Unload(Cancel As Integer)

Dim Total As Integer
Dim SQL As String
Static PrevLoc As String

're-filter, in case the user has selected "Browse All Calls"
SQL = "select * from Support where Support.LICENSEE_ID = " & Prevloc & ""
SupportCalls.RecordSource = SQL
SupportCalls.Refresh

'Calculate the total support time used to date for that licensee
Total = 0
Do While Not SupportCalls.Recordset.EOF
    Total = Total + SupportCalls.Recordset("SPRT_TM")
    SupportCalls.Recordset.MoveNext
Loop
CSTSMain.Licensees.Recordset.Edit
CSTSMain.Licensees.Recordset("LIC_TOT_SPRT_TM") = Total
CSTSMain.Licensees.Recordset.Update

End Sub

Sub tedLicID_GotFocus()
    tedDescription.SetFocus
End Sub
Customer Support Tracking System Company Deletion Screen (Visual Basic Version)

Company Deletion Form Object Definitions (CSTSMNT.FRM)

VERSION 2.00
Begin Form CSTSMnt
  Caption = "CSTS Company Maintenance"
  ClientHeight = 3405
  ClientLeft = 1095
  ClientTop = 1485
  ClientWidth = 7365
  Height = 3810
  Left = 1035
  LinkTopic = "Form1"
  ScaleHeight = 3405
  ScaleWidth = 7365
  Top = 1140
  Width = 7485
Begin CommandButton Command2
  Caption = "Return"
  Height = 615
  Left = 5280
  TabIndex = 1
  Top = 2400
  Width = 1455
End
Begin TextBox texCompanyName
  DataField = "CMPY_NM"
  DataSource = "Companies"
  Height = 495
  Left = 960
End

- 146 -
TabIndex = 2
TabStop = 0 'False
Top = 1320
Width = 2175
End

Begin TextBox tedCompanyZip
DataField = "CMPY_ZIP"
DataSource = "Companies"
Height = 495
Left = 3960
TabIndex = 3
TabStop = 0 'False
Top = 1320
Width = 2175
End

Begin CommandButton Command1
Caption = "Delete"
Height = 615
Left = 3360
TabIndex = 0
Top = 2400
Width = 1455
End

Begin Data Companies
Caption = "Companies"
Connect = DatabaseName = "C:\RAFILES\THESIS\TEST_BED\VB\CSTS\CSTS.MDB"
Exclusive = 0 'False
Height = 615
Left = 720
Options = 0
ReadOnly = 0 'False
RecordSource = "Companies"
Top = 2400
Width = 2175
End

Begin Label Label3
Alignment = 2 'Center
AutoSize = -1 'True
Caption = "Company Maintenance"
FontBold = -1 'True
FontItalic = 0 'False
FontName = "MS Sans Serif"
FontSize = 18
FontStrikethru = 0 'False
FontUnderline = 0 'False
Height = 435
Left = 1485
TabIndex = 6
Top = 360
Width = 4005
End

Begin Label Label2

- 147 -
Company Deletion Form Object Behaviors (CSTSMNT.FRM)

Option Explicit

Sub Command1_Click ()
    Companies.Recordset.Delete
    Companies.Recordset.MoveNext
End Sub

Sub Command2_Click ()
   Unload CSTSMnt
End Sub
Customer Support Tracking System Main Screen (ObjectVision Version)
<table>
<thead>
<tr>
<th>Company Name: Floors-A-Rama</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Address: 333 Downtown Sweet 16</td>
</tr>
<tr>
<td>Company City: Sue City</td>
</tr>
<tr>
<td>Company Zip: 88888</td>
</tr>
<tr>
<td>Company Country: USA</td>
</tr>
</tbody>
</table>

Customer Support Tracking System Company Maintenance Screen
(ObjectVision Version)
Support Description:
We had another of those little crashes.
1. Right-click on the field to bring up Attributes menu; Select “Field Type”

2. Select & OK “Combo Box”

3. Select & OK “Automatic”; values will be populated from data base

Visual “Source Code” for a Typical Automatic Combo Box
After Selecting "Field Type" from Attribute Menu, and Selecting "Date/Time" from the "Field Type" Dialog, Select & OK desired "Date Format"

Visual "Source Code" for a Typical Date Field

After Selecting "Protection" from Attribute Menu, Select & OK "No Override" and "No Tree Display"

Visual "Source Code" for a Typical Protected (non-editable) Field

After Selecting "Field Type" from Attribute Menu, and Selecting "Picture" from the "Field Type" Dialog, Type in & OK desired "Picture String"

Visual "Source Code" for a Typical Picture (constrained) Field
1. Open "Data Links" Tool, Select the desired Data Base Type, and Click on "Create..."

2. IF a Table already exists, Type in a new "Link Name" on the "Link Creation" Dialog, Type in (or "Search..." for ) a Table, Click on "Defaults"; ObjectVision matches and links "Data Base Table Fields" with "ObjectVision Fields"; IF the Table must be created, Click on "Create Table..." and go on to step 3

Visual "Source Code" for Data Link Creation
3. On the "Data Base Table Creation" Dialog, Type in a new Table Name and then edit (or accept as-is) the "Table Definitions" automatically drafted by ObjectVision based on the user interface fields created to that point.

Visual "Source Code" for Data Link Creation (continued)
4. Once the link is OK'd, the "Optional Link Capabilities" Dialog appears for selecting (for example) Referential Integrity Rules and Filters

5. If "Filters..." is Clicked, the "Link Filters" Dialog is presented which allows the programmer to filter the contents of the database before evaluation by the ObjectVision application

Visual "Source Code" for Data Link Creation (continued)
Visual "Source Code" for a "Change Event" on the "Licensee ID" Field

Visual "Source Code" for an "Open Event" on the "Change Company Information" Form
Visual "Source Code" for a "Click Event" on the "Return" Button on the "Change Company Information" Form

Visual "Source Code" for a "Click Event" on the "Cancel" Button on the "Change Company Information" Form
Visual “Source Code” for a “Click Event” on the “New Company” Button on the “Change Company Information” Form

Visual “Source Code” for assigning the value of the “LicID” Field on the “Support Call” Form
Visual “Source Code” for a “Click Event” on the “Accept” Button on the “Support Call” Form

Visual “Source Code” for a “Click Event” on the “Cancel” Button on the “Support Call” Form
Tic-Tac-Toe Requirements Definition Statement

The application shall provide a Graphic User Interface which allows a player to select Tic-Tac-Toe moves by clicking on a mouse-sensitive board and to begin the game by clicking on a <New game> button. The game shall respond by painting a blank Tic Tac Toe board and presenting a message to "click on a square or select <You Go First> to begin play." The game shall alternately accept a user's move and make its own move with the goal of winning the game. The system shall reject illegal moves attempted by the user and shall fill in (legal) moves made by the user and itself. The system shall monitor for a win or a draw and display an appropriate message. The player shall be "X" and the program shall be "O." No player records or statistics will be kept; each game shall be a clean start. The gaming strategy shall first rule out a win by the player (this should be impossible), then look for a win for itself, then look for a block of an imminent win by the player and then determine an offensive move.
Coad/Yourdon Object-Oriented Analysis

Classes/Objects: (Domain Related)
Playing Board, with Tic Tac Toe icon
Cells (one for each play location)
Tokens ("X", "O")
Rows, Columns, Diagonals
Player
Strategies and Plays
(Program Related)
Window
Message Box (to communicate with User)
Controls (for starting a new game, quitting and letting the program go first)
Game Engine (to make moves on behalf of the application)

Gen-Spec Structure: None

Whole-Part Structure: Window:Board|Controls|Message Box
Board:Cells
Cells:Tokens
Board:Rows|Columns|Diagonals (RICD)

Attributes: Cell.Value (internal integer representation of Token, -1 for "O", +1 for "X" and 0 for "blank")
Cell.Token (external string representation, including Font and Color)
Rows|Columns|Diagonals.Sum (an integer whose value is the sum of the three Cell.Value in that row, column or diagonal)
Window and Board Geometry (in general, such as color and border)

Services/Calculations:

On Cell
Monitor for Mouse-Click over Cell
Validate User Changes to Cell.Token (is Cell empty?)
Send a Message if Cell is taken (or game is over)
Set Cell.Token to "X" after valid User click on Cell
Set Cell.Value based on changes to Cell.Token
Deactivate the < You Go First> control (on first move)
Give control to Game Engine to make its move

Game Strategies
Look for User Win (any Sum = 3) (should be impossible)
Look for Game Winning Move (any Sum = -2)
Look for Blocking Move (any Sum = 2)
Look for a Wedge-prevention Move (to avoid the several ways a User might create a "double bind")
Pick a Cell according to the following search pattern:

<table>
<thead>
<tr>
<th>2</th>
<th>6</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>
On RICID

Update the R/CID.Sum whenever a member changes value

Application

Navigate Cells and Controls when the User presses the <Tab> key
Emulate a Mouse-Click when the User presses other keys

On <New Game> control (when clicked)
Initialize all Cells to empty
Activate the <You Go First> control
Display a Message to the User

On <You Go First> control (when clicked)
The Game Engine will take the center Cell
Deactivate the <You Go First> control

On <Quit> control (when clicked)
Close the Application
Coad/Yourdon Object-Oriented Design

Note: For Visual Basic implementation, there is no inheritance and only Classes/Objects/Behaviors related to the User Interface

Human Interaction Component

User Classes: Tic Tac Toe Players (only one skill level; multiple skill levels is future scope)

Description: People who don’t mind never being able to win a game they are playing

Command Hierarchy: New Game --> User First | Game First --> Alternating Moves
Quit Button Available at all times
Game Over when all Cells are Taken, or when User (impossible) or Game gets three of their Tokens in a row

Window: Titled “Tic Tac Toe”
Large enough to contain a Tic Tac Toe board, three buttons and a Message Box

Fields: Cell Array (9) Each consists of an editable TextBox (not sizable)
May contain a single <blank> (the default value), a large bold “X”, or “O” (18point Sans Serif or equivalent)
The Mouse Pointer Icon should change when it is over the active area of a Cell
Each Cell should provide its own validation and updating services when clicked upon
If possible, the Cell should keep two values, one textual (“X”, “O”, <blank>) and one numeric (+1, -1, 0)

Message Box: A non-editable TextBox in which to display messages/prompts to the User
Sized to display up to 4, 40-character lines, with word wrap
Default contents should be “Click on <New Game> to begin.”

Quit: A Command Pushbutton which allows the User to exit the game
Caption reads “Quit”

New Game: A Command Pushbutton which allows the User to start a new game
Caption reads “New Game”

You Go First: A Command Pushbutton which allows the User to instruct the program to make the first move
Caption reads “You Go First”
The Command should only be visible and enabled just after <New Game> is clicked, but before the User has clicked on any Cell

Graphic Lines: Four straight lines, organized to look like a traditional Tic Tac Toe board
Note: The User should be able to operate the system without a mouse by using the <Tab> key to navigate the Board and Buttons, and any standard key to place an “X” or activate a button.

Note: Standard MSWindows pull-down menus (e.g., File, Edit, etc.) were deemed unnecessary for this application.

### Task Management Component

<table>
<thead>
<tr>
<th>Task Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event Driven Tasks</td>
<td>See User Interface and Game Engine Diagrams</td>
</tr>
<tr>
<td>Clock Driven Tasks</td>
<td>None</td>
</tr>
<tr>
<td>Priority/Critical Tasks</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Other Tasks</td>
<td>See User Interface and Game Engine Diagrams</td>
</tr>
</tbody>
</table>
User Interface Service Diagram (Main Event Loop and Command Buttons)

Begin

Draw Window and Objects

Send Click Event to "New Game" Button

Main Event Loop

User Interface Behavior

Clicked on "Quit" Button

Exit Program

End

Clicked on "New Game" Button

Set GameState to SYSTEM

Set Each BoardCell(i).Text to " "

Clicked on "You Go First" Button

Hide/Disable "You Go First" Button

Clicked on BoardCell(i)

Call MakeMove()

Done

Changed BoardCell(i)

A

B

NOTE: This spawns a "Changed BoardCell" Event

Call UpdateSums()

User Message: "Click on any cell to make your first move, or... Click on the <You Go First> Button if you want me to go first."

Show/Enable "You Go First" Button

Done
User Interface Service Diagram (Clicked on Text Cell)

A

IF "You Go First" Button is Enabled

Hide/Disable "You Go First" Button

User Message: "Get over it... because the Game is. Click on <New Game> to play again."

IF GameState <> PLAY

User Message: "Sorry, that cell is already in use... please try again."

IF BoardCell(i).Text <> " "

User Message: "Processing."

Set BoardCell(i).Text to "X"

NOTE: This spawns a "Changed BoardCell" Event

Call MakeMove()

User Message: "Your move."

User Message: "I guess the cat got this one... Click on <New Game> to play again."

User Message: "I don't believe it, YOU WON!!! Quick, Click on <New Game>.

Else, GameState = USERWINS

Done

Done

Done

Done

Done

NOTE: This spawns a "Changed BoardCell" Event
User Interface Service Diagram (Changed Value on Text Cell)

B

IF GameState = PLAY

Done

IF BoardCell(i).Text = "X"

BoardCell(i).Value = 1

IF BoardCell(i).Text = "O"

BoardCell(i).Value = -1

Call UpdateSums

Done

Done
User Interface Subroutine

Begin
UpdateSums()

Column(0) = BoardCell(0).Value + BoardCell(3).Value + BoardCell(6).Value
Column(1) = BoardCell(1).Value + BoardCell(4).Value + BoardCell(7).Value
Column(2) = BoardCell(2).Value + BoardCell(5).Value + BoardCell(8).Value
Row(0) = BoardCell(0).Value + BoardCell(1).Value + BoardCell(2).Value
Row(1) = BoardCell(3).Value + BoardCell(4).Value + BoardCell(5).Value
Row(2) = BoardCell(6).Value + BoardCell(7).Value + BoardCell(8).Value
Diagonal(0) = BoardCell(0).Value + BoardCell(4).Value + BoardCell(8).Value
Diagonal(1) = BoardCell(2).Value + BoardCell(4).Value + BoardCell(6).Value

Done
Game Engine Service Diagram (Main Move Selection Logic)

Begin
MakeMove()

IF
LookForUserWin()

Set GameState = USERWINS

Done

IF
FindAWin()

Done

IF
FindABlock()

Done

IF
BustAWedge()

Done

IF
PickCell(4)

Done

IF
PickCell(0)

Done

IF
PickCell(2)

Done

IF
PickCell(6)

Done

IF
PickCell(8)

Done

IF
PickCell(1)

Done

IF
PickCell(3)

Done

IF
PickCell(5)

Done

IF
PickCell(7)

Done

Done
Game Engine Service Diagram (Look for User Win and Look for Draw)

Begin
LookForUserWin()

For i = 0 to 2
  IF Column(i) = 3
    Done; Return 1
  Next i

For i = 0 to 2
  IF Row(i) = 3
    Done; Return 1
  Next i

For i = 0 to 1
  IF Diagonal(i) = 3
    Done; Return 1
  Next i

Done; Return 0

Begin
LookForDraw()

Set Count = 0

For i = 0 to 8
  IF BoardCell(i).Text <> " "
    Count++
    Done; Return 1
  IF Count >= 8
    Done; Return 0
  Next i

Next i
Begin FindAWin()

IF (BoardSum) = -2

PickCell(1st Choice)

PickCell(2nd Choice)

PickCell(3rd Choice)

Done; Return 1

Done; Return 0

Begin FindABlock()

IF (BoardSum) = 2

PickCell(1st Choice)

PickCell(2nd Choice)

PickCell(3rd Choice)

Done; Return 1

Done; Return 0

Game Engine Service Diagram (Look for Win and Look for Block)

## Logic Table

<table>
<thead>
<tr>
<th>BoardSum</th>
<th>1st Choice</th>
<th>2nd Choice</th>
<th>3rd Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column(0)</td>
<td>0</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Column(1)</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Column(2)</td>
<td>2</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Row(0)</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Row(1)</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Row(2)</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Diagonal(0)</td>
<td>0</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Diagonal(1)</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
Game Engine Service Diagram (Bust a Wedge)

```
Begin
BustAWedge()

IF
Diagonal(0) + Diagonal(1) = 0

PickCell(4)
Done; Return 1

IF
Row(0) + Column(0) = 2

PickCell(0)
Done; Return 1

IF
Row(0) + Column(2) = 2

PickCell(2)
Done; Return 1

IF
Row(2) + Column(0) = 2

PickCell(6)
Done; Return 1

IF
Row(2) + Column(2) = 2

PickCell(8)
Done; Return 1

Done; Return 0
```
Game Engine Service Diagram (Pick a Cell)

Begin PickCell(i)

IF BoardCell(i).Text = " "

Done; Return 0

Set GameState = SYSTEM

Set BoardCell(i).Text = "O"

Set BoardCell(i).Value = -1

Set GameState = PLAY

IF LookForDraw()

Set GameState = DRAW

Done; Return 1
Click on <New Game> to begin.

Tic Tac Toe Visual Basic Listings/Screens

Tic Tac Toe Main Screen (Visual Basic Version)
Main Form Object Definitions (MAIN.FRM)

VERSION 2.00

Begin Form frmMain
 BorderStyle = 3 'Fixed Double
  Caption = "Tic Tac Toe"
  ClientHeight = 5820
  ClientLeft = 1065
  ClientTop = 1740
  ClientWidth = 7365
  Height = 6225
  Left = 1005
  LinkTopic = "Form1"
  ScaleHeight = 5820
  ScaleWidth = 7365
  Top = 1395
  Width = 7485
Begin CommandButton btnQuit
  Caption = "Quit"
  Height = 495
  Left = 5640
  TabIndex = 12
  Top = 3840
  Width = 1455
End

Begin TextBox txtCell
  Alignment = 2 'Center
  BorderStyle = 0 'None
  FontBold = -1 'True
  FontItalic = 0 'False
  FontName = "MS Sans Serif"
  FontSize = 18
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height = 435
  Index = 8
  Left = 3120
  MousePointer = 10 'Up Arrow
  TabIndex = 11
  Text = ""
  Top = 2400
  Width = 375
End

Begin TextBox txtCell
  Alignment = 2 'Center
  BorderStyle = 0 'None
  FontBold = -1 'True
  FontItalic = 0 'False
  FontName = "MS Sans Serif"
  FontSize = 18
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height = 435

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Index = 7
Left = 2520
MousePointer = 10 'Up Arrow
TabIndex = 10
Text = ""
Top = 2400
Width = 375
End
Begin TextBox txtCell
  Alignment = 2 'Center
  BorderStyle = 0 'None
  FontBold = -1 'True
  FontItalic = 0 'False
  FontName = "MS Sans Serif"
  FontSize = 18
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height = 435
  Index = 6
  Left = 1920
  MousePointer = 10 'Up Arrow
  TabIndex = 9
  Text = ""
  Top = 2400
  Width = 375
End
Begin TextBox txtCell
  Alignment = 2 'Center
  BorderStyle = 0 'None
  FontBold = -1 'True
  FontItalic = 0 'False
  FontName = "MS Sans Serif"
  FontSize = 18
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height = 435
  Index = 5
  Left = 3120
  MousePointer = 10 'Up Arrow
  TabIndex = 8
  Text = ""
  Top = 1800
  Width = 375
End
Begin TextBox txtCell
  Alignment = 2 'Center
  BorderStyle = 0 'None
  FontBold = -1 'True
  FontItalic = 0 'False
  FontName = "MS Sans Serif"
  FontSize = 18
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
FontUnderline = 0 'False
Height = 435
Index = 1
Left = 2520
MousePointer = 10 'Up Arrow
TabIndex = 4
Text = ""
Top = 1200
Width = 375

End

Begin CommandButton btnYouGoFirst
Caption = "You Go First"
Enabled = 0 'False
Height = 495
Left = 5640
TabIndex = 0
Top = 1320
Visible = 0 'False
Width = 1455

End

Begin CommandButton btnNewGame
Caption = "New Game"
Height = 495
Left = 5640
TabIndex = 1
Top = 3240
Width = 1455

End

Begin TextBox txtCell
Alignment = 2 'Center
BorderStyle = 0 'None
DragIcon = MAIN.FRX:0000
FontBold = -1 'True
FontItalic = 0 'False
FontName = "MS Sans Serif"
FontSize = 18
FontStrikeThru = 0 'False
FontUnderline = 0 'False
Height = 435
Index = 0
Left = 1920
MousePointer = 10 'Up Arrow
TabIndex = 3
Text = ""
Top = 1200
Width = 375

End

Begin TextBox txtMsgBox
Height = 1095
Left = 480
MultiLine = -1 'True
TabIndex = 2
TabStop = 0 'False
Text = "Click on <New Game> to begin."
Top = 3240
Width = 4575
End
Begin Line Line2
  BorderWidth = 2
  X1 = 3000
  X2 = 3000
  Y1 = 1080
  Y2 = 2880
End
Begin Label Label1
  Caption = "Labell"
  Height = 375
  Index = 0
  Left = 3600
  TabIndex = 13
  Top = 1080
  Width = 615
End
Begin Line Line4
  BorderWidth = 2
  X1 = 1800
  X2 = 3600
  Y1 = 2280
  Y2 = 2280
End
Begin Line Line3
  BorderWidth = 2
  X1 = 1800
  X2 = 3600
  Y1 = 1680
  Y2 = 1680
End
Begin Line Line1
  BorderWidth = 2
  X1 = 2400
  X2 = 2400
  Y1 = 1080
  Y2 = 2880
End
End
Main Form Object Behaviors (MAIN.FRM)

Sub btnNewGame_Click ()

    Dim i As Integer

    'Blank out board
    gnGameState = SYSTEM_CONTROL
    For i = 0 To 8
        txtCell(i).Tag = 0
        txtCell(i).Text = " "
        Label1(i).Caption = txtCell(i).Tag
    Next

    'Set up for play
    gnGameState = PLAY
    Call UpdateSums
    txtMsgBox.Text = "Click on any cell to make your first move, or... Click on the <You Go First> button if you want me to go first."
    btnYouGoFirst.Enabled = True
    btnYouGoFirst.Visible = True
End Sub

Sub btnQuit_Click ()
    End
End Sub

Sub btnYouGoFirst_Click ()

    Dim temp As Integer

    btnYouGoFirst.Enabled = False
    btnYouGoFirst.Visible = False

    temp = PickCell(4)
End Sub

Sub Form_Load ()
    Call btnNewGame_Click
End Sub

Sub txtCell_Change (Index As Integer)

    If gnGameState = PLAY Then
        If Val(txtCell(Index).Tag) = 1 Then
            txtCell(Index).Text = "X"
    End If
End Sub
ElseIf Val(txtCell(Index).Tag) = -1 Then
    txtCell(Index).Text = "O"
Else txtCell(Index).Text = "X"
    txtCell(Index).Tag = 1
    Label1(Index).Caption = txtCell(Index).Tag
Update ColRowDiag Sums
    Call UpdateSums
End If
End If

End Sub

Sub txtCell_Click (Index As Integer)

'Just in case the User is faster than the system
    If gnGameState = SYSTEM_CONTROL Then
        Exit Sub
    End If

'Get rid of <You Go First> if it is still there
    If btnYouGoFirst.Enabled = True Then
        btnYouGoFirst.Enabled = False
        btnYouGoFirst.Visible = False
    End If

'See if game is still in progress
    If gnGameState <> PLAY Then
        txtMsgBox.Text = "Get over it... because the game is. Click on <New Game> to play again."
        Exit Sub
    End If

'Validate User Move
    If txtCell(Index).Text <> " " Then
        txtMsgBox.Text = "Sorry, that cell is already in use...please try again."
        Exit Sub
    End If

'Set Cell to X
        txtMsgBox.Text = "Processing..." "this invokes txtCell_Change()"
    txtCell(Index).Text = "X"

'Let program make its move
    Call MakeMove

'Handle Game State

Select Case (gnGameState)
    Case PLAY
        txtMsgBox.Text = "Your Move"
    Case GAME_WINS
        txtMsgBox.Text = "Tic Tac Toe, Three in a Row... You lose, I win! You will have to try again (Click on <New Game>)"
    Case DRAW
txtMsgBox.Text = "I guess the cat got this one...Click on <New Game> to play again."
    Case USER_WINS
      txtMsgBox.Text = "I don't believe it, YOU WON!!!...Quick, click on <New Game>.",
    End Select

End Sub

Sub txtCell_KeyPress (Index As Integer, KeyAscii As Integer)
      Call txtCell_Click(Index)
End Sub

Global varColTot(3) As Integer
Global varRowTot(3) As Integer
Global varDiagTot(2) As Integer
Global gnGameState As Integer

Global Const SYSTEM_CONTROL = -1
Global Const PLAY = 0
Global Const GAME_WINS = 1
Global Const DRAW = 2
Global Const USER_WINS = 3
Supporting Functions and Subroutines (TTT.BAS)

Function BustAWedge ()

    If (varDiagTot(0) + varDiagTot(1)) = 0 Then
        If PickCell(4) Then
            BustAWedge = 1
            Exit Function
        End If
        If PickCell(1) Then
            BustAWedge = 1
            Exit Function
        End If
    End If

    If (varRowTot(0) + varColTot(0)) = 2 Then
        If PickCell(0) Then
            BustAWedge = 1
            Exit Function
        End If
    End If

    If (varRowTot(0) + varColTot(2)) = 2 Then
        If PickCell(2) Then
            BustAWedge = 1
            Exit Function
        End If
    End If

    If (varRowTot(2) + varColTot(0)) = 2 Then
        If PickCell(6) Then
            BustAWedge = 1
            Exit Function
        End If
    End If

    If (varRowTot(2) + varColTot(2)) = 2 Then
        If PickCell(8) Then
            BustAWedge = 1
            Exit Function
        End If
    End If

    BustAWedge = 0

End Function
Function FindABlock ()

    Dim i As Integer
    If varColTot(0) = 2 Then
        i = PickCell(0)
        i = PickCell(3)
        i = PickCell(6)
        FindABlock = 1
        Exit Function
    End If

    If varColTot(1) = 2 Then
        i = PickCell(1)
        i = PickCell(4)
        i = PickCell(7)
        FindABlock = 1
        Exit Function
    End If

    If varColTot(2) = 2 Then
        i = PickCell(2)
        i = PickCell(5)
        i = PickCell(8)
        FindABlock = 1
        Exit Function
    End If

    If varRowTot(0) = 2 Then
        i = PickCell(0)
        i = PickCell(1)
        i = PickCell(2)
        FindABlock = 1
        Exit Function
    End If

    If varRowTot(1) = 2 Then
        i = PickCell(3)
        i = PickCell(4)
        i = PickCell(5)
        FindABlock = 1
        Exit Function
    End If

    If varRowTot(2) = 2 Then
        i = PickCell(6)
        i = PickCell(7)
        i = PickCell(8)
        FindABlock = 1
        Exit Function
    End If
If \text{varDiagTot}(0) = 2 \text{ Then}
  \begin{align*}
    i &= \text{PickCell}(0) \\
    i &= \text{PickCell}(4) \\
    i &= \text{PickCell}(8) \\
    \text{FindABlock} &= 1 \\
    \text{Exit Function}
  \end{align*}
End If

If \text{varDiagTot}(1) = 2 \text{ Then}
  \begin{align*}
    i &= \text{PickCell}(2) \\
    i &= \text{PickCell}(4) \\
    i &= \text{PickCell}(6) \\
    \text{FindABlock} &= 1 \\
    \text{Exit Function}
  \end{align*}
End If

End Function

Function \text{FindAWin} ()
  \text{Dim } i \text{ As Integer}
  \text{If } \text{varColTot}(0) = -2 \text{ Then}
    \begin{align*}
      i &= \text{PickCell}(0) \\
      i &= \text{PickCell}(3) \\
      i &= \text{PickCell}(6) \\
      \text{FindAWin} &= 1 \\
      \text{Exit Function}
    \end{align*}
  \text{End If}

  \text{If } \text{varColTot}(1) = -2 \text{ Then}
    \begin{align*}
      i &= \text{PickCell}(1) \\
      i &= \text{PickCell}(4) \\
      i &= \text{PickCell}(7) \\
      \text{FindAWin} &= 1 \\
      \text{Exit Function}
    \end{align*}
  \text{End If}

  \text{If } \text{varColTot}(2) = -2 \text{ Then}
    \begin{align*}
      i &= \text{PickCell}(2) \\
      i &= \text{PickCell}(5) \\
      i &= \text{PickCell}(8) \\
      \text{FindAWin} &= 1 \\
      \text{Exit Function}
    \end{align*}
  \text{End If}

  \text{If } \text{varRowTot}(0) = -2 \text{ Then}
    \begin{align*}
      i &= \text{PickCell}(0) \\
      i &= \text{PickCell}(1) \\
      i &= \text{PickCell}(2) \\
      \text{FindAWin} &= 1 \\
      \text{Exit Function}
    \end{align*}
  \text{End If}

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End If

If varRowTot(1) = -2 Then
    i = PickCell(3)
    i = PickCell(4)
    i = PickCell(5)
    FindAWin = 1
    Exit Function
End If

If varRowTot(2) = -2 Then
    i = PickCell(6)
    i = PickCell(7)
    i = PickCell(8)
    FindAWin = 1
    Exit Function
End If

If varDiagTot(0) = -2 Then
    i = PickCell(0)
    i = PickCell(4)
    i = PickCell(8)
    FindAWin = 1
    Exit Function
End If

If varDiagTot(1) = -2 Then
    i = PickCell(2)
    i = PickCell(4)
    i = PickCell(6)
    FindAWin = 1
    Exit Function
End If

End Function

Function LookForDraw ()
    Dim count, i As Integer
    count = 0
    For i = 0 To 8
        If frmMain.txtCell(i).Text <> " " Then
            count = count + 1
        End If
    Next
    If count >= 8 Then
        LookForDraw = 1
        Exit Function
    End If
End If
LookForDraw = 0

End Function

Function LookForUserWin ()

Dim i As Integer

For i = 0 To 2
    If varColTot(i) = 3 Then
        LookForUserWin = 1
        Exit Function
    End If
Next

For i = 0 To 2
    If varRowTot(i) = 3 Then
        LookForUserWin = 1
        Exit Function
    End If
Next

For i = 0 To 1
    If varDiagTot(i) = 3 Then
        LookForUserWin = 1
        Exit Function
    End If
Next

LookForUserWin = 0

End Function

Sub MakeMove ()
    Dim i

    If LookForUserWin() Then
        Beep
gnGameState = USER_WINS
        Exit Sub
    End If

    If FindAWin() Then
        Beep
gnGameState = GAME_WINS
        Exit Sub
    End If

    If FindABlock() Then
        Exit Sub
    End If

    If BustAWedge() Then
Exit Sub
End If

If PickCell(4) Then
   i = 4
   Exit Sub
End If
If PickCell(0) Then
   i = 0
   Exit Sub
End If
If PickCell(2) Then
   i = 2
   Exit Sub
End If
If PickCell(6) Then
   i = 6
   Exit Sub
End If
If PickCell(8) Then
   i = 8
   Exit Sub
End If
If PickCell(1) Then
   i = 1
   Exit Sub
End If
If PickCell(3) Then
   i = 3
   Exit Sub
End If
If PickCell(5) Then
   i = 5
   Exit Sub
End If
If PickCell(7) Then
   i = 7
   Exit Sub
End If

End Sub

Function PickCell (Index As Integer)

If frmMain.txtCell(Index).Text = " " Then
   gnGameState = SYSTEM_CONTROL
   frmMain.txtCell(Index).Text = "O"
   frmMain.txtCell(Index).Tag = -1
   frmMain.Label1(Index).Caption = frmMain.txtCell(Index).Tag
   gnGameState = PLAY

   If LookForDrawO() Then

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Beep
  gnGameState = DRAW
End If

PickCell = 1
  Exit Function
End If

PickCell = 0
  Exit Function

End Function

Sub UpdateSums()

  varColTot(0) = Val(frmMain.txtCell(0).Tag) + Val(frmMain.txtCell(3).Tag) + Val(frmMain.txtCell(6).Tag)
  varColTot(2) = Val(frmMain.txtCell(2).Tag) + Val(frmMain.txtCell(5).Tag) + Val(frmMain.txtCell(8).Tag)

  varRowTot(0) = Val(frmMain.txtCell(0).Tag) + Val(frmMain.txtCell(1).Tag) + Val(frmMain.txtCell(2).Tag)

  varDiagTot(0) = Val(frmMain.txtCell(0).Tag) + Val(frmMain.txtCell(4).Tag) + Val(frmMain.txtCell(8).Tag)

End Sub
APPENDIX F

Tic Tac Toe Smart Elements Listings/Screens

Click on <New Game> to begin.

Tic Tac Toe Main Screen (Smart Elements Version)
Open Interface Resource File for Tic Tac Toe (TTT_SE.RC)

Note: For better readability, the object scripts were pulled from the individual objects and put into the "Script File" which follows this Resource File listing. Also, objects and operations not related to the application (i.e., overhead) were removed.

(Win.Compile
  Name: "ttt_se.winMain"
  Version: 8
  Flags: 0x0001
  Deco: 0x0007
  MinWidth: 10
  MinHeight: 40
  LabelColor: "Win.DefLabelColor"
  FocusColor: "Win.DefFocusColor"
  IconFont: "Win.DefIconFont"
  Icon: "Win.DefIcon"
  PosFlags: 0x0001
  OptFlags: 0x0010
  DpiX: 78
  DpiY: 78
  KeysNext: "Panel.KeysNextWgt"
  KeysNextInGrp: "Panel.KeysNextRadio"
  Label: "Tic Tac Toe"
  FgColor: "Win.DefFgColor"
  BgColor: "Win.DefBgColor"
  Font: "Win.DefFont"
  Pen: "Win.DefPen"
  Pattern: "Patt.Empty"
  Cursor: "Curs.DefArrow"
  X: 125
  Y: 50
  W: 440
  H: 310
  WgtFlags: 0x0001
  Script: <MOVED TO SCRIPT FILE>
)

(PBut.Compile
  Name: "ttt_se.winMain.btnQuit"
  Version: 8
  Label: "Quit"
  FgColor: "TBut.DefFgColor"
  BgColor: "TBut.DefBgColor"
  Font: "TBut.DefFont"
  Pen: "Wgt.DefPen"
  Pattern: "Patt.Empty"
  Cursor: "Curs.DefArrow"
  X: 331
  Y: 257
  W: 91

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H: 34
WgtFlags: 0x0001
Script: "on event TBUT_HIT\nWIN_Terminate(WGT_GetWin(SELF));\nend event\n"
)

(PBut.Compile
Name: "ttt_se.winMain.btnNewGame"
Version: 8
Label: "New Game"
FgColor: "TBut.DefFgColor"
BgColor: "TBut.DefBgColor"
Font: "TBut.DefFont"
Pen: "Wgt.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.DefArrow"
Index: 1
X: 331
Y: 202
W: 91
H: 34
WgtFlags: 0x0001
Script: <MOVED TO SCRIPT FILE>
)

(PBut.Compile
Name: "ttt_se.winMain.btnYouGoFirst"
Version: 8
Label: "You Go First"
FgColor: "TBut.DefFgColor"
BgColor: "TBut.DefBgColor"
Font: "TBut.DefFont"
Pen: "Wgt.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.DefArrow"
Index: 2
X: 331
Y: 47
W: 91
H: 34
WgtFlags: 0x0001
Script: <MOVED TO SCRIPT FILE>
)

(Panel.Compile
Name: "ttt_se.winMain.pnlBoard"
Version: 8
KeysNext: "Panel.KeysNextWgt"
KeysNextInGrp: "Panel.KeysNextRadio"
LabelJustif: 0x0001
FgColor: "Panel.DefFgColor"
BgColor: "Panel.DefBgColor"
)
Font:  "Wgt.DefFont"
Pen:   "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.DefArrow"
Index:  3
X:     81
Y:     42
W:     136
H:     136
WgtFlags:   0x0001

(IArea.Compile
Name:  "ttt_se.winMain.pnIBoard.imgBoard"
Version: 8
Icon:   "IArea.DefIcon"
FgColor: "IArea.DefFgColor"
BgColor: "IArea.DefBgColor"
Font:   "Wgt.DefFont"
Pen:    "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.DefArrow"
W:      311
H:      186
WgtFlags:   0x0001
)

(LBox.Compile
   Name:  "ttt.se.winMain.pnIBoard.lbCell1"
   Version: 8
   StartCol: 0x0001
   StartRow: 0x0001
   ColWidth: 0x0032
   RowHeight: 0x0014
   ColNum:  1
   RowNum:  1
   LbKeys: "LBox.KeysDef"
   CellPen: "Win.DefPen"
   TextEditor: "NMsgEd.EditTEd"
   SbSepW:   4
   SbSepH:   4
   KeysNext: "Panel.KeysNextWgt"
   KeysNextInGrp: "Panel.KeysNextRadio"
   FgColor: "LBox.DefFgColor"
   BgColor: "LBox.DefBgColor"
   Font:   "ttt_se.Font2"
   Pen:    "Win.DefPen"
   Pattern: "Patt.Empty"
   Cursor: "Curs.Cross"
   Index:  1
   X:      5

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(LBox.Compile
   Name: "ttt_se.winMain.pnlBoard.lbCell2"
   Version: 8
   StartCol: 0x0001
   StartRow: 0x0001
   ColWidth: 0x0032
   RowHeight: 0x0014
   ColNum: 1
   RowNum: 1
   LbKeys: "LBox.KeysDef"
   CellPen: "Win.DefPen"
   TextEditor: "NMsgEd.EditTEd"
   SbSepW: 4
   SbSepH: 4
   KeysNext: "Panel.KeysNextWgt"
   KeysNextInGrp: "Panel.KeysNextRadio"
   FgColor: "LBox.DefFgColor"
   BgColor: "LBox.DefBgColor"
   Font: "ttt_se.Font2"
   Pen: "Win.DefPen"
   Pattern: "Patt.Empty"
   Cursor: "Curs.Cross"
   Index: 2
   X: 50
   Y: 13
   W: 26
   H: 31
   WgtFlags: 0x0001
   Script: <MOVED TO SCRIPT FILE>
)

(LBox.Compile
   Name: "ttt_se.winMain.pnlBoard.lbCell3"
   Version: 8
   StartCol: 0x0001
   StartRow: 0x0001
   ColWidth: 0x0032
   RowHeight: 0x0014
   ColNum: 1
   RowNum: 1
   LbKeys: "LBox.KeysDef"
   CellPen: "Win.DefPen"
   TextEditor: "NMsgEd.EditTEd"
   SbSepW: 4
   SbSepH: 4
   KeysNext: "Panel.KeysNextWgt"
   KeysNextInGrp: "Panel.KeysNextRadio"
   FgColor: "LBox.DefFgColor"
   BgColor: "LBox.DefBgColor"
   Font: "ttt_se.Font2"
   Pen: "Win.DefPen"
   Pattern: "Patt.Empty"
   Cursor: "Curs.Cross"
   Index: 2
   X: 50
   Y: 13
   W: 26
   H: 31
   WgtFlags: 0x0001
   Script: <MOVED TO SCRIPT FILE>
)
(LBox.Compile
Name: "ttcse.winMain.pnlBoard.lbCell5"
Version: 8
StartCol: 0x0001
StartRow: 0x0001
ColWidth: 0x0032
RowHeight: 0x0014
ColNum: 1
RowNum: 1
LbKeys: "LBox.KeysDef"
CellPen: "Win.DefPen"
TextEditor: "NMsgEd.EditTEd"
SbSepW: 4
SbSepH: 4
KeysNext: "Panel.KeysNextWgt"
KeysNextInGrp: "Panel.KeysNextRadio"
FgColor: "LBox.DefFgColor"
BgColor: "LBox.DefBgColor"
Font: "ttcse.Font2"
Pen: "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.Cross"
Index: 5
X: 50
Y: 48
W: 26
H: 31
WgtFlags: 0x0001
Script: <MOVED TO SCRIPT FILE>
)

(LBox.Compile
Name: "ttcse.winMain.pnlBoard.lbCell6"
Version: 8
StartCol: 0x0001
StartRow: 0x0001
ColWidth: 0x0032
RowHeight: 0x0014
ColNum: 1
RowNum: 1
LbKeys: "LBox.KeysDef"
CellPen: "Win.DefPen"
TextEditor: "NMsgEd.EditTEd"
SbSepW: 4
SbSepH: 4
KeysNext: "Panel.KeysNextWgt"
KeysNextInGrp: "Panel.KeysNextRadio"
FgColor: "LBox.DefFgColor"
BgColor: "LBox.DefBgColor"
Font: "ttcse.Font2"
Pen: "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.Cross"
Index: 5
X: 50
Y: 48
W: 26
H: 31
WgtFlags: 0x0001
Script: <MOVED TO SCRIPT FILE>
ColNum: 1
RowNum: 1
LbKeys: "LBox.KeysDef"
CellPen: "Win.DefPen"
TextEditor: "NMsgEd.EditTEd"
SbSepW: 4
SbSepH: 4
KeysNext: "Panel.KeysNextWgt"
KeysNextInGrp: "Panel.KeysNextRadio"
FgColor: "LBox.DefFgColor"
BgColor: "LBox.DefBgColor"
Font: "ttt_se.Font2"
Pen: "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.Cross"
Index: 8
X: 50
Y: 83
W: 26
H: 31
WgtFlags: 0x0001
Script: <MOVED TO SCRIPT FILE>

(LBox.Compile
Name: "ttt_se.winMain.pnlBoard.lbCell9"
Version: 8
StartCol: 0x0001
StartRow: 0x0001
ColWidth: 0x0032
RowHeight: 0x0014
ColNum: 1
RowNum: 1
LbKeys: "LBox.KeysDef"
CellPen: "Win.DefPen"
TextEditor: "NMsgEd.EditTEd"
SbSepW: 4
SbSepH: 4
KeysNext: "Panel.KeysNextWgt"
KeysNextInGrp: "Panel.KeysNextRadio"
FgColor: "LBox.DefFgColor"
BgColor: "LBox.DefBgColor"
Font: "ttt_se.Font2"
Pen: "Win.DefPen"
Pattern: "Patt.Empty"
Cursor: "Curs.Cross"
Index: 9
X: 95
Y: 83

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Click on <New Game> to begin.
Open Interface Script File for Tic Tac Toe

On "winMain" object:

on event WIN_OPENED

    //Collect some useful pointers
    winMainptr = WGT_GetWin(SELF);

    txtGameStateptr = WIN_GetNamedWgt(winMainptr,"txtGameState");

    txtMsgBoxptr = WIN_GetNamedWgt(winMainptr,"txtMsgBox");

    //Initialize text areas
    TED_SetStr(txtGameStateptr,"SYSTEM");

    TED_SetStr(txtMsgBoxptr,"Processing...");

    //Initialize Nexpert
    NOIR_RestartSession();

    //Initialize Cells
    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell1");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell2");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell3");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell4");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell5");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell6");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell7");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell8");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell9");
    LBOX_SetCellString(lbCellptr,1,1," ");

    // Enable <You Go First> Button
    WGT_Enable(WIN_GetNamedWgt(winMainptr,"btnYouGoFirst"));
//Set text areas for play
TED_SetStr(txtMsgBoxptr, "Click on any cell to make your first move, or... Click on the
You Go First button if you want me to go first.");

TED_SetStr(txtGameStateptr, "PLAY");

end event /*WIN_OPENED*/

On “lbCell” object:

on event LBOX_CELLCLICKED
    //Collect some useful pointers
    winMainptr = WGT_GetWin(SELF);
    txtGameStateptr = WIN_GetNamedWgt(winMainptr, "txtGameState");
    txtMsgBoxptr = WIN_GetNamedWgt(winMainptr, "txtMsgBox");

    //Just in case the User is faster than the system
    while(TED_GetStr(txtGameStateptr) == "SYSTEM")
        {
            LBOX_UnselectCell(SELF, 1,1);
            return;
        }

    //Gray out <You Go First> Button
    WGT_Disable(WIN_GetNamedWgt(winMainptr, "btnYouGoFirst"));

    //Make sure the game is still in progress
    while(TED_GetStr(txtGameStateptr) != "PLAY")
        {
            TED_SetStr(txtMsgBoxptr, "Get over it... because the game is. Click on <NewGame>
            to play again.");
            LBOX_UnselectCell(SELF, 1,1);
            return;
        }

    //Validate User Move
    currVal = LBOX_GetCellString(SELF, 1,1);
    if(currVal != ""){
        TED_SetStr(txtMsgBoxptr, "Sorry, that cell is already in use... please try again.");
    }
    else{
        //Take Control and process User's move
        TED_SetStr(txtGameStateptr, "SYSTEM");
        TED_SetStr(txtMsgBoxptr, "Processing...");

        //Update board with User's move
        LBOX_SetCellString(SELF, 1,1,"X");
// Update and run the NEXPERT game engine
NOIR_Volunteer(NOIR_GetAtomId("Cell1.Val", NXP_ATYPE_SLOT), NXP_DESC_INT, 1, NXP_VSTRAT_VOLFWRD);

NOIR_SendMessage("mthdUpdate", NOIR_GetAtomId("Sums", NXP_ATYPE_CLASS), "");

NOIR_Suggest(NOIR_GetAtomId("hypMakeAMove", NXP_ATYPE_HYPO), NXP_SPRIO_SUG);

NOIR_Knowcess();

NOIR_ProcessForm(winMainptr);

// Handle Game State
NOIR_UpdateWgt(txtGameStateptr);

if (TED_GetStr(txtGameStateptr) == "PLAY")
    TED_SetStr(txtMsgBoxptr, "Your move.");
else {
    if (TED_GetStr(txtGameStateptr) == "GAME WINS")
        TED_SetStr(txtMsgBoxptr, "Tic Tac Toe, Three in a Row... You lose, I win! You will have to try again (click on <New Game>).");
    else {
        if (TED_GetStr(txtGameStateptr) == "DRAW")
            TED_SetStr(txtMsgBoxptr, "I guess the cat got this one... Click on <New Game> to play again.");
        else {
            if (TED_GetStr(txtGameStateptr) == "USER WINS")
                TED_SetStr(txtMsgBoxptr, "I don't believe it, YOU WON!!!...Quick, click on <New Game>.");
        }
    }
}

} // end else process the User's move

LBOX_UnselectCell(SELF, 1, 1);

end event // LBOX_CELLCLICKED

on event NOIR_PROCESSFORM

// Test to see if the NEXPERT game engine placed an O in this cell
currVal = LBOX_GetCellString(SELF,1,1);
if(currVal == " "){
    nxpCellVal = NOIR_GetIntVal(NOIR_GetAtomId("Cell1.Val", NXP_ATYPE_SLOT));
    if(nxpCellVal == -1)
        LBOX_SetCellString(SELF,1,1,"0");
}
end event // NOIR_PROCESSFORM

On “btnNewGame” Object:

on event TBUT_HIT
    //Collect some useful pointers
    winMainptr = WGT_GetWin(SELF);
    txtGameStateptr = WIN_GetNamedWgt(winMainptr,"txtGameState");
    txtMsgBoxptr = WIN_GetNamedWgt(winMainptr,"txtMsgBox");

    //Initialize text areas
    TED_SetStr(txtGameStateptr, "SYSTEM");
    TED_SetStr(txtMsgBoxptr, "Processing...");

    //Initialize Nexpert
    NOIR_RestartSession();

    //Initialize Cells
    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell1");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell2");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell3");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell4");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell5");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell6");
    LBOX_SetCellString(lbCellptr,1,1," ");

    lbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell7");
    LBOX_SetCellString(lbCellptr,1,1," ");
IbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell8");
LBOX_SetCellString(lbCellptr,1,1," ");

IbCellptr = WIN_GetNamedWgt(winMainptr,"lbCell9");
LBOX_SetCellString(lbCellptr,1,1," ");

// Enable <You Go First> Button
WGT_Enable(WIN_GetNamedWgt(winMainptr,"btnYouGoFirst");

//Set text areas for play
TED_SetStr(txtMsgBoxptr,"Click on any cell to make your first move, or... Click on the <You Go First> button if you want me to go first.");
TED_SetStr(txtGameStateptr,"PLAY");
end event //TBUT_HIT

On “btnQuit” Object:
on event TBUT_HIT
WIN_Terminate(WGT_GetWin(SELF));
end event //TBUT_HIT

On “btnYouGoFirst” Object:
on event TBUT_HIT

//Collect some useful pointers
winMainptr = WGT_GetWin(SELF);

txtGameStateptr = WIN_GetNamedWgt(winMainptr,"txtGameState");
txtMsgBoxptr = WIN_GetNamedWgt(winMainptr,"txtMsgBox");

// Gray out <You Go First> Button
WGT_Disable(WIN_GetNamedWgt(winMainptr,"btnYouGoFirst");

//Take Control and process User's move
TED_SetStr(txtGameStateptr,"SYSTEM");
TED_SetStr(txtMsgBoxptr,"Processing...");

//Update and run the NEXPERT game engine
NOIR_SendMessage("mthdUpdate", NOIR_GetAtomId("Sums", NXP_ATYPE_CLASS), "");
NOIR_Suggest(NOIR_GetAtomId("hypMakeAMove", NXP_ATYPE_HYPO), NXP_SPRIO_SUG);
NOIR_Knowcess();
NOIR_ProcessForm(winMainptr);

//Handle Game State
NOIR_UpdateWgt(txtGameStateptr);

TED_SetStr(txtMsgBoxptr, "Your move.");

end event //TBUT_HIT

On "txtGameState" Object:

on event INITIALIZE

NOIR_LinkTextEdit(SELF, NOIR_GetAtomId("Game.State", NXP_ATYPE_SLOT), 1);

end event //INITIALIZE
Nexpert Object Graphs and File Excerpts for Tic Tac Toe (TTT.KB)

Class-Object Hierarchy for the “Cells” Class
Class-Object Hierarchy for the “Sums” Class
Class-Object Hierarchy for the "Game" Object
Typical Object Dialog in Nexpert Object
Rules Listing:

(@RULE= R_hypUserWins
@INFCAT=30;
(@LHS=
  (= (Isumsl.Sum) 3))
) (@HYPO= hypMakeAMove)
(@RHS=
  (Assign ("USER WINS") (Game.State))
)
)

(@RULE= R_hypGameWins
@INFCAT=20;
(@LHS=
  (= (Isumsl.Sum) 0-2))
) (@HYPO= hypMakeAMove)
(@RHS=
  (SendMessage ("mthdPickLastCell") (@TO=Cellsi.Val;@ARG1|=lsumsl;))
)
(Assign ("GAME WINS") (Game.State))

(@RULE= R_hypBlockUser
   @INFCAT=10;
   (@LHS=
      (= (\<lSumsl>.Sum) (2))
   )
   (@HYPO= hypMakeAMove)
   (@RHS=
      (SendMessage ("mthdPickLastCell") (@TO=lCellsI.Val; @ARG1=\<lSumsl>.))
      (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
   )
)

(@RULE= R_hypBustAWedge1A
   @INFCAT=6;
   (@LHS=
      (= (SUM(Diag1.Sum,Diag2.Sum)) (0))
      (= (Cell5.Val) (0))
   )
   (@HYPO= hypMakeAMove)
   (@RHS=
      (Assign ((0-1)) (Cell5.Val))
      (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
   )
)

(@RULE= R_hypBustAWedge1B
   @INFCAT=5;
   (@LHS=
      (= (SUM(Diag1.Sum,Diag2.Sum)) (0))
      (= (Cell2.Val) (0))
   )
   (@HYPO= hypMakeAMove)
   (@RHS=
      (Assign ((0-1)) (Cell2.Val))
      (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
   )
)

(@RULE= R_hypBustAWedge4
   @INFCAT=2;
   (@LHS=
      (= (SUM(Row3.Sum,Coll1.Sum)) (2))
      (= (Cell7.Val) (0))
   )
   (@HYPO= hypMakeAMove)
   (@RHS=
      (Assign ((0-1)) (Cell7.Val))
      (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
   )
)

(@RULE= R_hypBustAWedge5
   (@LHS=
      (= (SUM(Row3.Sum,Coll3.Sum)) (2))
   )
)

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(= (Cell9.Val) (0))

(@HYPO= hypMakeAMove)
(@RHS=)
  (Assign ((0-1)) (Cell9.Val))
  (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
)

(@EHS=)
  (SendMessage ("mthdPickCell5") (@TO=Cell5.Val;))
)
Methods Listing:

(@METHOD= IfChange
   (@ATOMID=Cells.Val;@TYPE=SLOT;)
   (@FLAGS=PUBLIC;)
   (@RHS=
      (SendMessage ("UpdateSum") (@TO=<ISums1>.Sum;)))
)

(@METHOD= mthdCheckDraw
   (@ATOMID=Game.Moves;@TYPE=SLOT;)
   (@FLAGS=PUBLIC;)
   (@LHS=
      (= (Game.Moves) (5))
   )
   (@RHS=
      (Assign ("DRAW") (Game.State))
   )
)
(@EHS=
    (Assign ("PLAY") (Game.State))
)

(@METHOD= mthdPickCell1
(@ATOMID=Cells.Val;@TYPE=SLOT;)
(@FLAGS=PUBLIC;)
(@LHS=
    (= (Cell1.Val) 0))
)

(@RHS=
    (Assign ((0-1)) (Cell1.Val))
    (SendMessage ("mthdCheckDraw") (@TO/Game.Moves;))
)

(@EHS=
    (SendMessage ("mthdPickCell3") (@TO=Cell3.Val;))
)

(@METHOD= mthdPickCell2
(@ATOMID=Cells.Val;@TYPE=SLOT;)
(@FLAGS=PUBLIC;)
(@LHS=
    (= (Cell2.Val) 0))
)

(@RHS=
    (Assign ((0-1)) (Cell2.Val))
    (SendMessage ("mthdCheckDraw") (@TO/Game.Moves;))
)

(@EHS=
    (SendMessage ("mthdPickCell4") (@TO=Cell4.Val;))
)

(@METHOD= mthdPickCell3
(@ATOMID=Cells.Val;@TYPE=SLOT;)
(@FLAGS=PUBLIC;)
(@LHS=
    (= (Cell3.Val) 0))
)

(@RHS=
    (Assign ((0-1)) (Cell3.Val))
    (SendMessage ("mthdCheckDraw") (@TO/Game.Moves;))
)

(@EHS=
    (SendMessage ("mthdPickCell7") (@TO=Cell7.Val;))
)

(@METHOD= mthdPickCell4
(@ATOMID=Cells.Val;@TYPE=SLOT;)
(@FLAGS=PUBLIC;)
(@LHS=
    (= (Cell4.Val) 0))
)

(@RHS=
(Assign ((0-1)) (Cell4.Val))
(SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
)

(@EHS=
(SendMessage ("mthdPickCell6") (@TO=Cell6.Val;))
)

(@METHOD= mthdPickCell5
 (@ATOMID=Cells.Val;@TYPE=SLOT;)
 (@FLAGS=PUBLIC;)
 (@LHS=
 (= (Cell5.Val) (0))
 )
 (@RHS=
 (Assign ((0-1)) (Cell5.Val))
 (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
 )
 (@EHS=
 (SendMessage ("mthdPickCell1") (@TO=Cell1.Val;))
 )
)

(@METHOD= mthdPickCell6
 (@ATOMID=Cells.Val;@TYPE=SLOT;)
 (@FLAGS=PUBLIC;)
 (@LHS=
 (= (Cell6.Val) (0))
 )
 (@RHS=
 (Assign ((0-1)) (Cell6.Val))
 (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
 )
 (@EHS=
 (SendMessage ("mthdPickCell8") (@TO=Cell8.Val;))
 )
)

(@METHOD= mthdPickCell7
 (@ATOMID=Cells.Val;@TYPE=SLOT;)
 (@FLAGS=PUBLIC;)
 (@LHS=
 (= (Cell7.Val) (0))
 )
 (@RHS=
 (Assign ((0-1)) (Cell7.Val))
 (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
 )
 (@EHS=
 (SendMessage ("mthdPickCell9") (@TO=Cell9.Val;))
 )
)

(@METHOD= mthdPickCell8
 (@ATOMID=Cells.Val;@TYPE=SLOT;)
 (@FLAGS=PUBLIC;)
 (@LHS=

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(= (Cell8.Val) (0))

(@RHS=
  (Assign ((0-1)) (Cell8.Val))
  (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
)

(@EHS=
  (Assign ("DRAW") (Game.State))
)

(@METHOD= mthdPickCell9
  (@ATOMID=Cells.Val;@TYPE=SLOT;)  
  (@FLAGS=PUBLIC;)  
  (@LHS=
    (= (Cell9.Val) (0))
  )

  (@RHS=
    (Assign ((0-1)) (Cell9.Val))
    (SendMessage ("mthdCheckDraw") (@TO=Game.Moves;))
  )

  (@EHS=
    (SendMessage ("mthdPickCell2") (@TO=Cell2.Val;))
  )
)

(@METHOD= mthdPickLastCell
  (@ATOMID=Cells.Val;@TYPE=SLOT;)  
  (@ARGS=._CurSum;@NATURE=Object;@LIST;)  
  (@FLAGS=PUBLIC;)  
  (@LHS=
    (Member «/Cells/> «_CurSum>)  
    (= «/Cells/>.Val) (0)
  )

  (@RHS=
    (Assign ((0-1) «/Cells/>.Val)
  )
)

(@METHOD= mthdUpdate
  (@ATOMID=Sums;@TYPE=CLASS;)  
  (@FLAGS=PUBLIC;)  
  (@RHS=
    (SendMessage ("UpdateSum") (@TO=<Sums>.Sum))
    (Assign ((Game.Moves+1)) (Game.Moves))
    (Reset (hypMakeAMove))
  )
)

(@METHOD= UpdateSum
  (@ATOMID=Sums.Sum;@TYPE=SLOT;)  
  (@FLAGS=PUBLIC;)  
  (@RHS=
    (Assign (SUM<SELF>.Val) (SELF.Sum))
  )
)
APPENDIX G

SA2VB.EXE Bridge Listings and Sample Results

Source Code for SA2VB.C

```c
#include <stdio.h>
#include <ctype.h>
#include "SA-VB.h"
//#include <strings.h>*/

/* global variables */
FILE *infile; /* to point to the input file */
FILE *outfile; /* to point to the output file */
int COUNTER = 1;

// doControl (recursively) processes CONTROL statements
int doControl(FILE *infile, FILE *outfile) {
    char nextword[256];
    char caption[256];
    char name[256];
    char type[256];
    char style[256];
    char count[4];
    int datum, len, flag = 0;

    // Scan for CONTROL to process or END to bail
    while (fscanf(infile, "%s", &nextword) != EOF) {
        if (!strcmp(nextword, "CONTROL"))
            break;
        else {
            if (!strcmp(nextword, "END"))
                return 0;
            }
    }

    // Pull out the Caption/Text, based on ",", as the delimiter
    strcpy(caption, "");
    while (fscanf(infile, "%s", &nextword) != EOF) {
        if (strstr(nextword, ",")) == NULL) {
            strcat(caption, nextword);  // keep parsing the caption
            strcat(caption, ",");
```

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else{
    len = strlen(nextword);   // lose the comma and break
    strcat(caption,nextword,len-1);
    break;
}
}

/// Grab the object name, checking for illegal names
strcpy(name,"\0");
 fscanf(infile, "%s", &nextword);
 len = strlen(nextword);
 strcat(name,nextword,len-1);

/// set flag if name begins with a non-alpha, so we can create a good name later
if(!isalpha(name[0])){
    flag = 1;
}

/// Grab the type of the object
strcpy(type,"\0");
 fscanf(infile, "%s", &nextword);
 len = strlen(nextword);
 strcat(type,nextword,len-1);

/// Check the flag and generate a unique name, if appropriate
if(flag){
    itoa(COUNTER,&count,10);
    strcpy(name,"SA2VB_");
    strcat(name,type);
    strcat(name,count);
    flag = 0;
}

/// Grab the style info
strcpy(style,"\0");
 fscanf(infile, "%s", &nextword);
 len = strlen(nextword);
 strcat(style,nextword,len-1);

/// Set up a COMMAND_BUTTON
if(!strcmp(type, "BUTTON") && strstr(style, "PUSHBUTTON")){
    fprintf(outfile, "Begin CommandButton %s\n",name);
    fprintf(outfile, "Caption\t=\t%s\n",caption);
    //HANDLE STYLE OPTIONS
    if(strstr(style, "DEFPUSHBUTTON")){
        fprintf(outfile, "Default\n\t=\t1\nTrue\n");
    }
}
else{

/// Set up a TEXT_EDIT_BOX
    if(!strcmp(type, "EDIT")){

    }

}
fprintf(outfile," Begin TextBox %s
",name);
fprintf(outfile," Text\t\%s\n",caption);

//HANDLE STYLE OPTIONS
if(strstr(style,"VSCROLL") && strstr(style,"HSCROLL")){
    fprintf(outfile," ScrollBars\t\%=3 \"Both\"");
}
else {
    if(strstr(style,"HSCROLL")){
        fprintf(outfile," ScrollBars\t\%=1 \"Horizontal\"");
    }
    else {
        if(strstr(style,"VSCROLL")){
            fprintf(outfile," ScrollBars\t\%=2 \"Vertical\"");
            //HANDLE STYLE OPTIONS
            if(strstr(style,"RIGHT")){
                fprintf(outfile," Alignment\t\%=1 \"Right Justify\"");
                //HANDLE STYLE OPTIONS
                if(strstr(style,"CENTER")){
                    fprintf(outfile," Alignment\t\%=2 \"Center\"");
                }
            }
        }
        if(!strstr(style,"BORDER")){
            fprintf(outfile," BorderStyle\t\%=0 \"None\"");
        }
    }
}
else {

    // Set up a LABEL
    if(!strcmp(type,"STATIC")){
        fprintf(outfile," Begin Label %s\n",name);
        fprintf(outfile," Caption\t\%=\"\n",caption);
        //HANDLE STYLE OPTIONS
        if(strstr(style,"RIGHT")){
            fprintf(outfile," Alignment\t\%=1 \"Right Justify\"");
        }
        if(strstr(style,"CENTER")){
            fprintf(outfile," Alignment\t\%=2 \"Center\"");
        }
    }
}
else{

    // Relinquish processing to the next object
    COUNTER++;
    doControl(infile,outfile);
    return 0;
}
}
// If we're still here, that means it's time to do the coordinates
fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile, " Left\t=\t%d
",datum);

fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile, " Top\t=\t%d
",datum);

fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile, " Width\t=\t%d
",datum);

fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile, " Height\t=\t%d
",datum);

// Close out this object
fprintf(outfile, " End\n");

COUNTER++;

// Process the next object
doControl(infile,outfile);

return 0;

} //end doControl()

void main(int argc, char *argv[ ]) {

char nextword[256];
char caption[256];
int datum;

if(argc != 2){ /* verify something was entered as a command line argument */
    printf("You must enter an input filename as a command line argument...exiting.
");
    exit(0);
}

infile = fopen(argv[1],"r");

if(infile == NULL){ /* error-check to confirm successful file opening */
    printf("Can't open input file...exiting.
");
    exit(0);
}

outfile = fopen("out.frm","w");

if(outfile == NULL){ /* error-check to confirm successful file opening */
    printf("Can't open output file...exiting.
");
    fclose(infile);
    exit(0);
}

// Opening Header and Object Name
fscanf(infile, "%s", &nextword);
fprintf(outfile,"VERSION 2.00
Begin Form %s
",
nextword);

II Verify DIALOG, then scan, calc and output window dimensions
fscanf(infile, "%s", &nextword);
if(strcmp(nextword, "DIALOG")
{
    printf("Couldn't find DIALOG in input file...exiting
");
    fclose(infile);
    fclose(outfile);
    exit(0);
}
fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile," Left		=	%d
",
datum);

fscanf(infile, "%s", &nextword);
datum = FACTOR * atoi(nextword);
fprintf(outfile," Top		=	%d
",
datum);

fscanf(infile, "%s", &nextword);
datum = (FACTOR * atoi(nextword)) + 60;
fprintf(outfile," Width	=	%d
",
datum);

fscanf(infile, "%s", &nextword);
datum = (FACTOR * atoi(nextword)) + 360;
fprintf(outfile," Height	=	%d
",
datum);

II Verify STYLE information is present
fscanf(infile, "%s", &nextword);
if(strcmp(nextword, "STYLE")
{
    // Handle STYLE information
    fscanf(infile, "%s", &nextword);
    if(!strstr(nextword,"BORDER") && !strstr(nextword, "THICKFRAME")
    {
        fprintf(outfile," BorderStyle	=	0 'None'
");
    }
    if(strstr(nextword,"BORDER") && !strstr(nextword, "THICKFRAME")
    {
        fprintf(outfile," BorderStyle	=	1 'Fixed Single'
");
    }
    if(!strstr(nextword,"SYSMENU")
    {
        fprintf(outfile," ControlBox	=	0 'False'
");
    }
    if(!strstr(nextword,"MAXIMIZEBOX")
    {
        fprintf(outfile," MaxButton	=	0 'False'
");
    }
    if(!strstr(nextword,"MINIMIZEBOX")
    {
        fprintf(outfile," MinButton	=	0 'False'
");
    }
}

II Verify CAPTION is present
fscanf(infile, "%s", &nextword);
if(!strcmp(nextword,"CAPTION")
{
// Handle CAPTION
strcpy(caption,"");
fscanf(infile, "%s", &nextword);
strcat(caption,nextword);
while (fscanf(infile, "%s", &nextword) != EOF){
  if(strcmp(nextword,"BEGIN")){
    strcat(caption," ");
    strcat(caption,nextword);
  }
  else
    break;
}
fprintf(outfile," Caption=%s
",caption);
}
doControl(infile,outfile);

fprintf(outfile,"End
");
fclose(infile);
fclose(outfile);
} /* end main */
“TestForm” Screen Designs

“TEST.DLG” from System Architect

TestForm DIALOG 48, 51, 192, 117
STYLE WS_TABSTOP|WS_GROUP|WS_BORDER|WS_BORDER|WS_DLGFRAME|
|WS_MINIMIZEBOX|WS_MAXIMIZEBOX|WS_THICKFRAME
CAPTION "TestForm"
BEGIN
CONTROL "Label1", IDO_LABEL1, STATIC, SS_LEFT, 56, 16, 25, 9
CONTROL "Label2", IDO_LABEL2, STATIC, SS_LEFT, 58, 44, 25, 9
CONTROL ",", IDO_TEXT1, EDIT,
|WS_TABSTOP|WS_BORDER|WS_BORDER|WS_VSCROLL|WS_HSCROLL|
|ES_MULTILINE|ES_CENTER, 102, 11, 68, 23
CONTROL ",", IDO_TEXT2, EDIT, WS_TABSTOP|WS_BORDER|WS_BORDER|ES_LEFT,
|102, 40, 69, 13
CONTROL "Command1", IDO_COMMAND1, BUTTON,
|WS_TABSTOP|WS_DEF_PUSHBUTTON, 22, 76, 43, 25
CONTROL "Quit", IDO_COMMAND2, BUTTON, WS_TABSTOP|WS_PUSHBUTTON, 106,
|77, 20, 24
END
"TEST.FRM" from Visual Basic

VERSION 2.00
Begin Form TestForm
Left = 1440
Top = 1530
Width = 5820
Height = 3870
ControlBox = 0 'False
Caption = "TestForm"
Begin Label IDG_LABEL1
Caption = "Label1"
Left = 1680
Top = 480
Width = 750
Height = 270
End
Begin Label IDG_LABEL2
Caption = "Label2"
Left = 1740
Top = 1320
Width = 750
Height = 270
End
Begin TextBox IDG_TEXT1
Text = "" ScrollBars = 3 'Both
MultiLine = -1 'True
Alignment = 2 'Center
Left = 3060
Top = 330
Width = 2040
Height = 690
End

Begin TextBox IDG_TEXT2
Text = ""
Left = 3060
Top = 1200
Width = 2070
Height = 390
End

Begin CommandButton IDG_COMMAND1
Caption = "Command1"
Default = -1 True
Left = 660
Top = 2280
Width = 1290
Height = 750
End

Begin CommandButton IDG_COMMAND2
Caption = "Quit"
Left = 3180
Top = 2310
Width = 600
Height = 720
End

End
"Difficult Test" Screen Designs

```
hardtest DIALOG 14, 17, 227, 140
STYLE WS_BORDER|WS_BORDER|WS_DLGFRAME|WS_VSCROLL|WS_HSCROLL|
|WS_SYSMENU|WS_THICKFRAME
CAPTION "Difficult Test"
BEGIN
CONTROL "&OK", IDG_BUTTON1, BUTTON, WS_TABSTOP|WS_DEFPUSHBUTTON, 78, 115, 29, 15
CONTROL "&Clear", IDG_BUTTON2, BUTTON, WS_TABSTOP|WS_PUSHBUTTON, 134, 115, 28, 15
CONTROL "Enter Your Memo in the Box Below", IDG_TITLE, STATIC, SS_NOPREFIX|SS_CENTER, 63, 8, 117, 9
CONTROL "", IDG_MEMO, EDIT, WS_TABSTOP|WS_BORDER|WS_BORDERS|WS_AUTOSCROLL|WS_MULTI
|WS_LEFT, 63, 29, 117, 79
END
```

"TEST4.DLG" from System Architect
VERSION 2.00
Begin Form hardtest
  Left   =  420
  Top    =  510
  Width  =  6870
  Height =  4560
  MaxButton = 0 'False
  MinButton = 0 'False
  Caption = "Difficult Test"
Begin CommandButton IDG_BUTTON1
  Caption = "&OK"
  Default = -1 'True
  Left    =  2340
  Top     =  3450
  Width   =   870
  Height  =   450
End
Begin CommandButton IDG_BUTTON2
  Caption = "&Clear"
  Left    =  4020
  Top     =  3450
  Width   =   840
  Height  =   450
End
Begin Label IDG_TITLE
  Caption = "Enter Your Memo in the Box Below"
  Alignment = 2 'Center
Left = 1890
Top = 240
Width = 3510
Height = 270
End
Begin TextBox IDG_MEMO
Text = ""
ScrollBars = 2 'Vertical
MultiLine = -1 'True
Left = 1890
Top = 870
Width = 3510
Height = 2370
End
End
APPENDIX H

Test Bed (Self) Observation Data Sheets
### Software Engineering Methods versus Visual Programming Tools/Languages
#### Synergy/Conflict Observations

<table>
<thead>
<tr>
<th>Observation Type</th>
<th>Project</th>
<th>Category</th>
<th>Date Initially Observed</th>
<th>Number of Times Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>Customer for 18</td>
<td>User interface layout</td>
<td>3/28/94 15:15</td>
<td>1</td>
</tr>
</tbody>
</table>

**Description:**
When using the screen layout facility of the CASE tool to design the User Interface, the work must be duplicated in the Visual Programming tool/language.

**Circumstances:**
This problem only manifests when using the CASE tool's screen layout facility. It would also apply to the use of drawing and charting tools.

**Guidance Ideas:**
Look for CASE tools that can automatically generate the User Interface code in the native commands of the Visual tool/language, thus remediying this conflict. (Note: I don't know of any yet on the market.)

---

<table>
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<tr>
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<th>Date Initially Observed</th>
<th>Number of Times Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>Customer for 18</td>
<td>Event-based design</td>
<td>4/23/94 14:15</td>
<td>1</td>
</tr>
</tbody>
</table>

**Description:**
If only provides "subchanged" event processing on the primary attribute of an object (as determined by the "factory"); this means that changes to other properties, such as the "age" property, go unnoticed.

**Circumstances:**
In the GUI case, the design called for tracking of both the text value ("X", "Y", or "Z") and its numerical equivalent (1, -1, or 0) for each cell. The original design had the User selecting the text value (primary) to change to "X" and using a map_changed method to update the numerical value (delta) by 1. The current method of the numerical value to update the strategy values (sum of rows, columns, and diagonals) this approach had to be altered to let the first event drive both updates.

**Guidance Ideas:**
When it is known to be the implementation language, the design should be geared to have only one property per object causing event-based behaviors to execute.
### Software Engineering Methods versus Visual Programming Tools/Languages
#### Synergy/Conflict Observations

**Observation Type:** Conflict/Synergy

<table>
<thead>
<tr>
<th>Project:</th>
<th>Category: Front-end design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Rev 2a</td>
<td>Initial Date: 4/28/94</td>
</tr>
<tr>
<td>Pit Test Rev</td>
<td>Number of Times Observed: 1</td>
</tr>
</tbody>
</table>

| SE Application: Manual/Manual |
| --- | --- |
| 8/9 | Manual |

<table>
<thead>
<tr>
<th>SE Method:</th>
<th>Tool/Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man &amp; Array</td>
<td>Visual Basic</td>
</tr>
</tbody>
</table>

**Description:**
When using an object-oriented approach, it is common to abstract all system parameters as objects; however, VB only uses objects to represent screen entities (so-called controls). Ware entities that would normally be represented as objects, other than those visible to the user, must be represented as variables of some type.

**Circumstances:**
In the VB pit tests, there is a strategy area kept 'behind the scenes' for use by the program to determine its next move (the sum of the cell values on rows, columns, and diagonals). The original design called for creation of a strategy object to maintain such information. The design had to be altered to use global variables instead.

**Guidance Ideas:**
When VB is known to be the implementation language, one should avoid the use of objects other than those destined for the user interface. Another approach (not tested) is to create a Visual Basic to hold objects which will be used internally but never actually displayed to the user; this would be easier 'inside VB into having a collection of objects for use 'behind the scenes.'

---

**Observation Type:** Conflict/Coherence

<table>
<thead>
<tr>
<th>Project:</th>
<th>Category: Front-end design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Rev 2a</td>
<td>Initial Date: 4/28/94</td>
</tr>
<tr>
<td>Pit Test Rev</td>
<td>Number of Times Observed: 1</td>
</tr>
</tbody>
</table>

| SE Application: Manual/Manual |
| --- | --- |
| 8/9 | Manual |

<table>
<thead>
<tr>
<th>SE Method:</th>
<th>Tool/Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man &amp; Array</td>
<td>Visual Basic</td>
</tr>
</tbody>
</table>

**Description:**
From the object-oriented nature of VB, we were interested and forewarned into the testing; the implementation of the VTT game in VB went very smoothly. I was able to construct the program incrementally without any noteworthy difficulties.

**Circumstances:**
The O/J methodology preserves a certain level of support of both object-oriented constructs and event-driven behaviors, while VB only partially supports them (see related conflicts).

**Guidance Ideas:**
Some VB has been chosen as the implementation language, avoid fighting the language; it is better to adapt (limit) the design methodology to these object-oriented/event-driven features supported by VB and use procedural approaches for the balance.
Software Engineering Methods versus Visual Programming Tools/Languages
Synergy/Conflict Observations

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</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SE Application:</th>
<th>SE Method:</th>
<th>Tool/Languages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Visual</td>
<td>Visual</td>
</tr>
<tr>
<td>O/R</td>
<td>C++</td>
<td>Smart Elements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication of events via inVentors from the user interface (open interface) to the engine (remote object) is limited to a single target object. Updating of the state of the various types required the events to be broadcast to all children of the event. To get around this limitation, we implemented an object attached to the event that allowed the interface to interact at a single point of contact, and a more complex one which was then activated by the single event object control was passed from the interface to the engine.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circumstances:</th>
</tr>
</thead>
<tbody>
<tr>
<td>This was a minor inconvenience; in fact, once the second, more complex method was in place, I found more ways to take advantage of it.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Guidance Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>It may actually be preferable to have communication links between major system modules be simple (like a &quot;pinch point&quot;). A single, simple message from one module to the other is easy to follow and debug if problems do arise. The target method can then open a window and issue a set of procedures as required.</td>
</tr>
</tbody>
</table>

Software Engineering Methods versus Visual Programming Tools/Languages
Synergy/Conflict Observations

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<th>Observation Type:</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Conflict</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>SE Method:</th>
<th>Tool/Languages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>[ ]</td>
<td>Visual basic</td>
</tr>
<tr>
<td>O/R</td>
<td>C++</td>
<td>Smart Elements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The design called for a simple Text Edit box as the mechanism for building the size cells in the Tic Tac Toe board. However, the Smart Elements Text Edit object provided a very limited set of automatic events; in particular, it did not provide a beforeClick event as called for in the design. Instead, I had to use the more complex Text Edit object (which is similar to a spreadsheet in nature) limiting it to a single row and a single column. This provided access to the beforeClick event.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circumstances:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Elements does support the creation of custom widgets, so I could have gone outside of the &quot;built-in&quot; widgets and added the beforeClick event to the basic Text Edit object. However, a row of a few cells to use the &quot;off the shelf&quot; widgets and scripting language to implement the design.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Guidance Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look beyond the obvious in stretching the features of the tool. A list spreadsheet looks exactly like a Text Edit object and behaves just the design seemed it to.</td>
</tr>
</tbody>
</table>
### Observation Type: Synergy

<table>
<thead>
<tr>
<th>Project:</th>
<th>Category:</th>
<th>Date Initially Observed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE Application:</td>
<td>BE Method:</td>
<td>Tool/Language:</td>
</tr>
<tr>
<td>layout pm</td>
<td>code/pattern</td>
<td>visual css</td>
</tr>
</tbody>
</table>

#### Description:

Smart Elements does not provide a mechanism to pass arguments to the interface (open interface). To work around this, each time control is returned to the interface I had to use the interface query for the current value of the corresponding object in the Engine and update its new current value accordingly.

#### Circumstances:

Smart Elements does not provide a mechanism to pass arguments to the interface (open interface). To work around this, each time control is returned to the interface I had to use the interface query for the current value of the corresponding object in the Engine and update its new current value accordingly.

#### Guidance Ideas:

The mechanism used in this case causes a great deal of extra work, since every interface object must be "pruned" after each call to the Engine. In a full strength application, whose performance could be improved, the move from seamless interface would have been natural (e.g., a "Black Diamond" tool). In a partial strength application, where the interface deals with a smaller part of the Engine data, the move from seamless interface would have been more challenging. Alternatively, the linking mechanism could have been used "as is" and then have an interface method current the Engine value into its symbolic equivalent.
## Software Engineering Methods versus Visual Programming Tools/Languages

### Synergy/Conflict Observations

<table>
<thead>
<tr>
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<th>Project:</th>
<th>Category:</th>
<th>Date Initially Observed:</th>
<th>Number of Times Observed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>Customer &amp; Dev</td>
<td>Function Design</td>
<td>1/17/94 01:18</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Observations

**Observation Type:** Synergy

**Project:** Customer & Dev

**Category:** Function Design

**Date Initially Observed:** 1/17/94 01:18

<table>
<thead>
<tr>
<th>SE Application:</th>
<th>SE Method:</th>
<th>Tool/Languages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>C++</td>
<td>SMART ELEMENTS</td>
</tr>
<tr>
<td>Code/Frontend</td>
<td>both</td>
<td>SMART ELEMENTS</td>
</tr>
</tbody>
</table>

**Description:**
The SMART ELEMENTS Engine (SMART object) fully and externally supports the object hierarchy and inheritance called for in the design. Extensive generic methods were written and applied at the class level, inherited down to the appropriate child objects and then applied to give the desired result.

**Circumstances:**

By goal was to not have to touch the code used in methods based on where code was attached. The evolution of the application was inspiring. A more detailed of the game was used to develop the methods, when the rest of the game objects were added, the fully implemented game board worked on the SMART.

**Guidance Ideas:**

If you are going to use an object-oriented tool to implement an application, do for the whole in the design process. Craft methods that are as generic as possible. Apply these as high in the hierarchy as possible. Take full advantage of classification structures and list the benefits of any class through.

---

### Software Engineering Methods versus Visual Programming Tools/Languages

### Synergy/Conflict Observations

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<th>Date Initially Observed:</th>
<th>Number of Times Observed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflict</td>
<td>Customer &amp; Dev</td>
<td>Function Design</td>
<td>11/31/94 17:30</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Observations

**Observation Type:** Conflict

**Project:** Customer & Dev

**Category:** Function Design

**Date Initially Observed:** 11/31/94 17:30

<table>
<thead>
<tr>
<th>SE Application:</th>
<th>SE Method:</th>
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<tbody>
<tr>
<td>Manual</td>
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<td>SMART ELEMENTS</td>
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<tr>
<td>Code/Frontend</td>
<td>both</td>
<td>SMART ELEMENTS</td>
</tr>
</tbody>
</table>

**Description:**
The rules in SMART ELEMENTS are easily visualized in the rules browser. This aids in very to implement the desired game strategy in the inference engine. Although this system is neither an expert system nor performing any reasoning or inferring, the rule-based paradigm proved to facilitate the implementation process.

**Circumstances:**

Implementation of the control logic for deciding the appropriate response to a user selection of a space on the playing board.

**Guidance Ideas:**

Consider the use of a tool that provides an explicit rule-based paradigm, even if the application is not an expert system or does not require inferring. The rules can be used to explicate control strategy/logic or to explicitly represent the business rules to be followed.

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## Software Engineering Methods versus Visual Programming Tools/Languages
### Synergy/Conflict Observations

<table>
<thead>
<tr>
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<th>Date Initially Observed:</th>
<th>Number of Times Observed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflict</td>
<td>Customer Dev 10</td>
<td>DB Schema</td>
<td>1/15/94 0:00</td>
<td>3</td>
</tr>
</tbody>
</table>

**Description:**
Unable to directly create the schema using the CASE tool.

**Circumstances:**
The versions of the development tools being used were built to support less open databases. In particular, automated schema generation was not available for VB (Access 1.1) or ObjectVision (Oracle 2.3 or dBase).

**Guidance Ideas:**
1. Update design methodology/inventory rules and design update frequencies and manually synchronize the design in the CASE tool from time to time.
2. Author the CASE tool and databases such that reverse engineering can be used to convey changes implemented in the development tool back to the CASE tool.

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<td>Customer Dev 10</td>
<td>DB Schema</td>
<td>1/15/94 0:00</td>
<td>3</td>
</tr>
</tbody>
</table>

**Description:**
Difficult to keep CASE representation of the application in sync with changes which evolved during the implementation process.

**Circumstances:**
The versions of the development tools being used were built to support less open databases. In particular, reverse engineering was not available for VB (Access 1.1) or ObjectVision (Oracle 2.3 or dBase).

**Guidance Ideas:**
1. Update design methodology/inventory rules and design update frequencies and manually synchronize the design in the CASE tool from time to time.
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### Software Engineering Methods versus Visual Programming Tools/Languages

#### Synergy/Conflict Observations

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</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>-</td>
<td>-</td>
<td>11/23/94 5:17</td>
<td>1</td>
</tr>
</tbody>
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<table>
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<tr>
<th>SE Application:</th>
<th>SE Method:</th>
<th>Tool/Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Data Flow</td>
<td>Visual Basic</td>
</tr>
<tr>
<td>Data</td>
<td>Design</td>
<td>Objective</td>
</tr>
<tr>
<td>DBMS</td>
<td>Both</td>
<td>Both</td>
</tr>
</tbody>
</table>

**Description:**

Manual creation of the data schema was extremely easy (about 5 minutes given that the user interface was already mapped out).

**Circumstances:**

Observation process that the development process will call for creation of the user interface (called Form) prior to creation of the database (called Table). It is a very simplistic schema creation utility that assumes that data items grouped on a form will likely be in the same table, and that their data types and sizes will conform with how they are specified on the form as well. It then creates a "store map" data structure which can then be edited for those places where the assumption does not hold.

**Guidance Ideas:**

Some of your tool’s assumptions and go with the flow. By simply understanding the expected sequence of development, one can streamline the development process. Conversely, building the system can easily cripple or otherwise useful tool. This is not to say that one should use only one satisfactory development practice. And, of course, never, never, never would I suggest that one change the problem to fit the tool. However, if one approach is about the same as another, then let the expected synergy with the development tool make the decision. This, in turn, means that someone on the development team must know (or be able to find out) how the tool expects the problem to be tackled.

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### Software Engineering Methods versus Visual Programming Tools/Languages

#### Synergy/Conflict Observations

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<tr>
<th>SE Application:</th>
<th>SE Method:</th>
<th>Tool/Language:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Data Flow</td>
<td>Visual Basic</td>
</tr>
<tr>
<td>Data</td>
<td>Design</td>
<td>Objective</td>
</tr>
<tr>
<td>DBMS</td>
<td>Both</td>
<td>Both</td>
</tr>
</tbody>
</table>

**Description:**

I did not find the Data & Pattern Designing technique to be aggressive enough to take directly to implementation. Ideally, the desired design could be modelled to a fairly detailed level without prior knowledge of the implementation tool, with perhaps a final layer which takes into account particulars of the tool.

**Circumstances:**

Each of the implementation tools turned out to require quite different designs in certain key areas. The process model in the design was blind, leading most of the details to be worked out during implementation. Especially troublesome were the built-in 'power' features, such as automation of referential integrity in C++, but not in VB, or automated joins in C++, but not in VB. As I look at the working application, I still ponder how to represent the (new given) design in these 3 forms. (11) I need to look at this some more to make sure the problem isn't my prescience in using one process model. If so, I will reorient this one towards how to make better. (11)

**Guidance Ideas:**

To accommodate process and/or schema of the implementation tool, the design must be kept general (tool-free) down to a point. Then, if the tool and the data model are known, a layer of specialisation can be added. (Note the data a person process modelling techniques use a drill-down approach to specificity, thus making it suitable for this approach.)
APPENDIX I

Peer Observation Data Sheets
## Software Engineering Methods versus Visual Programming Tools/Languages
### Synergy/Conflict Observations

<table>
<thead>
<tr>
<th>Observation Type:</th>
<th>Project:</th>
<th>Category:</th>
<th>Data of Interview:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflict</td>
<td>Custom</td>
<td>Query</td>
<td>11/30/95 15:45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SE Application:</th>
<th>SE Method:</th>
<th>Visual Tool:</th>
<th>Frequency of Observation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Any</td>
<td>Any</td>
<td>Often</td>
</tr>
</tbody>
</table>

**Description:**
There is frequently a decision between what is specified in the design of a query and the behavior that is actually implemented. Also a problem in non-visual tools, but with visual tools the wrong behavior can be implemented much faster.

**Circumstances:**
When a query is specified, the exact database schema is often not fully established. Sometimes the SQL dialect is also unknown. Thus, the query will likely be specified in a general way, typically using the language of the domain (as opposed to pre-defined or simplified SQL). Then it comes time for the application developer to implement the query. The essence of what was intended is lost. The query does not behave properly by returning incorrect, incorrect, or incomplete information.

**Guidance Ideas:**
An idea that instead is to include in the specification several examples of what the query should return. A query set of tables/records would so be provided to demonstrate how the query might operate.
As visual query tools evolve, perhaps a compatible method of diagramming a query at the design stage can be proposed.

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## Software Engineering Methods versus Visual Programming Tools/Languages
### Synergy/Conflict Observations

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<tr>
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<td>Custom</td>
<td>Query</td>
<td>11/23/95 16:30</td>
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</tbody>
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<th>SE Method:</th>
<th>Visual Tool:</th>
<th>Frequency of Observation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Any</td>
<td>Any</td>
<td>Usually</td>
</tr>
</tbody>
</table>

**Description:**
The SE layout facilities provided by most every visual tool are provide little or no benefit over paper or drawing tools similar.

**Circumstances:**
Most CASE tools do not generate native code for any of the visual tools in common use. The UI must be implemented manually. (Some CASE tools do generate C source code that will give a look and feel like that of the design, but that source code is not usable by any of the typical visual tools, such as Visual Basic, PowerBuilder or QDInuclear.)

**Guidance Ideas:**
In general, do not use the CASE tool to flesh out your GUI design. Instead, use the visual programming tool itself to sketch it out, but keep the result grouped with the design package. Later, when implementation begins, the GUI file can be copied into the source area and used as a starting point for developing the application.
### Observation Type:
- **Conflict/Synergy**

### Projects:
- CAN - Numerous Projects
- OSE - Numerous Projects

### Category:
- OSE Scenario

### Date of Interview:
- 11/23/94 16:19

### Frequency of Observations:
- Rare

### Observation Type:
- Project: CAN - Numerous Projects
- Category: OSE Scenario
- Date of Interview: 11/23/94 16:19

### Description:
The structured data modeling features provided in today’s CASE tools coupled with an automated schema generation facility provide significant productivity benefits.

### Circumstances:
- CASE tools typically provide an on-line data dictionary and the establishment of data domains. They also provide balancing routines which ensure that each layer of increasing detail has the same inputs and outputs structure as its parent. Automatic schema generation creates SQL code in the meta-definition language dialect of the chosen relational database product, typically covering the waterfront (i.e., Dates, Entities, Interacts, etc.). Once the base source file is processed by the target database engine, the desired tables and columns are created with the proper type and size.

### Guidance Ideas:
- There are no formal data modeling should be applied whenever possible. One very successful combination used frequently by CAN is DDL & DML data view diagrams and entity-relationship diagrams. Automatic schema generation should be exploited whenever possible. Benefits of this approach includes: enhanced ability to create the initial prototype, enhanced ability to understand how objects are used (cross-referencing to which tables/columns are used where), enhanced ability to find things and address things.

### Observation Type:
- Project: OSE - Numerous Projects
- Category: OSE Scenario
- Date of Interview: 11/23/94 16:19

### Description:
It is very difficult to describe the desired functional behavior of modern OSE database front ends using the traditional process modeling paradigms offered in most software engineering methodologies, data & screen being the case in point.

### Circumstances:
- The visual programming tools are anywhere from slightly to completely object-oriented in their design and usage, and all are event-based at least for their response to user interactions. Data & Screen, and the other more traditional modeling techniques provide little support for expressing object-oriented or event-based behaviors. This leads to wordy narratives accompanying such diagrams, or leaving the programmer to their own devices to translate a procedural design into its object-oriented, event-based counterparts.

### Guidance Ideas:
- Use DFD and E/R to model the data structures only (not behavior). Use Conf/Event Model/State Transition Diagram to model behavior.

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Software Engineering Methods versus Visual Programming Tools/Languages

Synergy/Conflict Observations

<table>
<thead>
<tr>
<th>Observation Type: Synergy</th>
<th>Project:</th>
<th>Category: Utility Modules</th>
<th>Date of Interview: 3/29/95 14:45</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frequency of Observation: Often</td>
</tr>
</tbody>
</table>

**BE Application:** Disk
**BE Method:** Any
**Visual Tool:** Any component-based

**Description:** It is very difficult to safely and reliably package a distribution difference when deploying an application built on a component-based tool or language (which includes most, if not all, of the visual ones). The problem includes both creation issues (e.g., knowing which components must be included) and installation/setup issues (e.g., version compatibility when two independently created applications rely on the same component).

**Circumstances:** The creation and use of reusable components is a key benefit of today's open and standardized software initiatives. Although still in its infancy, this goal provides a great deal of potential for leveraging the software development energies of the entire industry. It introduces a new set of challenges, however. Components include this, that, some drivers and the like, usually supplied by the major software tool vendors, such as Microsoft, and their third-party developers.

**Guidance Ideas:**
Create a library of components which are clearly labeled and clearly defined/operational. Clearly specify which components are to be used in a project and do not put literal copies of a standard component in the code directory for a project, but rather point to it. Insist that component vendors supply version and date in the component (to support programmatic version control), prevent overwriting a newer version with an older one, and provide forward compatibility for newer versions (so that if an application supplies a newer version of a component, someone else's application won't suddenly quit working).

Software Engineering Methods versus Visual Programming Tools/Languages

Synergy/Conflict Observations

<table>
<thead>
<tr>
<th>Observation Type: Synergy</th>
<th>Project:</th>
<th>Category: User Interface Layout</th>
<th>Date of Interview: 3/29/95 14:45</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frequency of Observation: Often</td>
</tr>
</tbody>
</table>

**BE Application:** Manual
**BE Method:** MS Access Methodology
**Visual Tool:** MS Access + DB

**Description:** Choosing behavior of combo box object only allowed the list box to contain static (predefined) choices; internal customer required dynamic additional to the list of choices. This lead to enormous expenditure of effort to provide the dynamic behavior (i.e., months, including hands-on support of tool vendor).

**Circumstances:** Internal customer desired "commercial-grade" behavior of combo box (i.e., the purpose of a combo box is to allow the user to either pick from a list of previously entered choices or type in a new one). Most Windows applications automatically add any newly typed-in items to the list for use by future users.

**Guidance Ideas:** Cut losses early in the process. This could be accomplished by relaxing the requirements (in this case, by sacrificing the dynamic-update behavior). Alternatively, the development tool could be switched to one more congruent with customer requirements (probably only makes sense if there are no serious instances of mismatch, since most every tool will have some limitations).
<table>
<thead>
<tr>
<th>Observation Type:</th>
<th>Conflict</th>
<th>Synergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects:</td>
<td>SE - Customer Service Application</td>
<td></td>
</tr>
<tr>
<td>Category:</td>
<td>Function Design</td>
<td></td>
</tr>
<tr>
<td>Date of Interview:</td>
<td>3/2/95 18:15</td>
<td></td>
</tr>
<tr>
<td>Frequency of Observation:</td>
<td>Daily</td>
<td></td>
</tr>
</tbody>
</table>

**Observation Type:**
- Conflict
- Synergy

**Project:**
- SE - Customer Service Application

**Category:**
- Function Design

**Date of Interview:**
- 3/2/95 18:15

**Frequency of Observation:**
- Daily

**Observation Type:**
- Manual
- CAE
- MIA

**Description:**
The functional design paradigm used by SE did not lend itself to 'world class' look & feel and behavior specified by internal customer.

**Circumstances:**
Excessive time and energy expended trying to force fit desired functionality into tool not really designed to provide the desired look & feel or behavior.

**Guidance Ideas:**
- Pick a 'good' initial deliverable based on the 'flow' or inherent capabilities of the chosen development tool; then perform a value/most assessment based on feedback on the pilot to determine whether the original requirements were indeed valid (we switched tools for follow-on) or not (we proceed with original tool to complete the final version).

**Observation Type:**
- Manual
- CAE
- MIA

**Description:**
There is a 'convex' path from CASE model to scheme: CASE also provides automatic serialization of data and automatic naming of tables and attributes. The auto-generated names are very cryptic in nature. Therefore, the developer typically edits the scheme to make the same more 'developer-friendly.'

**Circumstances:**
Once the scheme has been edited, the CASE representation is out of date, and must either be manually updated (i.e., all edits and maintenance of the scheme must be done twice), or else the CASE representation must be abandoned.

**Guidance Ideas:**
- Change to a tool that has reverse engineering capability (so that changes to the scheme can be fed back into the model). Change to a tool that generates schemes that are so good that they do not have to be edited; make maintenance changes in the CASE model and regenerate scheme each time. Then use the CASE tool to develop the initial version and then abandon it.
### Software Engineering Methods versus Visual Programming Tools/Languages

**Synergy/Conflict Observations**

<table>
<thead>
<tr>
<th>Observation Type</th>
<th>Project Category</th>
<th>Date of Interview</th>
<th>Frequency of Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synergy</td>
<td>Scripted Design</td>
<td>12/29 10:43</td>
<td>Very Often</td>
</tr>
</tbody>
</table>

**SE Application:**
- Scripted

**SE Methodology:**
- xxx methodology

**Visual Tool:**
- xxx - n/a

**Description:**
The xxx product and methodology were developed with script-based, client/server computing application development in mind. Thus, the development process and implementation process for applications targeted for such an architecture are excellent.

**Circumstances:**
For the subject project, the xxx product and methodology were chosen because the target application was slated for running multiple data servers on multiple platforms (xxx on mainframe, xxx on mainframe, and xxx on PC), and taking advantage of event-based programming. These aspects of the environment matched up very well (the problems mentioned in the other observations notwithstanding).

**Guidance Ideas:**
Match your tool's capabilities to the implementation architecture.
VITA

Mr. Touchton received a Bachelor of Science in Engineering (Nuclear Engineering) from the University of Florida in 1974 and a Master of Science in Nuclear Engineering from Carnegie-Mellon University in 1977. He is a licensed Professional Engineer in the state of Florida.

Mr. Touchton has 20 years experience including 10 years as a nuclear engineer for Westinghouse and a small consulting firm, and 10 years as a consultant in the application of advanced computing technologies for PathTech Software Solutions, Inc. Mr. Touchton is a co-founder and President of PathTech. His areas of expertise include the design and development of knowledge-based systems, client/server applications, and relational data bases. He is a champion of object-oriented programming and the incremental development paradigm.