Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
The Development of a Java Image Processing Framework

A thesis presented in partial fulfillment of the requirements for the degree of Master of Technology in Computer Systems Engineering at Massey University, Palmerston North, New Zealand.

Jesse Louis McLaughlin
2000
Abstract

Practical computer-based teaching methods are often used in conjunction with theory-based lecture sessions and textbooks when teaching image processing. In kind, electronic or on-line image processing courses commonly provide both theoretical and interactive components, however these are often disparate in that the software use to provide each component is independent rather than integrated. It is less common to find electronic instructional resources for image processing that integrate theoretical textual and practical interactive content together into one seamless package. An integrated approach has the advantage that the concepts are more easily conveyed and reinforced when taught ‘side-by-side’ this way.

The World Wide Web offers an attractive medium for delivering an integrated instructional resource on image processing. Applets written in Java may be seamlessly integrated into a hypertext environment. These applets can provide practical demonstrations of image processing concepts along side the relevant hypertext-based theoretical content. One of the major barriers to realising this kind of resource is the development effort required to create the necessary applets. This research demonstrates that the provision of a software framework can significantly reduce the burden of developing these applets. Such a framework provides a common code base that can be drawn upon during applet development, thereby avoiding the need to start from scratch each time a new applet is needed.

The framework’s design is modelled on a dataflow view of image processing, allowing applets to be built in terms of interconnections between operations. This design is intended to provide the developer with an intuitive and easy-to-use application programming interface (API) for developing applets. The framework also provides APIs for the programmer to implement new operations and data types, thereby extending the capabilities of the framework. Further, the framework’s design is general enough to allow it to be used for developing general purpose image processing programs, or other programs that lend themselves to development using a dataflow language. This thesis shows that the proposed framework achieves its aims through an example application of the development of an applet that demonstrates a thresholding operation.
# Table of Contents

Abstract .......................................................................................................................... iii
Acknowledgments ........................................................................................................... vii

1. Introduction ................................................................................................................. 1
   1.1 Image Processing ................................................................................................. 1
   1.2 Web-Based Instruction ......................................................................................... 3
   1.3 Electronic Textbooks ........................................................................................... 4
   1.4 The Java Programming Language ...................................................................... 6
   1.5 Framework Design .............................................................................................. 7

2. Framework Requirements ........................................................................................... 11
   2.1 Image Processing Software .............................................................................. 11
      2.1.1 Categories of Image Processing Software ............................................... 12
      2.1.2 Software for Interactive Image Processing Instruction .......................... 13
      2.1.3 Java Applets for Interactive Image Processing Instruction .................. 15
      2.1.4 The Basis of an Image Processing Framework ...................................... 16
   2.2 Framework Components ....................................................................................... 17
      2.2.1 Extensible Image Processing Operation Library ...................................... 18
      2.2.2 Data Types ................................................................................................. 19
      2.2.3 A Supervisory System ............................................................................... 20
      2.2.4 Applet Support .......................................................................................... 24
   2.3 A Data Oriented Model ......................................................................................... 25
      2.3.1 Algorithm Representation ......................................................................... 26
      2.3.2 A Dataflow Framework ............................................................................ 27
   2.4 Summary .............................................................................................................. 29

3. Framework Design ....................................................................................................... 33
   3.1 Introduction ......................................................................................................... 33
      3.1.1 Tools ........................................................................................................... 33
      3.1.2 UML Notation ............................................................................................ 35
      3.1.3 Methodology ............................................................................................... 38
      3.1.4 Definitions ................................................................................................. 39
   3.2 Operations ............................................................................................................. 39
      3.2.1 Operator ....................................................................................................... 39
      3.2.2 Primitive ..................................................................................................... 42
      3.2.3 Meta ............................................................................................................. 44
      3.2.4 Summary ..................................................................................................... 45
   3.3 Data Types ........................................................................................................... 46
      3.3.1 Data ............................................................................................................. 46
      3.3.2 Common Types ........................................................................................... 48
      3.3.3 Summary ..................................................................................................... 51
   3.4 Data Passing ......................................................................................................... 52
      3.4.1 Input and Output .......................................................................................... 52
      3.4.2 Progress ....................................................................................................... 53
      3.4.3 InputManager and OutputManager ............................................................ 57
      3.4.4 DataManager .............................................................................................. 70
      3.4.5 Port .............................................................................................................. 77
      3.4.6 FeedThru ..................................................................................................... 79
4. Application Example ................................................................. 109
  4.1 Concept ................................................................................. 109
  4.2 Design ..................................................................................... 110
  4.3 Implementation ...................................................................... 111
    4.3.1 Threshold ........................................................................ 112
    4.3.2 Control ........................................................................... 114
    4.3.3 DisplayImage .................................................................. 116
    4.3.4 ThreshDemo ................................................................. 118
  4.4 Conclusions ........................................................................... 121

5. Summary and Conclusions ....................................................... 123
  5.1 Future Work ........................................................................... 126

References ..................................................................................... 132

Appendix 1: Optimally Accessing Image Data in Java .................... 135
  A1.1 Introduction ........................................................................ 135
  A1.2 Storage/Access Patterns ...................................................... 136
    A1.2.1 Array Configuration .................................................... 136
    A1.2.2 Primitive Type Selection .............................................. 137
    A1.2.3 Access Strategy .......................................................... 138
  A1.3 Experimental Design .......................................................... 139
    A1.3.1 Evaluation Criteria ....................................................... 139
    A1.3.2 Patterns in the Experiment ............................................ 139
    A1.3.3 Experimental Conditions .............................................. 140
  A1.4 Results and Discussion ......................................................... 141
  A1.5 Conclusions ........................................................................ 143
  A1.6 Future Work ....................................................................... 144
Acknowledgments

First and foremost, thanks must go to my two very capable supervisors, Donald Bailey and Wyatt Page, each of whom made very different but equally important contributions to the research presented in this thesis. Thanks must go to Donald for his constant ability to provide expert advice and sound common sense in the face of my more fantastic and quick-conceived ideas. He was, after all, the originator of this research and therefore best qualified to provide the direction for the project, both overall and in its every detail. I would also like to thank Donald for inspiring me in the art of devising useful analogies, which itself proved useful when it came time to write this thesis. Wyatt, for his part (and to our fortune) had been less involved at the time the project was initially formulated, and so was able to bring a more objective perspective to the nature of the problem we had set out to solve. His speciality expertise in a variety of niche areas also proved invaluable on more than one occasion.

I am grateful to acknowledge Massey University’s assistance, in the form of a Massey Masterate Scholarship. In kind, Donald’s financial contribution to the project is also gratefully acknowledged in full, the sum of which afforded me an additional level of support that I might not have otherwise enjoyed.

I would like to give special thanks to my family. To my parents, for being forever interested in everything I do, and to my extended family, for being such a kind, generous and supportive bunch.

My friend and co-conspirator, David Orchiston, is deserving of thanks; his threats mixed with encouragement were of increasing value as the deadline for this thesis approached.

Finally, I would like to warmly thank Rachelle, not only for the constant companionship and much needed distraction she provided during this project, but also for being brave enough to love an aspiring computer systems engineer.