Visual Programming Languages

SWE 795, Spring 2017
Software Engineering Environments

Adapted from slides by Vishal Dwivedi,
Human Aspects of Software Development, Spring 2011
Today

• Part 1 (Lecture)(~50 mins)

• Break!

• Part 2 (Discussion)(~30 mins)
  • HW3 presentations

• Part 3 (Discussion)(~60 mins)
  • Project work
Definitions

“Programming”
“The process of transforming a mental plan of desired actions for a computer into a representation that can be understood by the computer”
– Jean-Michel Hoc and Anh Nguyen-Xuan

“Single-dimensional characteristics”
The compilers or interpreters programs as long, one-dimensional streams.
Definitions

“Visual Programming”
“Programming in which more than one dimension is used to convey semantics.” - Myers, 1990

“Token”
“A collection of one or more multi-dimensional objects”.
Examples:
- Multi-dimensional graphical objects
- Spatial relationships
- Use of the time dimension to specify “before-after” semantic relationships.

“Visual Expression”
“A collection of one or more tokens”
Definitions

“Visual Programming Language”

“Any system where the user writes a program using two or more dimensions”
[Myers, 1990]

“A visual language manipulates visual information or supports visual interaction, or allows programming with visual expressions”
[Golin, 1990]

“A programming language that lets users create programs by manipulating program elements graphically rather than by specifying them textually”.

“A set of spatial arrangements of text-graphic symbols with a semantic interpretation that is used in carrying out communication actions in the world”.
[Lakin, 1989]
What is not a Visual Programming Language?

Programming Languages like Visual Basic, Visual C++, Visual C sharp, Delphi, etc do not satisfy the *multi-dimensional characterization.*

They are primarily Textual languages with:

A graphical GUI builder

A visual user interface
Goal of VPL Research

• To strive for improvements in programming language design.
• To make programming more accessible to some particular audience.
• To improve correctness with which people perform programming tasks.
• To improve the speed with which people perform programming tasks.
Motivation from Psychology

Language determines thought and that linguistic categories limit and determine cognitive categories [1]

In longer sentences meaning of each word may be clear, but the way in which they are strung together makes little sense imposes a tremendous mental workload to understand. [2]

Most design tasks require 3 cognitive skills: search, recognition and inference.

Diverse set of views (and studies) exist today about whether VPLs aid in search or cognition. [3]

Motivation

Some applications are (believed to be) very well suited to graphical development approaches

Scientific visualization
Simulations
User Interfaces
Signal Processing
Data Displays
(Claimed) Advantages of VPLs

- Fewer programming concepts
- Concreteness
- Explicit depiction of relationships
- Immediate visual feedback
- Parallel computation is a natural consequence of many visual programming paradigms
(Claimed) Disadvantages of VPLs

“Deutsch Limit” *

The problem with visual programming is that you can't have more than 50 visual primitives on the screen at the same time.

Some situations in which text has superiority:

Documentation,

Naming to distinguish between elements that are of the same kind, and

Expressing well-known and compact concepts that are inherently textual, e.g. algebraic formulas.
Visual Programming Languages Techniques

• Concreteness: expressing some aspect of a program using instances
  • e.g., display the effects of computation on individual instance

• Directness: small distance between goal and actions required of the user to achieve goal
  • e.g., direct manipulation of object properties

• Explicitness: don’t require inference to understand semantics
  • e.g., depict dataflow edges between variables

• Liveness: offer automatic display of effects of program edits on output
  • e.g., after every edit, IDE reruns code and regenerates output
Levels of liveness

- Level 1: No semantic feedback offered
  - e.g., using ER diagram for documentation
- Level 2: Semantic feedback, but not offered automatically
  - e.g., interpreters
- Level 3: Incremental semantic feedback automatically provided after edit, regenerating onscreen output
  - e.g., spreadsheets
- Level 4: Incremental semantic feedback offered after edits & systems events (e.g., clock ticks, mouse clicks)
  - e.g., some Smalltalk environments (?)

History of VPLs

1960
Techniques
- Graphs
- Flowcharts
- Flowchart derivatives
- FORMS
- Demonstrational

1980
Techniques
- Action Graphics
- FORMAL
- Web
- Hi-Visual
- LabView
- PROGRAPH
- PIGS
- Pict
- Rehearsal
- SmallStar

1990
Techniques/Goals
- 3D Rendering
- Visual Hierarchy
- Procedures
- Control Structures
- Programmable Graphics
- Animations
- Video Imagery Exploitation
- General purpose, declarative language
- Audio, video and image processing
- Graphical models from behavioral models
- Learning and Cognitive abilities in vision processes
- Handling Scalability, typing, and imperative design
- Collaborative Software Development

2000
Techniques/Goals
- Child Learning
- Xquery by FORMS
- Spreadsheet Analysis
- Visual Model Query
- Layouts
- Specification and Interchange
- Mashups
- Web-based design
- Programming for end-users (2003) / non-Professionals

- AMBIT/G/L
- Grail
- GAL
- Graphical Program Editor
- Query by Example
- Pygmalion
- I/O Pairs

- Cubes
- Cantata
- SchemePaint
- CODE 2.0
- Iconicode
- MVViews
- MViews
- Miro
- StateMaster
- AVS
- Mondrian
- ChemTrains
- Vampire
- VIPR
- SPE

- LOFI/HIPI
- FOXQ
- VMQL
- GXL
- Euler View
- Yahoo Pipes
- Popfly
History of VPLs

Technology Trigger

Period of Early promises

1960

Period of Inflated Expectations

1980

1990

2000

Period of Reality Check

1960

[Ellis, 1969]: GRAIL

[Smith, 1975]: Pygmalion

[Myers, 1990]: Taxonomies for VPL

[Repenning, 1992]: Agent Sheet

[Burnett, 1994]: Broad Classifications for VPL Research

[Kirsten N. Whitley, 1997]: User Studies (for/against VPLs)

[Repenning, 1992]: Agent Sheet

[Smith, 1975]: Pygmalion

[Myers, 1990]: Taxonomies for VPL

[Ellis, 1969]: GRAIL

[MacLaurin, 2009]: KODU

Visual Programming

About 18,200 results (0.47 seconds)

Timeline

1960-2011

Search other dates
History of VPLs

- 1960: Support the cognition aspect of Programming
- 1980: Strive for improvements in programming language design
- 1990: Let users program in Visual Languages
- 2000: Make programming more accessible
- Make textual languages redundant
- Support domain-specific designs

Strive for improvements in programming language design
# Taxonomy of visual programming languages

<table>
<thead>
<tr>
<th>Specification Technique</th>
<th>Systems:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textual Languages:</td>
<td>Pascal, Ada, Fortran, Lisp, Ada, etc. Tinker, Smallstar</td>
</tr>
<tr>
<td>Flowcharts:</td>
<td>Grail, Pict, FPL, IBGE, OPAL</td>
</tr>
<tr>
<td>Flowchart derivatives:</td>
<td>GAL, PIGS, SchemaCode, PLAY</td>
</tr>
<tr>
<td>Petri nets:</td>
<td>MOPS-2, VERDI</td>
</tr>
<tr>
<td>Data flow graphs:</td>
<td>Graphical Program Editor, PROGRAPH, Graphical Thinglab, Music System, HI-VISUAL, LabVIEW, Fabrik, InterCONS</td>
</tr>
<tr>
<td>Directed graphs:</td>
<td>AMBIT/G/L, State Transition UIMS, Bauer’s Traces</td>
</tr>
<tr>
<td>Graph derivatives:</td>
<td>HiGraphs, Miro, StateMaster</td>
</tr>
<tr>
<td>Matrices:</td>
<td>ALEX, MPL</td>
</tr>
<tr>
<td>Jigsaw puzzle pieces:</td>
<td>Proc-BLOX</td>
</tr>
<tr>
<td>Forms:</td>
<td>Query by Example, FORMAL</td>
</tr>
<tr>
<td>Iconic Sentences:</td>
<td>SIL-ICON</td>
</tr>
<tr>
<td>Demonstrational*:</td>
<td>Pygmalion, Rehearsal World, Peridot</td>
</tr>
<tr>
<td>None*:</td>
<td>I/O Pairs, Editing by Example</td>
</tr>
</tbody>
</table>

Dataflow Program Representations

- Represent computation as a network
- Nodes correspond to components
- Edges correspond to data flow between components
Margaret M. Burnett, “Visual Programming” In the Encyclopedia of Electrical and Electronics Engineering (John G. Webster, ed.), 1999

*Figure 3: Dataflow programming in Prograph. Here the programmer is using the low-level (primitive) operations to find the hypotenuse of a right triangle. Prograph allows the programmer to name and compose such low-level graphs into higher-level graphs that can then be composed into even higher-level graphs, and so on.*
Industrial Example: Clarity

• “Clarity is a schematic functional programming environment that allows you to design and implement programs by drawing them. The picture below shows an example of the hypotenuse function that expresses Pythagoras' theorem.”

http://www.clarity-support.co.uk/products/clarity/
Industrial Example: Yahoo Pipes

https://en.wikipedia.org/wiki/Yahoo_Pipes

https://www.youtube.com/watch?v=Xv-4TOit5_g
Structured editors

- Structured editors that utilize extra dimension to capture program semantics can be considered visual programming languages
  - e.g., Alice, Scratch
Form Representations

- Program consists of a form, with a network of interconnected cells
- Developers define cell through combination of pointing, typing, gesturing
- Cells may define constraints describing relationships between cells
Forms/3

- Based on constraints between cells
- Supports graphics, animation, recursion
- Concreteness: resulting box is immediately seen
- Directness: demonstrates elements directly
- Level 4 liveness: immediate visual feedback

Figure 2: Defining the area of a square using spreadsheet-like cells and formulas in Forms/3. Graphical types are supported as first-class values, and the programmer can enter cell square’s formula either by sketching a square box or by typing textual specifications (e.g., “box 30 30”).

Margaret M. Burnett, “Visual Programming” In the Encyclopedia of Electrical and Electronics Engineering (John G. Webster, ed.), 1999
Forms/3 Example

http://web.engr.oregonstate.edu/~burnett/Forms3/LED.html
Forms/3 Example

bottles of beer on the wall,
bottles of beer...
Take one down, pass it around,
bottles of beer on the wall.

fixedWords

99 bottles of beer on the wall.
99 bottles of beer...
Take one down, pass it around,
98 bottles of beer on the wall.

compose bottles at (4 2)
with fixedWords at (5 2)
with bottles at (4 14)
with (bottles - 1) at (4 38)

by Dr. Margaret M. Burnett and Jonathan Jay Cadiz
Interstate

Figure 1: A basic InterState object, named draggable, which implements draggable and drag lock behaviors. Properties that control draggable’s display are represented as rows (e.g. x, y, and fill). States and transitions are represented as columns (e.g. no_drag and drag). An entry in a property’s row for a particular state specifies a constraint that controls that property’s value in that state. Here, while draggable is in the drag state, x and y will be constrained to mouse.x and mouse.y respectively, meaning draggable will follow the mouse.

http://interstate.from.so/
https://www.youtube.com/watch?v=M--9jsuDZis

Assessing Usability

• Empirical techniques assess usability through studies gathering data
• Analytical techniques use principles & guidelines to estimate the usability of a system
• Will look at a technique for analytical usability evaluation here
Cognitive Dimensions of Notations

- Analytical technique for assessing usability of notation through a set of heuristics
- Also terminology for describing usability problems

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstraction gradient</td>
<td>What are the minimum and maximum levels of abstraction? Can fragments be encapsulated?</td>
</tr>
<tr>
<td>Closeness of mapping</td>
<td>What ‘programming games’ need to be learned?</td>
</tr>
<tr>
<td>Consistency</td>
<td>When some of the language has been learnt, how much of the rest can be inferred?</td>
</tr>
<tr>
<td>Diffuseness</td>
<td>How many symbols or graphic entities are required to express a meaning?</td>
</tr>
<tr>
<td>Error-proneness</td>
<td>Does the design of the notation induce ‘careless mistakes’?</td>
</tr>
<tr>
<td>Hard mental operations</td>
<td>Are there places where the user needs to resort to fingers or penciled annotation to keep track of what’s happening?</td>
</tr>
<tr>
<td>Hidden dependencies</td>
<td>Is every dependency overtly indicated in both directions? Is the indication perceptual or only symbolic?</td>
</tr>
<tr>
<td>Premature commitment</td>
<td>Do programmers have to make decisions before they have the information they need?</td>
</tr>
<tr>
<td>Progressive evaluation</td>
<td>Can a partially-complete program be executed to obtain feedback on “How am I doing”?</td>
</tr>
<tr>
<td>Role-expressiveness</td>
<td>Can the reader see how each component of a program relates to the whole?</td>
</tr>
<tr>
<td>Secondary notation</td>
<td>Can programmers use layout, color, or other cues to convey extra meaning, above and beyond the ‘official’ semantics of the language?</td>
</tr>
<tr>
<td>Viscosity</td>
<td>How much effort is required to perform a single change?</td>
</tr>
<tr>
<td>Visibility</td>
<td>Is every part of the code simultaneously visible (assuming a large enough display), or is it at least possible to compare any two parts side-by-side at will? If the code is dispersed, is it at least possible to know in what order to read it?</td>
</tr>
</tbody>
</table>

Diffuseness / Terseness

• How many symbols or graphic elements is required to express a meaning?

• Simple rocket simulation program
  • Basic: 22 LOC, 140 words (fits on screen)
  • LabView: 45 icons, 59 wires (fits on screen)
  • Prograph: 52 icons, 79 connectors, 11 screens

Error-proneness

- Does the design of the notation induce slips?

- Compared to textual language, VPLs
  - Do not need delimiters & separators
  - Fewer identifiers are needed, easier to reference
  - Constructs inserted automatically (e.g., loops)
Viscosity

• How much effort is required to make a simple change?

• Edit Rocket program to take account of air resistance
  • Basic: 63.3 s
  • LabView: 508.3 s
  • Prograph: 193.6 s

• VPLs required many wires to be rebuilt, layout to be tweaked
Visibility

• Is every (relevant) part of the code simultaneously visible?

• LabView does not show both branches of conditional at same time (!)
  • Particular problem for nested conditionals
  • Prograph has poor support for deep nesting of routines
VPLs Discussion

• Often offers a representation that makes specific tasks easy
  • e.g., tracking data flow
  • Often involves structured editor targeted to specific domain, which may not support full range of programs

• But may make other tasks harder
  • Often limited focus on scalability

• May be possible to get benefits of task-specific representations without drawbacks through task specific editor rather than language