A CLASSIFICATION SYSTEM FOR VISUAL PROGRAMMING LANGUAGES

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ABSTRACT

We have developed a classification scheme for classifying visual programming language research papers. This paper presents the scheme, the motivations for developing it, and examples of its use.

INTRODUCTION

The literature about visual programming languages (VPLs) has grown to the point where some kind of organization must be imposed. Such an organization would make it possible for researchers to classify their work in terms of its main areas of contribution, thereby helping other researchers to easily and reliably locate relevant papers. This then is the goal of a classification system–to aid researchers in their search for relevant work.

The ACM Computing Reviews Classification System [1] exists for precisely this purpose, and is partially reprinted in Appendix A of this paper. The benefits of using the Computing Reviews system (ACM CR system) for classifying VPL research would have been many. The ACM CR system is the result of extensive work and analysis, it is widely used and understood, and all VPL work classified according to the system would have fit into the many databases and bibliographies that make use of the ACM CR system.

Unfortunately, the structure of the ACM CR system is unsuitable for classification of VPL research. There are two reasons for this. The first is granularity: the ACM CR system is already 3 levels deep, and only 4 are allowed. If we were able to add a new category to the system (such as *D.3.5: Visual Programming Languages*), only one level below it would be possible which would hardly be sufficient to organize the various kinds of work in the area. The second reason is fragmentation: if we were to use existing categories (such as *Control structures* under *D.3.3: Language Constructs and Features*, or *Object-oriented languages* under *D.3.2: Language Classifications*), VPL work would be lost in the forest of all non-visual programming language work in that area, making it very difficult for researchers to locate any VPL work at all. In short, although it is possible to classify VPL work using the ACM CR system, doing so does not achieve the goal of organizing the work in a way that is helpful to VPL researchers.

Given that the ACM CR system will not suffice for classifying VPLs, a second possibility would have been to devise a VPL classification system that exactly parallels the ACM CR *Programming Languages* area (D.3). Unfortunately, however, this too is unsuitable. A glance at Appendix A shows that the arrangement of subtopics in this area does not closely reflect the research subareas within VPLs. There are many areas that would never have any entries at all because work in them is not particular to VPLs (such as *Recursion* and *Dynamic storage* *management*), and there are other important areas particular to VPLs that are entirely missing from the ACM CR system (such as *Programming by demonstration*, and *Icon theory*). Thus, a new system devised especially for VPL research is required.

A VPL CLASSIFICATION SYSTEM

We have developed such a system for classifying VPL research. Although the scope of our work has been only within visual *programming* languages, figure 1 shows how we envision the VPL classification system in relation to classification systems that may later be developed for other subareas of visual computing. Determining whether a particular language should be classified in the *Visual Programming Languages* subarea depends on whether it can be used to program visually. For example, some visual query languages would best fit in the *Visual Database Systems* subarea, but if such a language can be used to program visually, it may also fit in the *Visual Programming Languages* subarea. The distinction between the *Visual Programming Languages* and *Visualization* subareas is that visualization employs visual techniques to display data, software, algorithms, and programs, but does not use these techniques to program visually. The classification system corresponding to the *Visual Programming Language*s subarea is given in table 1.

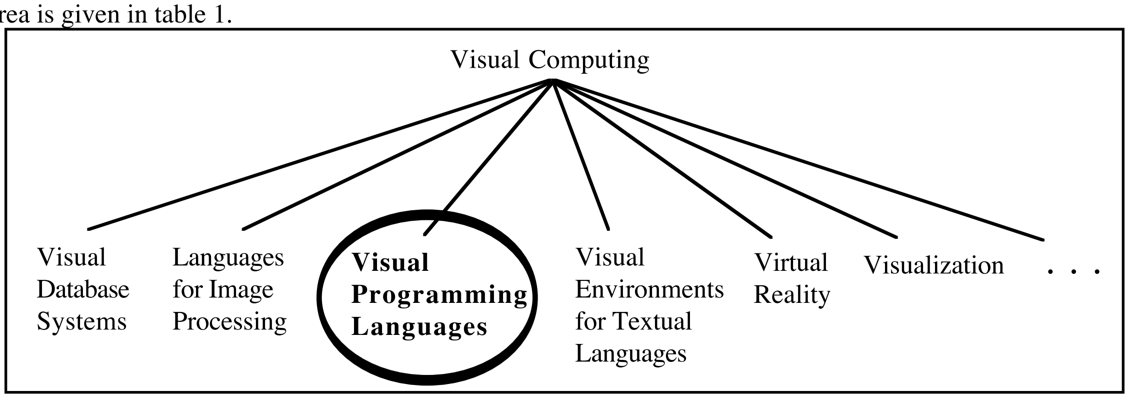

Figure 1: The VPL classification system in the context of other important subareas of visual computing. The branch labeled "..." indicates where further classifications reflecting new subareas of visual computing would be added.

VPL: Visual Programming Languages

- VPL-I. Environments and Tools for VPLs
- VPL-II. Language Classifications
  - A. Paradigms
    - 1. Concurrent languages
    - 2. Constraint-based languages
    - 3. Data-flow languages
    - 4. Form-based and spreadsheet-based languages
    - 5. Functional languages
    - 6. Imperative languages
    - 7. Logic languages
    - 8. Multi-paradigm languages
    - 9. Object oriented languages
    - 10. Programming-by-demonstration languages
    - 11. Rule-based languages
  - B. Visual representations
    - 1. Diagrammatic languages
    - 2. Iconic languages
    - 3. Languages based on static pictorial sequences
- VPL-III. Language Features
  - A. Abstraction
    - 1. Data abstraction
    - 2. Procedural abstraction
  - B. Control flow
  - C. Data types and structures
  - D. Documentation
  - E. Event handling
  - F. Exception handling
- VPL-IV. Language Implementation Issues
  - A. Computational approaches (e.g. demand-driven, data-driven)
  - B. Efficiency
  - C. Parsing
  - D. Translators (interpreters and compilers)
- VPL-V. Language Purpose
  - A. General-purpose languages
  - B. Database languages
  - C. Image-processing languages
  - D. Scientific visualization languages
  - E. User-interface generation languages
- VPL-VI. Theory of VPLs
  - A. Formal definition of VPLs
  - B. Icon theory
  - C. Language design issues
    - 1. Cognitive and user-interface design issues (e.g. usability studies, graphical perception)
    - 2. Effective use of screen real estate
    - 3. Liveness
    - 4. Scope
    - 5. Type checking and type theory
    - 6. Visual representation issues (e.g. static representation, animation)

Table 1: The Visual Programming Language classification system.

We initially tested the VPL classification system by classifying a variety of VPL research papers ourselves. A more extensive test of the system was performed by the original authors of additional VPL research papers, and improvements were incorporated as a result of their suggestions. The bibliography of papers classified by the original authors is shown in Appendix B and is available to all interested researchers via anonymous ftp[1].

HOW TO USE THE CLASSIFICATION SYSTEM

The classification system is designed with the intent that any node in the tree may be used to classify a paper, not just the leaf nodes.[2] For example, a paper about implementation issues that are particular to VPLs (as opposed to a paper about one specific implementation issue) would be placed in classification *VPL-IV: Language Implementation Issues*. Some broad survey papers such as S.-K. Chang's 1987 tutorial on visual languages [2] may even be best classified using the root node, *VPL: Visual Programming Languages*. This eliminates the need for categories labeled "miscellaneous" which people are unlikely to find particularly useful. It also reduces the number of subtopics needed since it is not necessary to create new leaf nodes for survey papers and for papers that report results from unusual perspectives.

Following the convention of the ACM CR Classification System, we do not formally define the terms, but rather leave it to the authors to use the terms they feel are most appropriate in classifying their own papers. In the VPL classification system, like others, it is intended that authors will classify their papers in terms of the *main* contributions of the paper. Authors should not attempt to cover every briefly-mentioned subtopic in their classification of a paper. Thus, two to four categories should suffice for most papers. For example, we would classify the paper "VIVA: A Visual Language for Image Processing" [3] as *VPL-II.A.3: Data-flow languages, VPL-IV.B: Efficiency*, *VPL-V.C: Image-processing languages*, and *VPL-VI.C.3: Liveness*. These particular categories were selected because they are the primary areas of substantive discussion and contribution in the paper.

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[1] Ftp to lynx.cs.orst.edu, log in as anonymous, cd to pub/burnett, and get VPLclassification.tr.ps.

[2] See Appendix B for examples.

Authors may also include the names of their systems and approach-specific phrases, if applicable, in their classification list. This facilitates searches for papers about a specific system or approach. For example, we would add the keyword VIVA to the list of keywords given in the previous paragraph for Tanimoto's paper.

Some authors describe their VPLs in terms of the representation system used (e.g., "XYZ is an iconic language ..."). Others tend to describe their VPLs in terms of the underlying paradigm (e.g., "XYZ is an object-oriented visual language ..."). For this reason, both ways of classifying VPLs are provided within *VPL-II: Language Classifications*.

In some cases, an author may wish to classify a paper using both VPL classifications and ACM CR classifications. To eliminate confusion as to which classification scheme is being used, the VPL classification is prefixed with "VPL-". For example, the paper "Interactive Visual Data Abstraction in a Declarative Visual Programming Language" [4] provides a description of the programming language Forms/3, and focuses on its approach to data abstraction and event handling. We classified it as *VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.A.1: Data abstraction* and *VPL-III.E: Event handling* in the VPL classification system, and classified it as *D.3.2: Nonprocedural languages* and *D.3.3: Abstract data types* in the ACM CR system. We also included the keyword Forms/3.

CONCLUSION

In the past, search techniques for VPL research have been limited primarily to ad-hoc scans through probable locations. The classification system presented here is a first step toward solving this problem. If the system comes into wide use by authors, it will be possible for those maintaining bibliographies in the VPL subarea of visual computing to organize entries more effectively than has been done in the past using only the traditional alphabetical order. This would enable researchers to find work in their specific interests more reliably and efficiently.

ACKNOWLEDGMENTS

We would like to thank S.-K. Chang for his encouragement of this project. We also thank the authors who have contributed to the VPL bibliography and the other researchers whose helpful comments led to many improvements.

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1. The Full Computing Reviews Classification System: 1991 Version, ACM, New York, 1992.
2. S.-K. Chang, Visual Languages: A Tutorial and Survey, *IEEE Software*, January 1987, 29-39.
3. S. Tanimoto, VIVA: A Visual Language for Image Processing, *Journal of Visual Languages and Computing*, 1(2), June 1990, 127-139.
4. M. M. Burnett and A. L. Ambler, Interactive Visual Data Abstraction in a Declarative Visual Programming Language, *Journal of Visual Languages and Computing*, March 1994, 29-60.

APPENDIX A: THE ACM COMPUTING REVIEWS CLASSIFICATION SYSTEM

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D. Software

. . .

- D.3 Programming Languages
  - D.3.0 General
    - Standards
  - D.3.1 Formal Definitions and Theory
    - Semantics
    - Syntax
  - D.3.2 Language Classifications
    - Applicative Languages
    - Concurrent, distributed, and parallel languages
    - Data-flow languages
    - Extensible languages
    - Macro and assembly languages
    - Microprogramming languages
    - Nondeterministic languages
    - Nonprocedural languages
    - Object-oriented languages
    - Specialized application languages
    - Very high-level languages
  - D.3.3 Language Constructs and Features
    - Abstract data types
    - Concurrent programming structures
    - Control structures
    - Coroutines
    - Data types and structures
    - Dynamic storage management
    - Input/Output
    - Modules, packages
    - Procedures, functions, and subroutines
    - Recursion
  - D.3.4 Processors
    - Code generation
    - Compilers
    - Interpreters
    - Optimization
    - Parsing
    - Preprocessors
    - Run-time environments
    - Translator writing systems and compiler generators
  - D.3.m Miscellaneous

ACM's Full Computing Reviews Classification System for the Programming Languages area. (Courtesy of the Association for Computing Machinery, Copyright 1991, ACM.)

APPENDIX B: SAMPLE BIBLIOGRAPHY OF VPL PAPERS

CLASSIFIED USING THE VPL CLASSIFICATION SCHEME[1]

VPL: VISUAL PROGRAMMING LANGUAGES

Burnett, Margaret M. and Marla J. Baker, A Classification System for Visual Programming Languages, Journal of Visual Languages and Computing, December 1994 (to appear).
Keywords and Phrases: VPL: Visual Programming Languages

Burnett, Margaret, Richard Hossli, Timothy Pulliam, Brian VanVoorst, and Xiaoyang Yang, Toward Visual Programming Languages for Steering in Scientific Visualization: a Taxonomy, CS-TR 92-12, Michigan Technological University, December 1992.
Keywords and Phrases: VPL: Visual Programming Languages, VPL-V.D: Scientific visualization languages

VPL-I: Environments and Tools for VPLs

VPL-II: Language Classifications

Boursier, P. and M. Mainguenaud, Spatial Query Languages : Extended SQL vs. Visual Languages vs. Hypermaps, 5th International Symposium on Spatial Data Handling, Charleston, USA, August 3-7, 1992.
Keywords and Phrases: VPL-II: Language Classifications

VPL-II.A: Paradigms

VPL-II.A.1: Concurrent languages

VPL-II.A.2: Constraint-based languages

VPL-II.A.3: Data-flow languages

Harvey, N. and J. Morris, NL: A General Purpose Visual Dataflow Language, Technical Report, University of Tasmania, October 1993.
Keywords and Phrases: VPL-II.A.3: Data-flow languages, VPL-V.A: General-purpose languages

Koelma, D., R. van Balen, and A. Smeulders, SCIL-VP: a multi-purpose visual programming environment, Proceedings of the 1992 ACM/SIGAPP Symposium on Applied Computing, 1188-1198, 1992.
Keywords and Phrases: VPL-II.A.3: Data-flow languages, VPL-III.A.2: Procedural abstraction, VPL-VI.C.4: Scope

[1] All entries in this bibliography were assigned classifications by their original authors.

VPL-II.A.4: Form-based and spreadsheet-based languages

Ambler, Allen L. and Margaret M. Burnett, Visual Languages and the Conflict Between Single Assignment and Iteration, 1989 IEEE Workshop on Visual Languages, Rome, Italy, 138-143, Oct. 1989.
Keywords and Phrases: Forms/2, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.B: Control flow

Ambler, Allen L. and Margaret M. Burnett, Visual Forms of Iteration that Preserve Single Assignment, Journal of Visual Languages and Computing, 1(2), Academic Press, June 1990.
Keywords and Phrases: Forms/2, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.B: Control flow

Burnett, Margaret M. and Allen L. Ambler, Generalizing Event Detection and Response in Visual Programming Languages, 1992 Proceedings of Advanced Visual Interfaces International Workshop, Rome, Italy, May 27-29, 1992.
Keywords and Phrases: Forms/3, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.A: Abstraction, VPL-III.E: Event handling

Burnett, Margaret M. and Allen L. Ambler, A Declarative Approach to Event-Handling in Visual Programming Languages, 1992 IEEE Workshop on Visual Languages, Seattle, WA, 34-40, Sept. 15-18, 1992.
Keywords and Phrases: Forms/3, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.A: Abstraction, VPL-III.E: Event handling

Burnett, Margaret M. and Allen L. Ambler, Interactive Visual Data Abstraction in a Declarative Visual Programming Language, Journal of Visual Languages and Computing, 29-60, March 1994.
Keywords and Phrases: Forms/3, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-III.A.1: Data abstraction, VPL-III.E: Event handling

Pandey, Rajeev and Margaret Burnett, Is It Easier to Write Matrix Manipulation Programs Visually or Textually? An Empirical Study, 1993 IEEE Symposium on Visual Languages, Bergen, Norway, August 24-27, 1993.
Keywords and Phrases: Forms/3, VPL-II.A.4: Form-based and spreadsheet-based languages, VPL-VI.C.1: Cognitive and user-interface design issues

VPL-II.A.5: Functional languages

Cordy, James R. and T. C. Nicholas Graham, GVL: Visual Specification of Graphical Output, Journal of Visual Languages and Computing, 3, 1992.
Keywords and Phrases: VPL-II.A.5: Functional languages, VPL-V.E: User-interface generation languages

Graham, T. C. Nicholas and Tore Urnes, Relational Views as a Model for Automatic Distributed Implementation of Multi-User Applications, Proceedings of the Fourth Conference on Computer-Supported Cooperative Work, Toronto, October 1992.
Keywords and Phrases: VPL-II.A.5: Functional languages, VPL-V.E: User-interface generation languages

Lakin, Fred, Computing with Text-Graphic Forms, Proceedings of the LISP Conference, Stanford University, August 1980.
Keywords and Phrases: computing with text-graphic forms, visual pattern manipulation language, visual lisp, VPL-II.A.5: Functional languages, VPL-V.A: General-purpose languages, VPL-IV.D: Translators (interpreters and compilers)

VPL-II.A.6: Imperative languages

VPL-II.A.7: Logic languages

Lakin, Fred, Visual Grammars for Visual Languages, Proceedings of the American Association for Artificial Intelligence, Seattle, Washington, July 1987.
Keywords and Phrases: visual grammar notation, declarative programming, visual rules, formal visual languages, informal conversational graphics, visual lisp, visual emacs, vmacs, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs, VPL-II.A.7: Logic languages

Meyer, Bernd, Beyond Icons: Towards New Metaphors for Visual Query Languages for Spatial Information Systems, Proceedings of the International Workshop on Interfaces to Database Systems, Glasgow, 113-135, July 1992. (published by Springer, London, 1993).
Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-II.B.1: Diagrammatic languages, VPL-V.B: Database languages

Meyer, Bernd, Pictures Depicting Pictures - On the Specification of Visual Languages by Visual Grammars, Proceedings of the IEEE Workshop on Visual Languages, Seattle, WA, 41-48, 1992.
Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs

Meyer, Bernd, Beyond Icons: Towards New Metaphors for Visual Query Languages for Spatial Information Systems, Computer Science Research Report No. 127, (Informatik Bericht Nr. 127), University of Hagen, Germany, 1992.
Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs

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Meyer, Bernd, Logic and the Structure of Space Towards a Visual Logic for Spatial Reasoning, Proceedings of the International Logic Programming Symposium, Vancouver, Canada, October 1993, (to appear). (published by MIT Press, 1993).
Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs

VPL-II.A.8: Multi-paradigm languages

VPL-II.A.9: Object oriented languages

VPL-II.A.10: Programming-by-demonstration languages

Calcinelli, D. and M. Mainguenaud, The Management of the Ambiguities in a Graphical Query Language for Geographical Information Systems, 2nd Symposium on Large Spatial Databases, Lecture Notes in Computer Science no. 525, Zurich, Switzerland, August 28-30, 1991.
Keywords and Phrases: VPL-II.A.10: Programming-by-demonstration languages

Calcinelli, D. and M. Mainguenaud, Cigales : A Visual Query Language for Geographical Information System : The User Interface, Journal of Visual Languages and Computing, Academic press, (to appear).
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Keywords and Phrases: VPL-II.A.10: Programming-by-demonstration languages

Mainguenaud, M. and M. A. Portier, CIGALES : A Graphical Query Language for Geographical Information Systems, 4th International Symposium on Spatial Data Handling, Zurich, Switzerland, July 22-28, 1990.
Keywords and Phrases: VPL-II.A.10: Programming-by-demonstration languages

VPL-II.A.11: Rule-based languages

VPL-II.B: Visual representations

VPL-II.B.1: Diagrammatic languages

Lakin, Fred, Visual Languages for Cooperation, NSF workshop on Technology and Cooperative Work, Tucson, Arizona, February 1988; reprinted as a chapter in Intellectual Teamwork: Social and Technical Bases of Collaborative Work, (Carmen Egido, Jolene Galegher, and Robert Kraut, eds.), Lawrence Erlbaum Publishers, 453-488, 1990.
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VPL-III: Language Features

VPL-III.A: Abstraction

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VPL-III.C: Data types and structures

VPL-III.D: Documentation

VPL-III.E Event handling

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Keywords and Phrases: executable graphics, spatial parsing, formal visual languages, informal conversational graphics, visual lisp, visual emacs, vmacs, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs, VPL-IV.D: Translators (interpreters and compilers)

Lakin, Fred, Visual Grammars for Visual Languages, Proceedings of the American Association for Artificial Intelligence, Seattle, Washington, July 1987.
Keywords and Phrases: visual grammar notation, declarative programming, visual rules, formal visual languages, informal conversational graphics, visual lisp, visual emacs, vmacs, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs, VPL-II.A.7: Logic languages

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Meyer, Bernd, Beyond Icons: Towards New Metaphors for Visual Query Languages for Spatial Information Systems, Computer Science Research Report No. 127, (Informatik Bericht Nr. 127), University of Hagen, Germany, 1992.
Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs

Meyer, Bernd, Deklarative Spezifikation visueller Sprachen durch graphische Beispiele oder: Ein Bild sagt mehr als tausend Formeln, 23. GI Jahrestagung, (Horst Reichel, ed.), (in German), Dresden, Germany, Springer Verlag, Berlin, 316-321, October 1993.
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Keywords and Phrases: VPL-II.A.7: Logic languages, VPL-IV.C: Parsing, VPL-VI.A: Formal definition of VPLs

VPL-IV.D Translators (interpreters and compilers)

Lakin, Fred, Computing with Text-Graphic Forms, Proceedings of the LISP Conference, Stanford University, August 1980.
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VPL-VI.A: Formal definition of VPLs

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