MATERIALS AND ENGINEERING RESEARCH INSTITUTE

Modelling Research Seminar

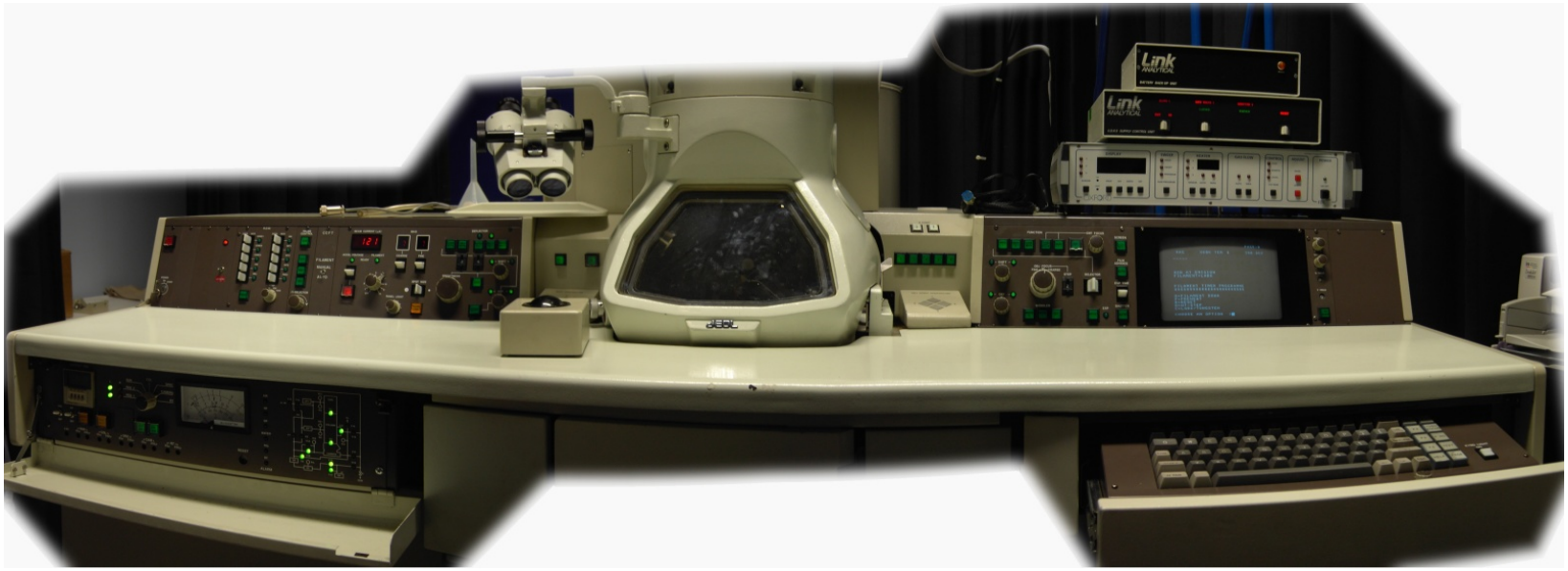
Machine vision and device integration with the Ruby Programming Language

J. Wedekind[a]

Friday, February 29th 2008

Microsystems and Machine Vision Laboratory

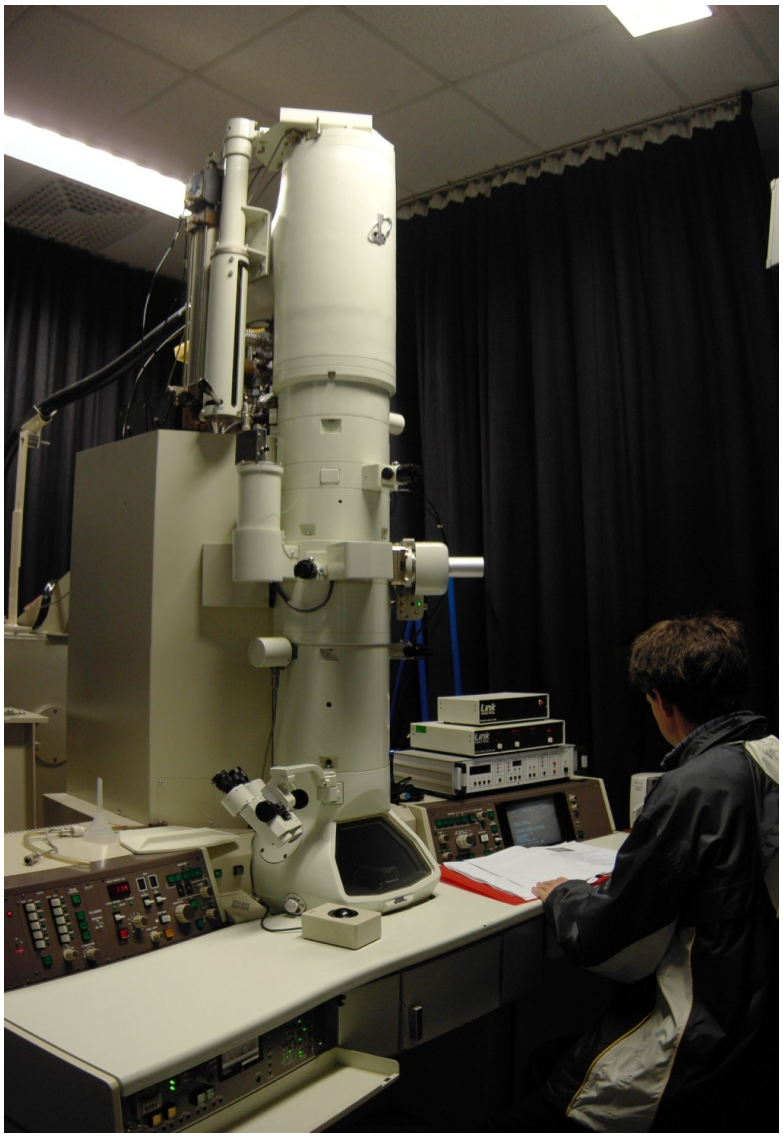
Modelling Research Centre, Materials Engineering Research Institute



[a]Dr J. R. Travis, Dr M. Thompson, Dr B. P. Amavasai, Nanorobotics EPSRC Basic Technology grant GR/S85696/01

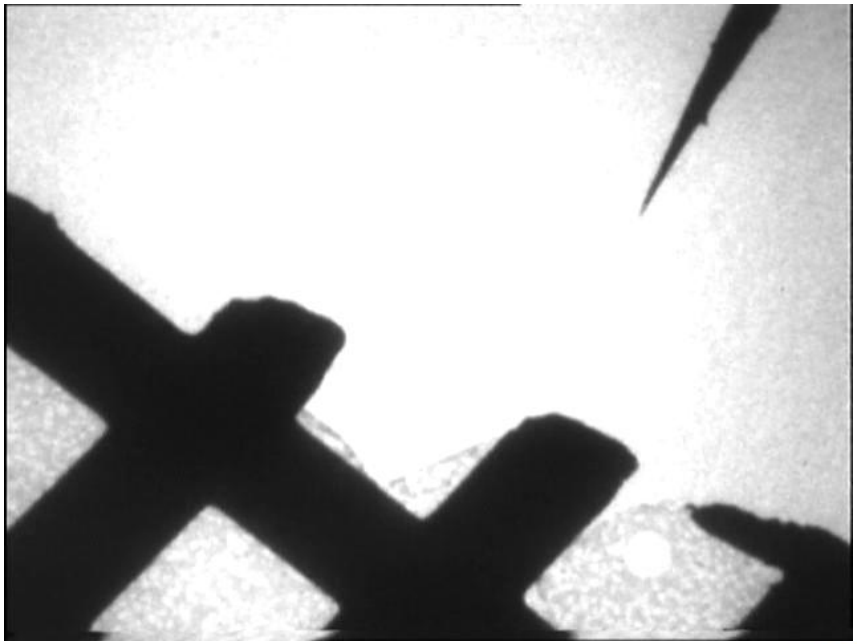
Sheffield Hallam University

Introduction
Nanorobotics Project

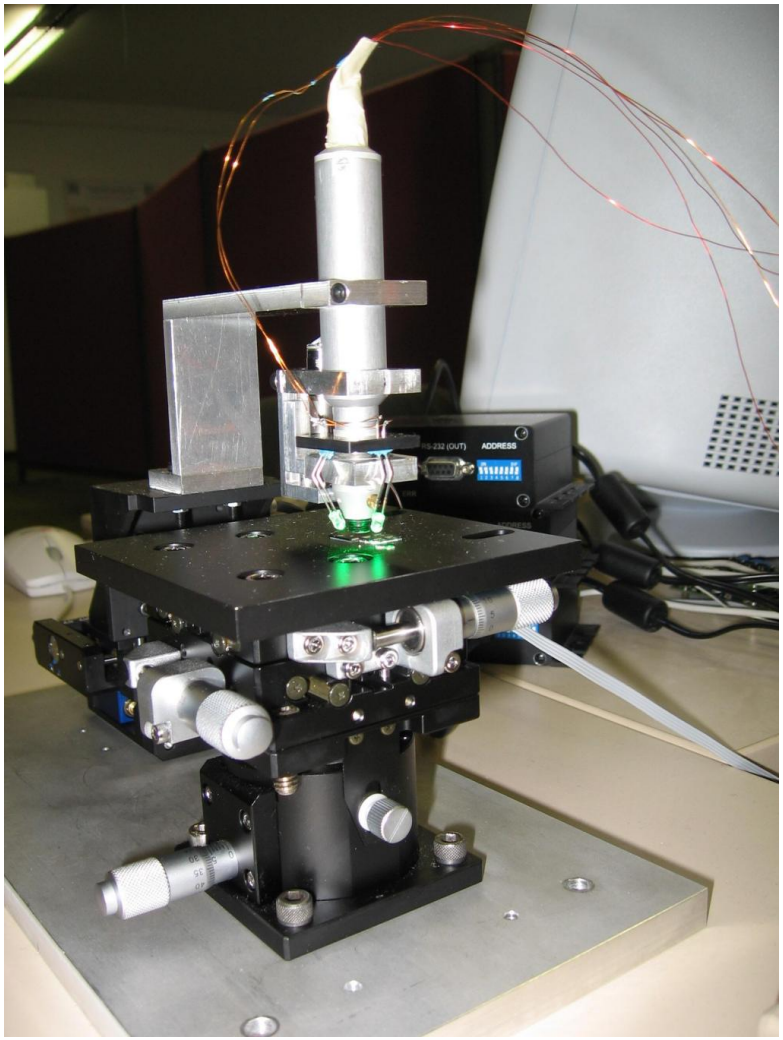


environment

- transmission electron microscope
- digital camera
- piezo controller
- nano indenter

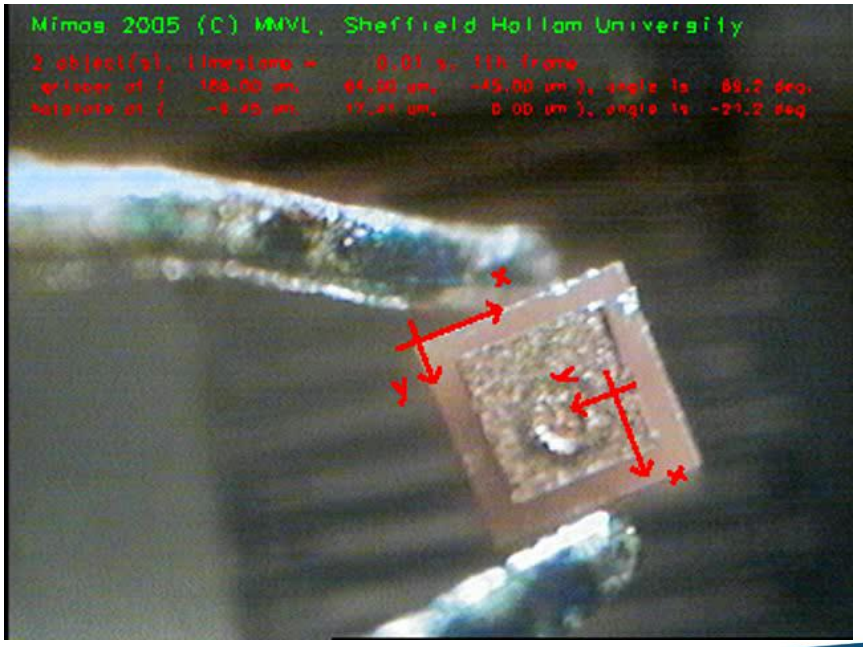


Introduction
MiCRoN Project

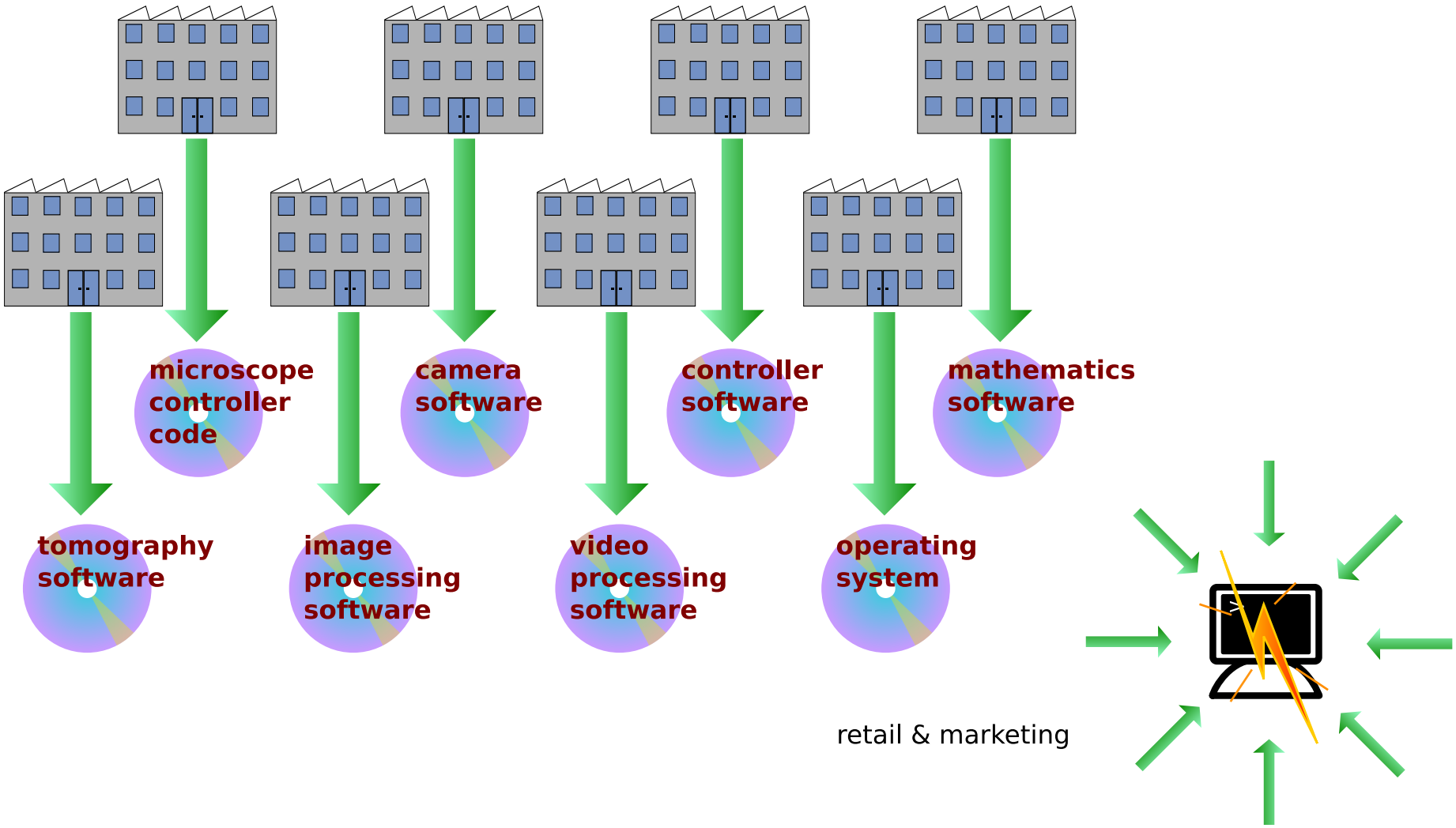


environment

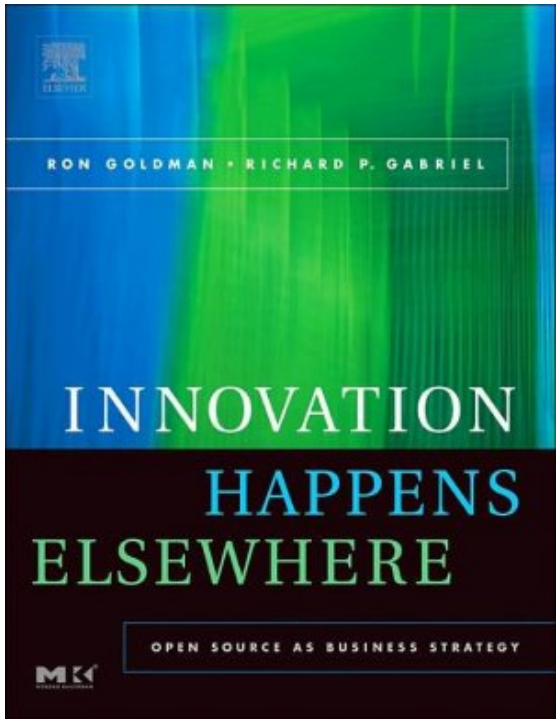
- micro camera
- digital camera
- piezo drives
- gripper

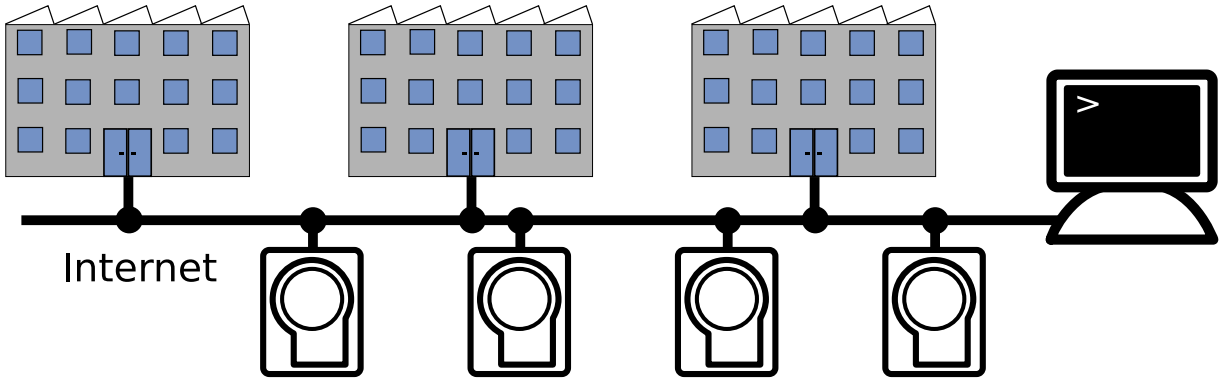


Introduction
Proprietary Business Model



Introduction
Community Development Model





"The market need is greatest for platform products because of the importance of a reliable promise that vendor lock-in will not endanger the survival of products built or modified on the software stack above that platform." - Ron Goldman & Richard P. Gabriel

"It is important to remove as many barriers to collaboration as possible: social, political, and technical." - Ron Goldman & Richard P. Gabriel

Introduction
GPLv3 versus BSD license

four freedoms (Richard Stallman)

1. The freedom to run the program, for any purpose.
2. The freedom to study how the program works, and adapt it to your needs.
3. The freedom to redistribute copies so you can help your neighbor.
4. The freedom to improve the program, and release your improvements to the public, so that the whole community benefits.

respect the freedom of downstream users (Richard Stallman)

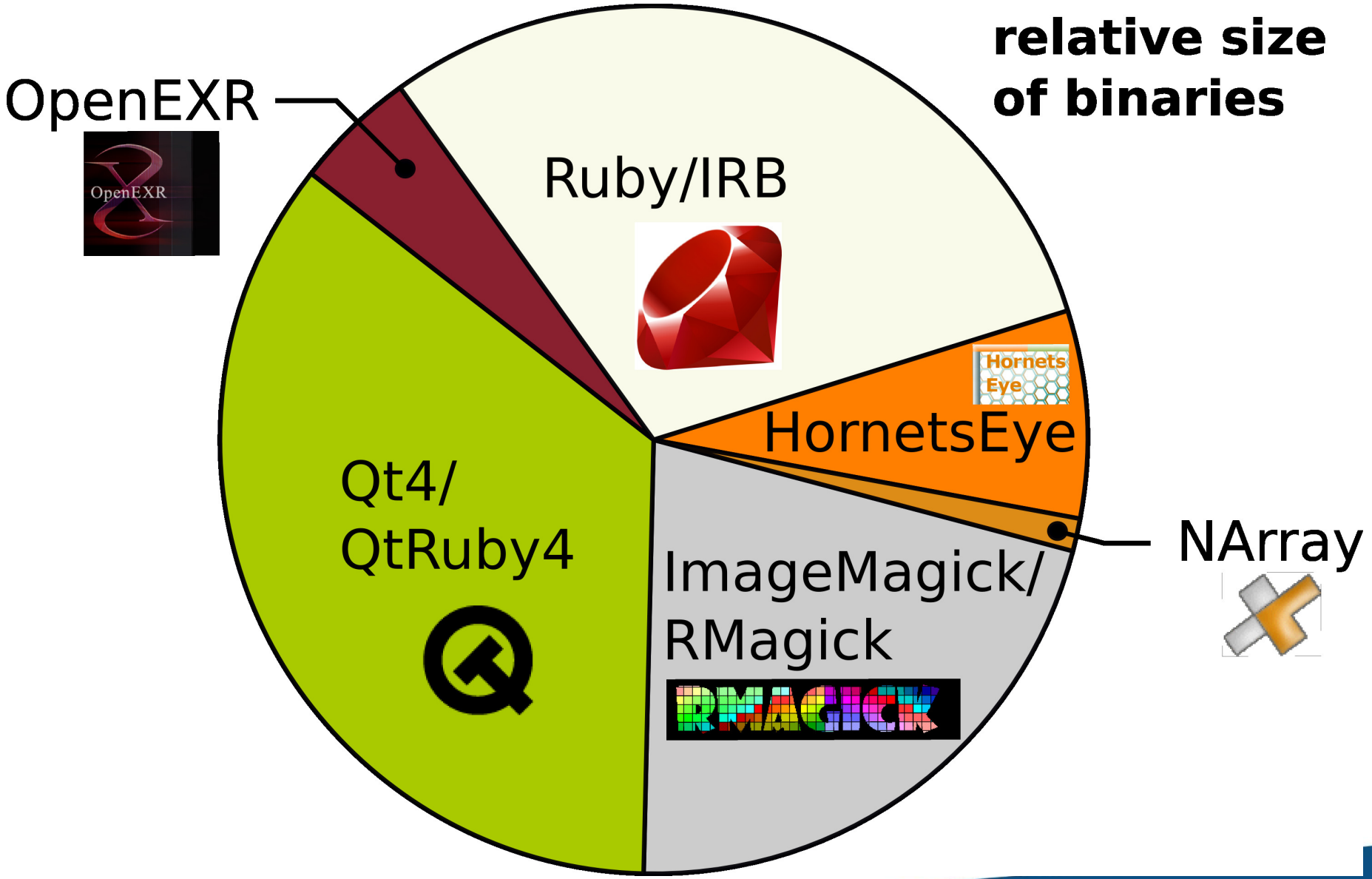
GPL requires derived works to be available under the same license.

covenant not to assert patent claims (Eben Moglen)

GPLv3 deters users of the program from instituting patent ligitation by the threat of withdrawing further rights to use the program.

other (Eben Moglen)

GPLv3 has regulations against DMCA restrictions and tivoization.


relative size
of binaries
OpenEXR
Ruby/IRB
HornetsEye
NArray
Qt4/
QtRuby4
ImageMagick/
RMagick

Ruby Programming Language
Tiobe Index

Position Feb 2008	Position Feb 2007	Delta in Position	Programming Language	Ratings Feb 2008	Delta Feb 2007	Status
1	1	=	Java	21.483%	+2.50%	A
2	2	=	C	14.859%	-1.24%	A
3	5	↑↑	(Visual) Basic	11.604%	+3.24%	A
4	4	=	PHP	9.890%	+1.04%	A
5	3	↓↓	C++	9.274%	-1.49%	A
6	6	=	Perl	6.205%	+0.13%	A
7	7	=	Python	4.763%	+1.20%	A
8	8	=	C#	4.510%	+1.32%	A
9	12	↑↑↑	Delphi	2.798%	+0.72%	A
10	9	↓	JavaScript	2.334%	-0.65%	A
11	10	↓	Ruby	1.862%	-0.67%	A
12	15	↑↑↑	D	1.190%	-0.01%	A
13	13	=	PL/SQL	0.981%	-0.65%	A
14	11	↓↓↓	SAS	0.949%	-1.38%	A
15	18	↑↑↑	COBOL	0.842%	+0.19%	A
16	22	↑↑↑↑↑↑	FoxPro/xBase	0.538%	+0.02%	B
17	19	↑↑	Pascal	0.445%	-0.15%	B
18	44	↑↑↑↑↑↑↑↑↑↑	Lua	0.388%	+0.27%	B
19	17	↓↓	Ada	0.385%	-0.28%	B
20	16	↓↓↓↓	Lisp/Scheme	0.354%	-0.37%	B

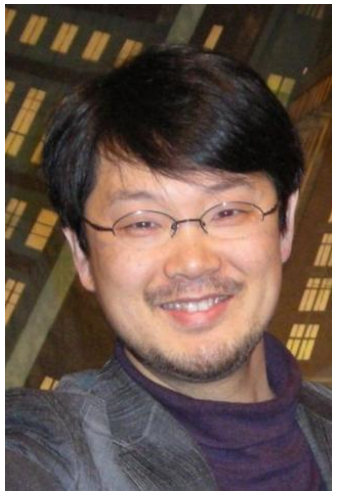
http://www.tiobe.com/

Ruby Programming Language
Speed Comparison

Language	**Implementation**	Time	Relative Speed
C	gcc 4.0.1	0.05 s	1.00×
Java	Java 1.4.2	0.40 s	8.00×
Lua	Lua 5.1	1.50 s	30.00×
Python	Python 2.5.1	9.99 s	199.80×
Perl	Perl 5.8.6	21.75 s	435.00×
Ruby	Ruby 1.8.4	34.31 s	686.18×
Lisp	Emacs Lisp	47.25 s	945.00×

http://www.timestretch.com/FractalBenchmark.html

Ruby Programming Language
Trivial Facts



Ruby

- created by Yukihiro Matsumoto
- released 1995
- inspired by Perl, Python, Smalltalk, Eiffel, Ada, and Lisp
- “pseudo simplicity”: simple syntax ⇔ multi-paradigm language
- highly portable

“Ruby is simple in appearance, but is very complex inside, just like our human body.” - Yukihiro Matsumoto

Ruby on Rails

- web application framework based on Ruby
- created by David Heinemeier Hansson
- released 2004

Ruby Programming Language
Simple Syntax

```
require 'complex'
class Mandelbrot
  def initialize
    for y in -15..15 do
      for x in -50..23 do
        print iterate( x/30.0, y/15.0 )
      end; puts; end
  end
  def iterate( x, y )
    c, z = Complex( x, y ), 0.0
    for i in 0...100
      z = z ** 2 + c
      return ' ' if ( z.abs2 > 4 )
    end
    return '#'
  end
end
Mandelbrot.new
```

Ruby Programming Language
Properties I

- interpreted language (“def” is a statement which defines a method)
- dynamically typed variable: name, value
- everything is an object (no basic types as in C++, Java, ...)
- type inspection

Ruby Programming Language
Properties II

- mark-and-sweep garbage collector
- object orientation, dynamic single-dispatch
- reflection (message passing)
- metaprogramming (overloading methods during runtime)

Ruby Programming Language
Properties III

- graph of context objects (using garbage collector) instead of global namespace and stack
- closures (lambda expression with context)
  - unifying concept for function objects, iterators
  - control structures can be exported as methods
- continuations instead of goto/break
- mixins: unifying concept for namespaces and interfaces
- exception handling: decouple occurrence and handling of error

mbrot.cc

```
// g++ -shared -fPIC -I/usr/lib/ruby/1.8/x86_64-linux -o mbrot.so mbrot.cc
#include <complex>
#include <ruby.h>
VALUE iterate( VALUE rbSelf, VALUE rbX, VALUE rbY )
{
  std::complex< double > c( NUM2DBL( rbX ), NUM2DBL( rbY ) ), z( 0, 0 );
  for ( int i=0; i<100; i++ ) {
    z = z * z + c;
    if ( std::norm( z ) > 4 ) return rb_str_new2( " " );
  };
  return rb_str_new2( "#" );
}
extern "C" void Init_mbrot(void) {
  VALUE cMandelbrot = rb_define_class( "Mandelbrot", rb_cObject );
  rb_define_method( cMandelbrot, "iterate", RUBY_METHOD_FUNC( iterate ), 2 );
  rb_require( "mbrot_ext.rb" );
}
```

Ruby Programming Language
Ruby Extensions II

mbrot_ext.rb

```
class Mandelbrot
  def initialize
    for y in -15..15 do
      for x in -50..23 do
        print iterate( x/30.0, y/15.0 )
      end; puts; end
  end
end
```

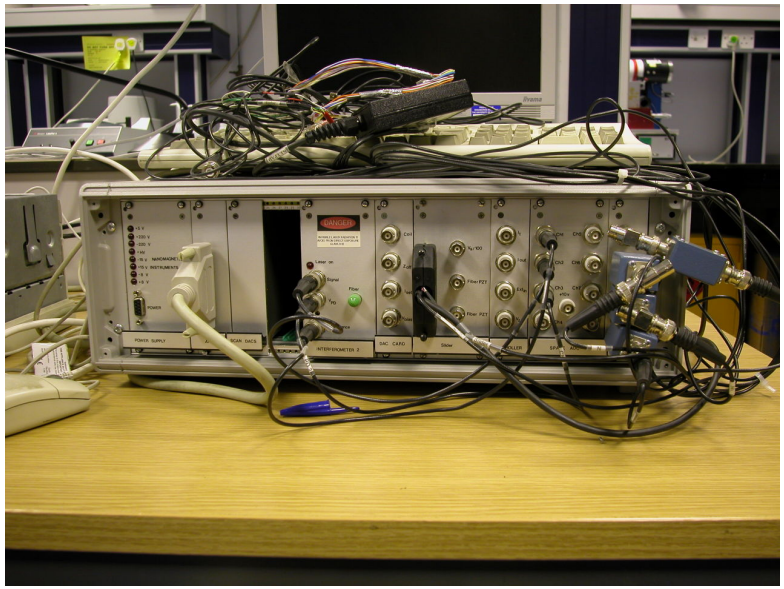
mandelbrot2.rb

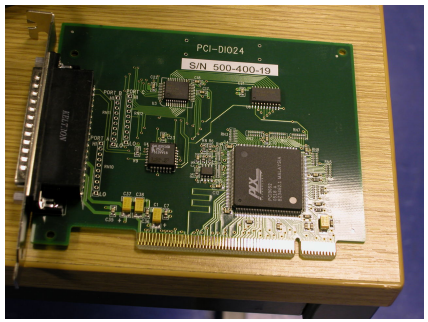
```
require 'mbrot'
Mandelbrot.new
```

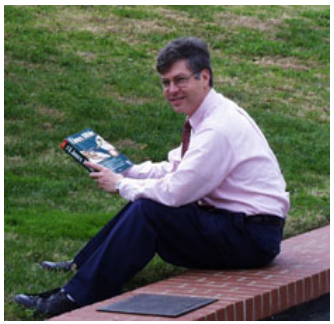
Device Integration
JEOL Transmission Electron Microscope

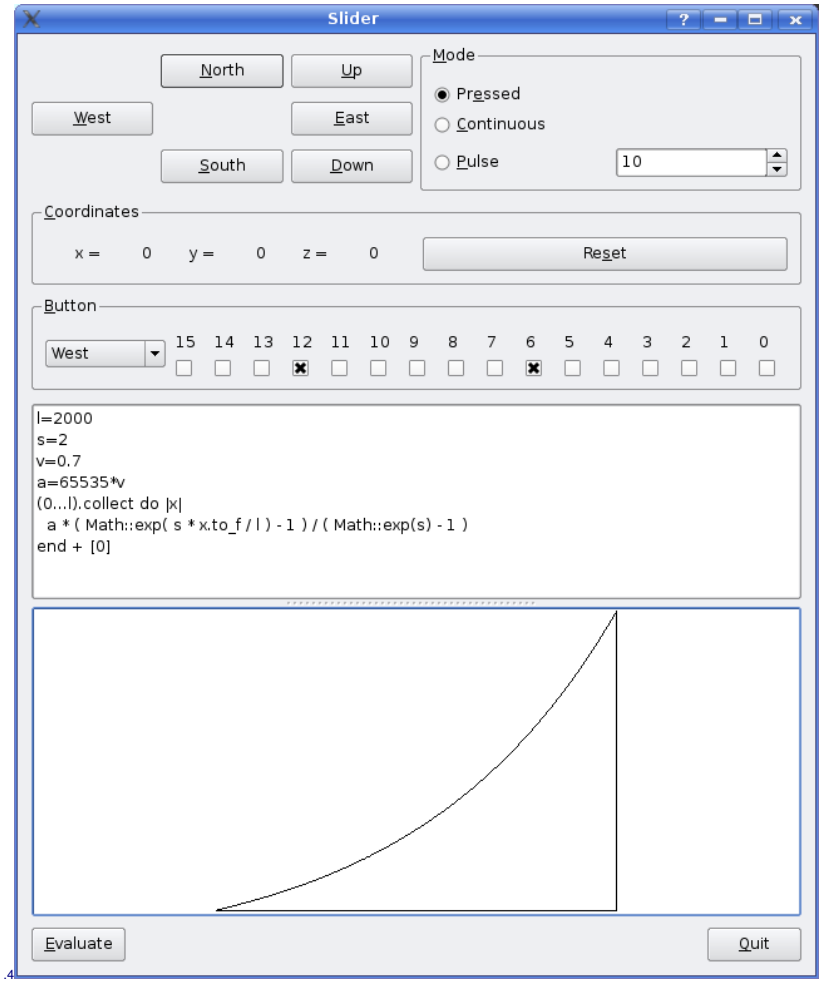
Serial Interface, ECL

Device Integration
Nanomagnetics Instruments Ltd



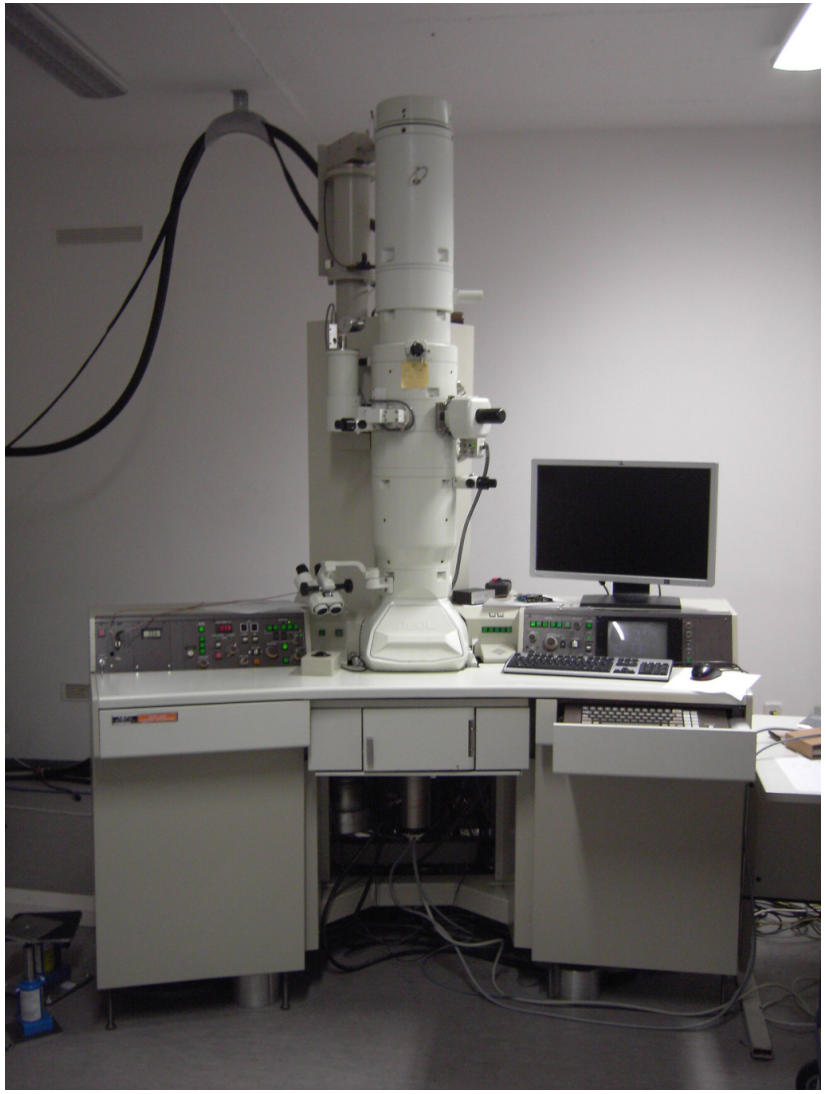


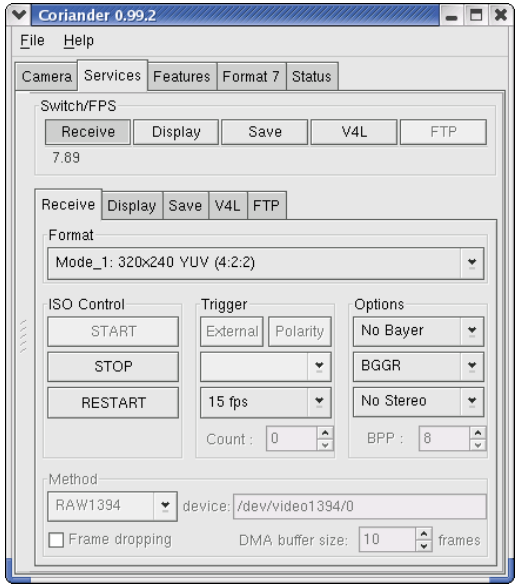




PCI-DIO24 driver by Warren Jasper

Device Integration
TVIPS Firewire Digital Camera

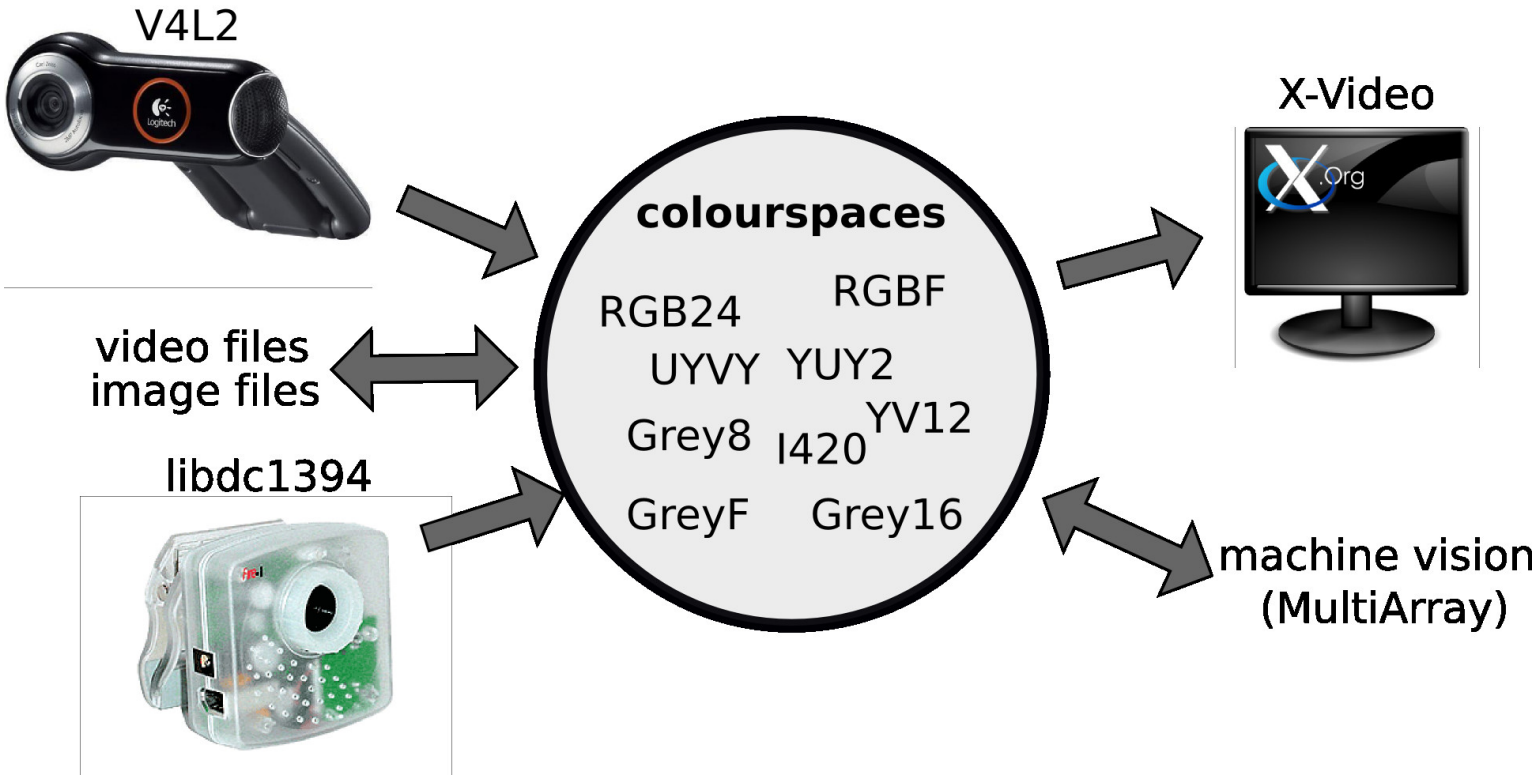




- IEEE1394 electronic interface
- IIDC/DCAM protocol

libdc1394 and coriander by Damien Douxchamps

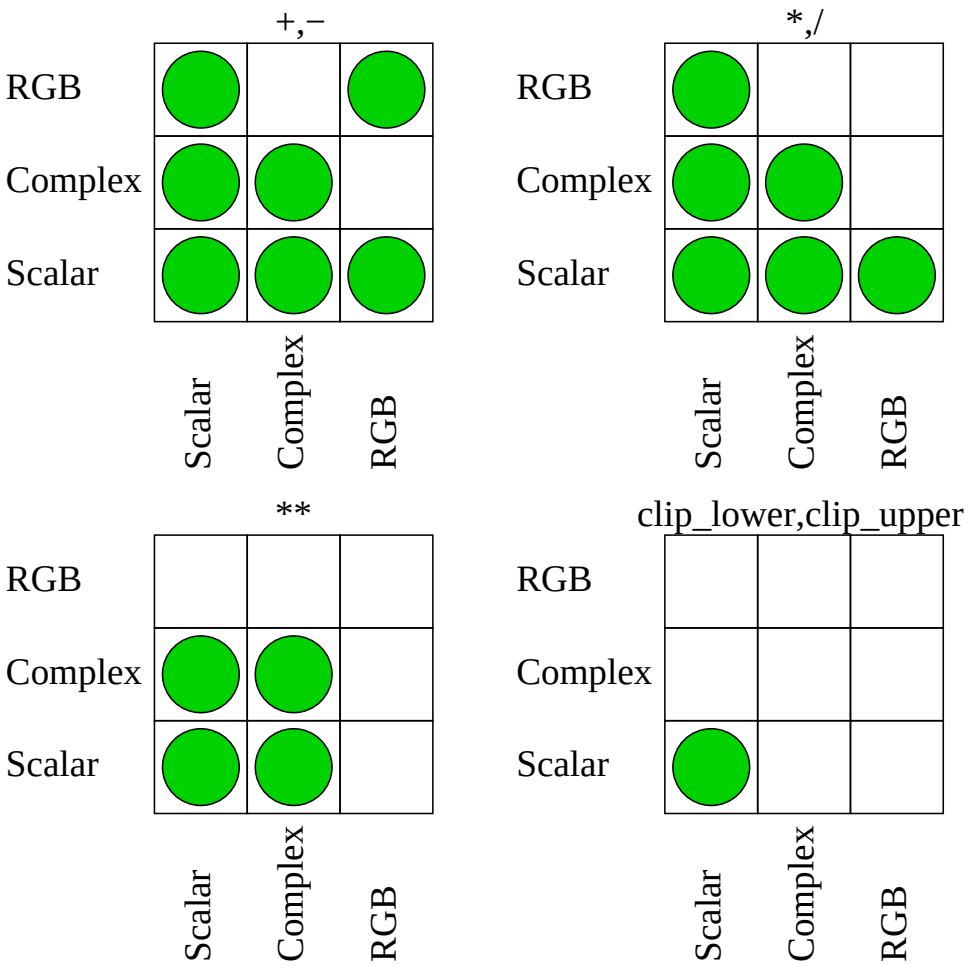
Machine Vision
Colourspace Conversions



$$\begin{pmatrix} Y \\ C_b \\ C_r \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.500 \\ 0.500 & -0.418688 & -0.081312 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 0 \\ 128 \\ 128 \end{pmatrix}$$

also see: `http://fourcc.org/`

Machine Vision
Array Operations

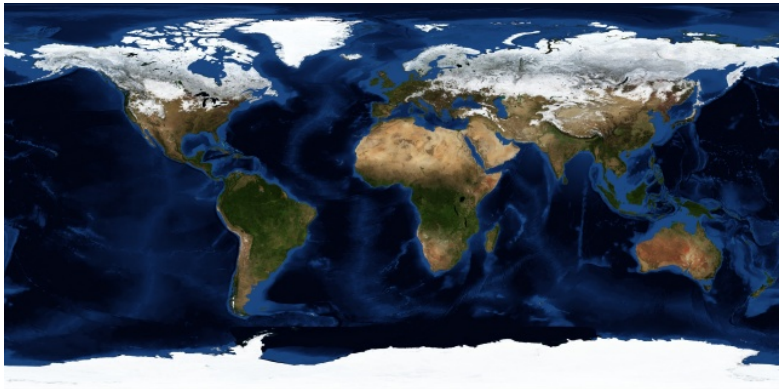


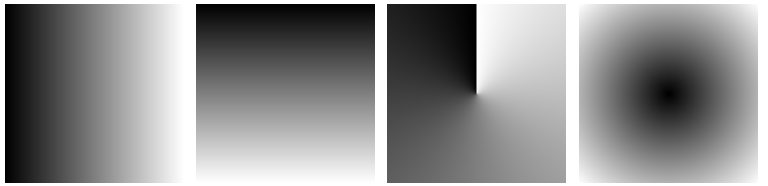
Computing “img/2”

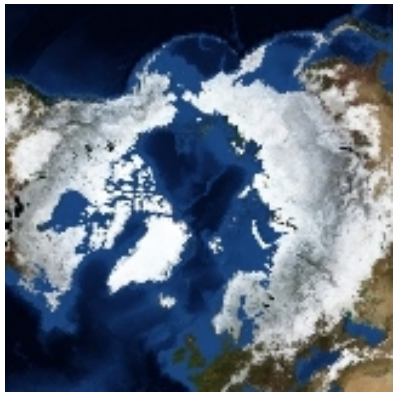
1. Message “/” with parameter “2” is send to “img”
2. Message is dispatched to class “MultiArray”
3. Method “scalarright_div_ubyte_ubytergb” is checked for
4. Native implementation is invoked

Machine Vision
Warps

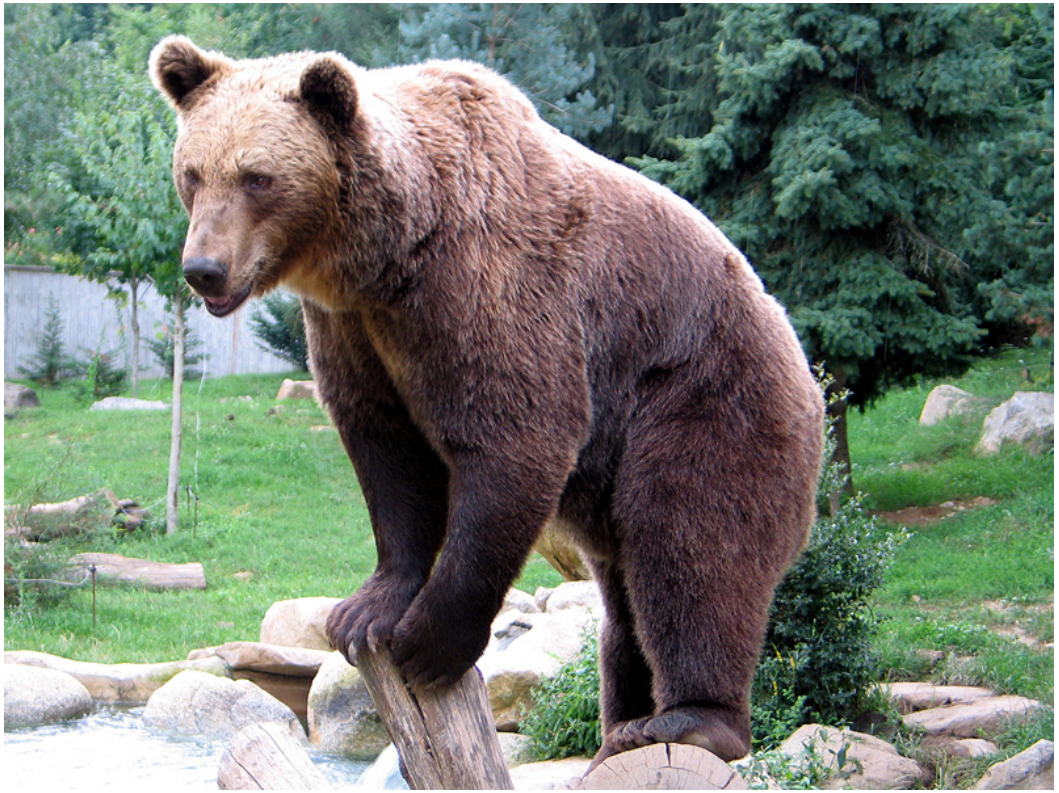
```
w, h = img.shape[0], img.shape[1] / 2
v = MultiArray.new( MultiArray::LINT,
                    h, h, 2 )
x = xramp( h, h )
y = yramp( h, h )
c = 0.5 * h
v[ 0...h, 0...h, 0 ] =
  ( ( ( x - c ).atan2( y - c ) / PI + 1 ) *
    w / 2 - 0.5 )
v[ 0...h, 0...h, 1 ] =
  ( ( x - c ) ** 2 + ( y - c ) ** 2 ).sqrt
result = img.warp_clipped( v )
```



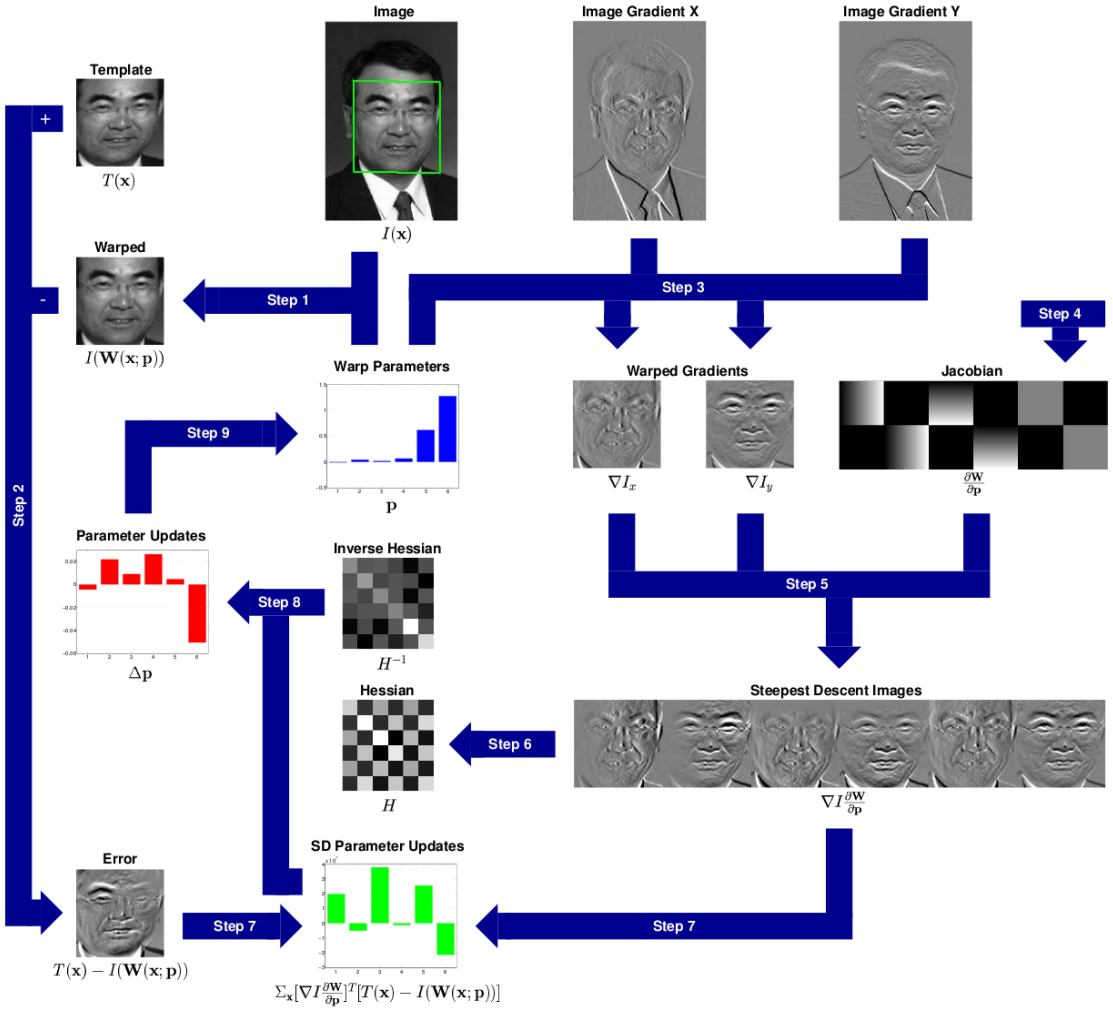




Machine Vision
Warps



Machine Vision
CMU project "Lucas-Kanade 20 Years On"



http://www.ri.cmu.edu/projects/project_515.html

Machine Vision
Lucas-Kanade Tracker

Initialisation

```
p = Vector[ xshift, yshift, rotation ]
x, y = xramp( *tpl.shape ), yramp( *tpl.shape )
gx = tpl.gauss_gradient_x( sigma )
gy = tpl.gauss_gradient_y( sigma )
c = Matrix[ [ 1, 0 ], [ 0, 1 ], [ -y, x ] ] * Vector[ gx, gy ]
hs = ( c * c.covector ).collect { |e| e.sum }
```

Tracking Iteration

```
field = MultiArray.new( MultiArray::LINT, w, h, 2 )
field[ 0...w, 0...h, 0 ] = x * cos( p[2] ) - y * sin( p[2] ) + p[0]
field[ 0...w, 0...h, 1 ] = x * sin( p[2] ) + y * cos( p[2] ) + p[1]
diff = img.warp_clipped( field ).to_type( MultiArray::SFLOAT ) - tpl
s = c.collect { |e| ( e * diff ).sum }
d = hs.inverse * s
p += Matrix[ [  cos(p[2]), -sin(p[2]), 0 ],
             [  sin(p[2]),  cos(p[2]), 0 ],
             [          0,          0, 1 ] ] * d
```

Conclusion

conclusion

- native implementation in C++, Ruby as glue-code
- development platform for microscopy software and general purpose machine vision
- used for medical imaging, industrial inspection, measuring abrasion

future work

- feature-based object recognition algorithm
- GPU acceleration, parallel processing
- support typical workflow on a microscope

web

http://www.wedesoft.demon.co.uk/hornetseye-api/
http://rubyforge.org/projects/hornetseye/
http://sourceforge.net/projects/hornetseye/