Compiling MATLAB

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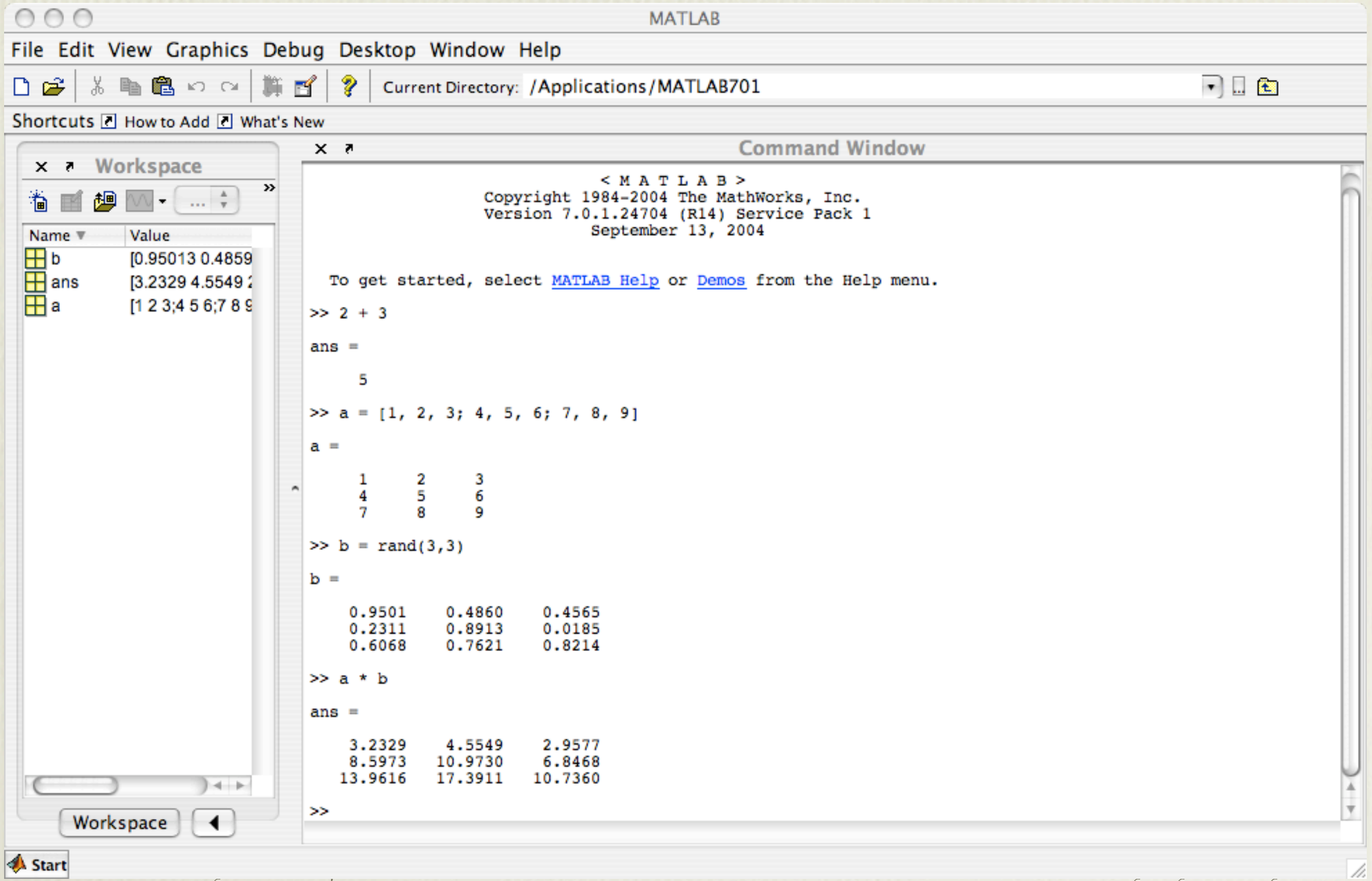
Overview

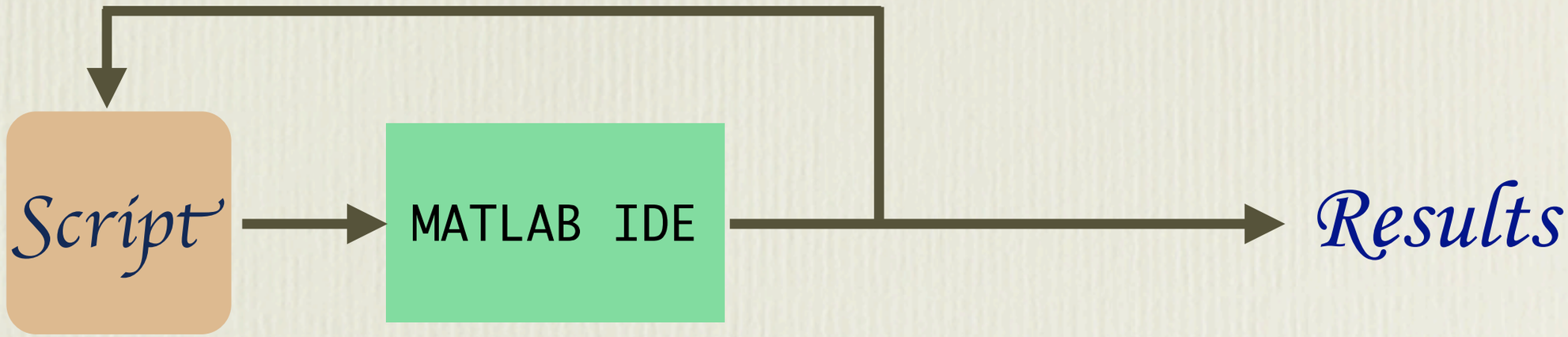
MATLAB IDE


MATLAB
File Edit View Graphics Debug Desktop Window Help
Current Directory: /Applications/MATLAB701
Shortcuts How to Add What's New
Workspace
Name Value
b [0.95013 0.4859
ans [3.2329 4.5549 2
a [1 2 3;4 5 6;7 8 9
Workspace
Command Window
< M A T L A B >
Copyright 1984-2004 The MathWorks, Inc.
Version 7.0.1.24704 (R14) Service Pack 1
September 13, 2004
To get started, select MATLAB Help or Demos from the Help menu.
>> 2 + 3
ans =
5
>> a = [1, 2, 3; 4, 5, 6; 7, 8, 9]
a =
1 2 3
4 5 6
7 8 9
>> b = rand(3,3)
b =
0.9501 0.4860 0.4565
0.2311 0.8913 0.0185
0.6068 0.7621 0.8214
>> a * b
ans =
3.2329 4.5549 2.9577
8.5973 10.9730 6.8468
13.9616 17.3911 10.7360
>>
Start

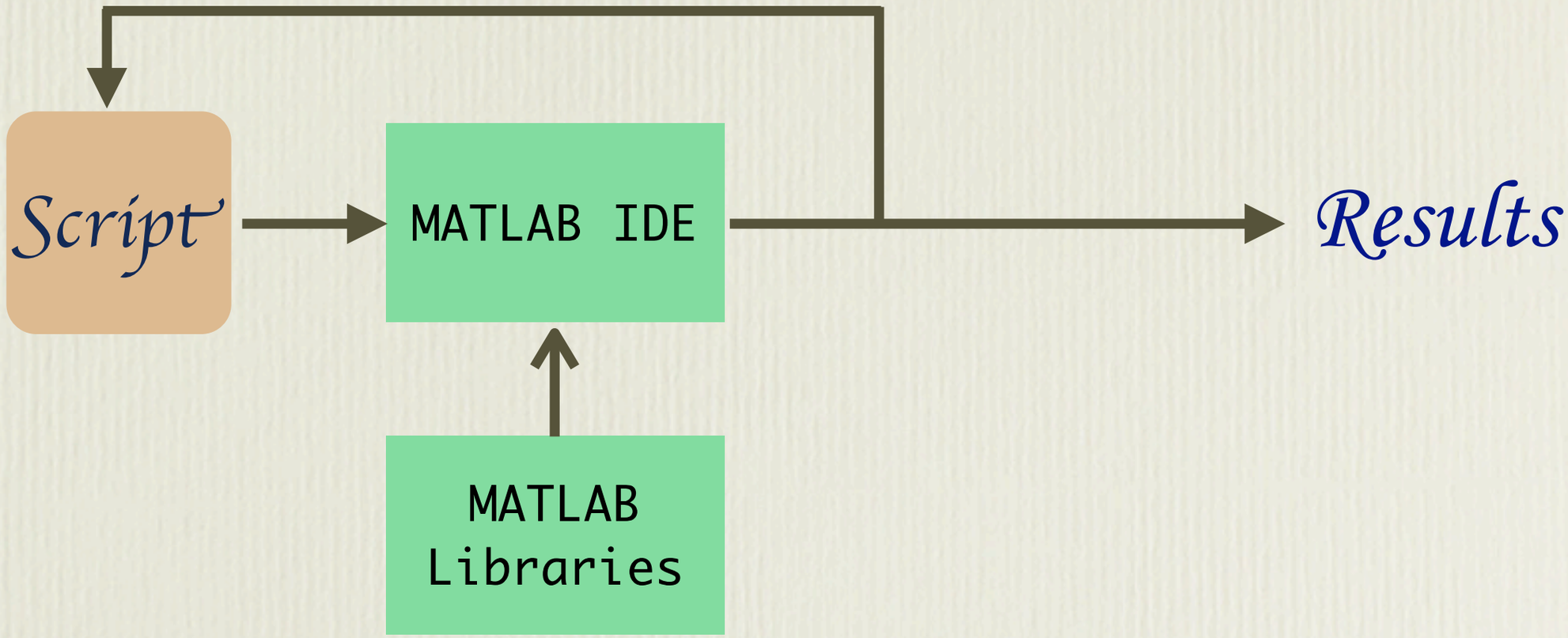
Why MATLAB?

- Ease of Use
  - writing
  - debugging
  - maintaining

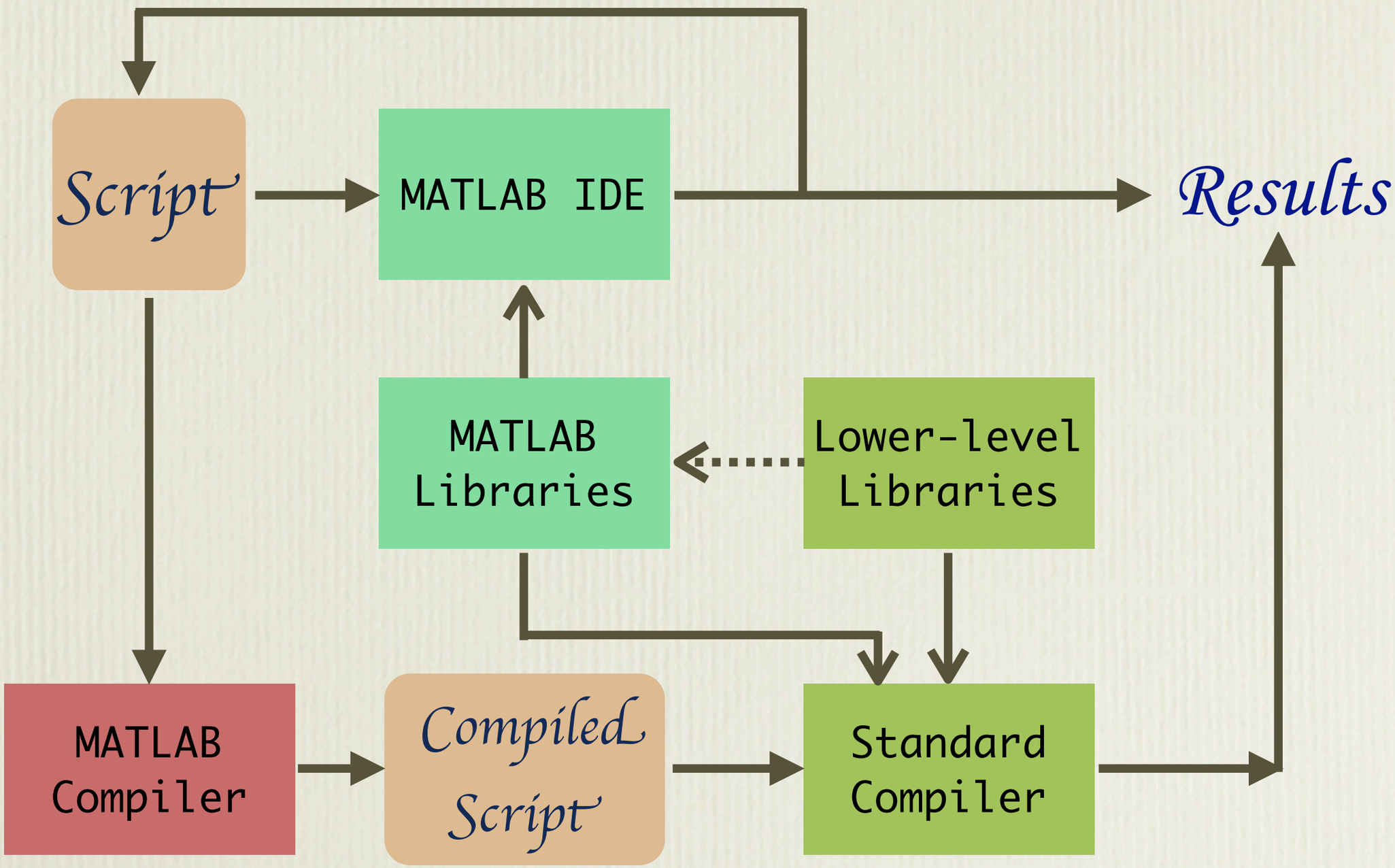
Operating Model



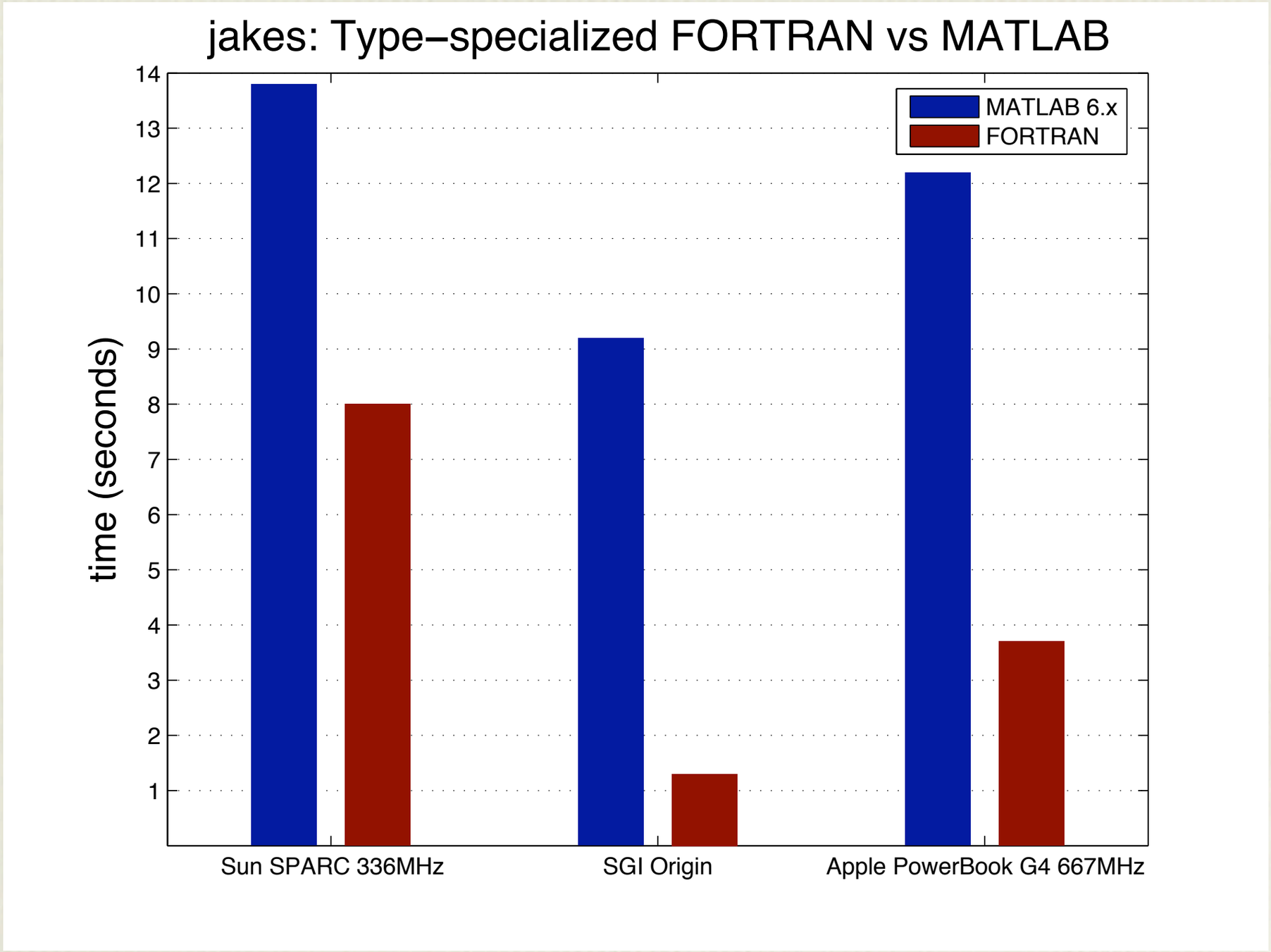
Operating Model



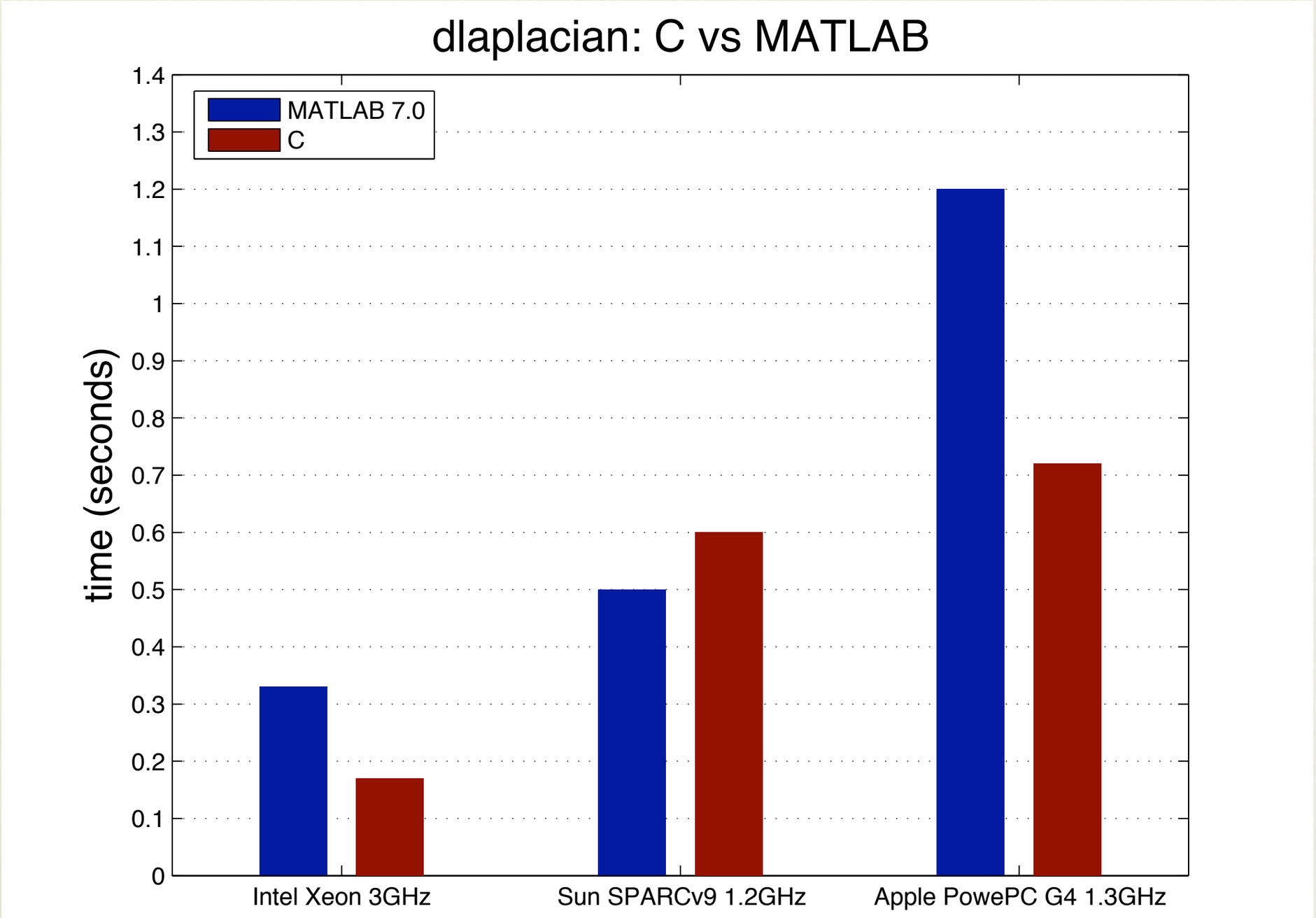
Operating Model



Lowering for Performance



Lowering for Performance (II)



Compiling and Lowering

- Lowering as the first step
  - enabled by type inference
- High-level operators enable contextual analysis
  - standard black-box technique is inadequate
- Compiler awareness of additional properties
  - annotations by library developers
  - automatic discovery

Optimizing Libraries

```
for ii = 1:200
  ...
  chan = jakes_mp1 (16500, 160, ii, num_paths);
  ...
  for snr = 2:2:20
     ...
     [s,x,ci,h,L,a,y,n0] = newcodesig (NO, I, num_paths, M, snr, chan, sig_pow_paths);
     [o1,d1,d2,d3,mf,m] = codesdhd (y, a, h, NO, Tm, Bd, M, B, n0);
     ...
  end
  ...
end
```

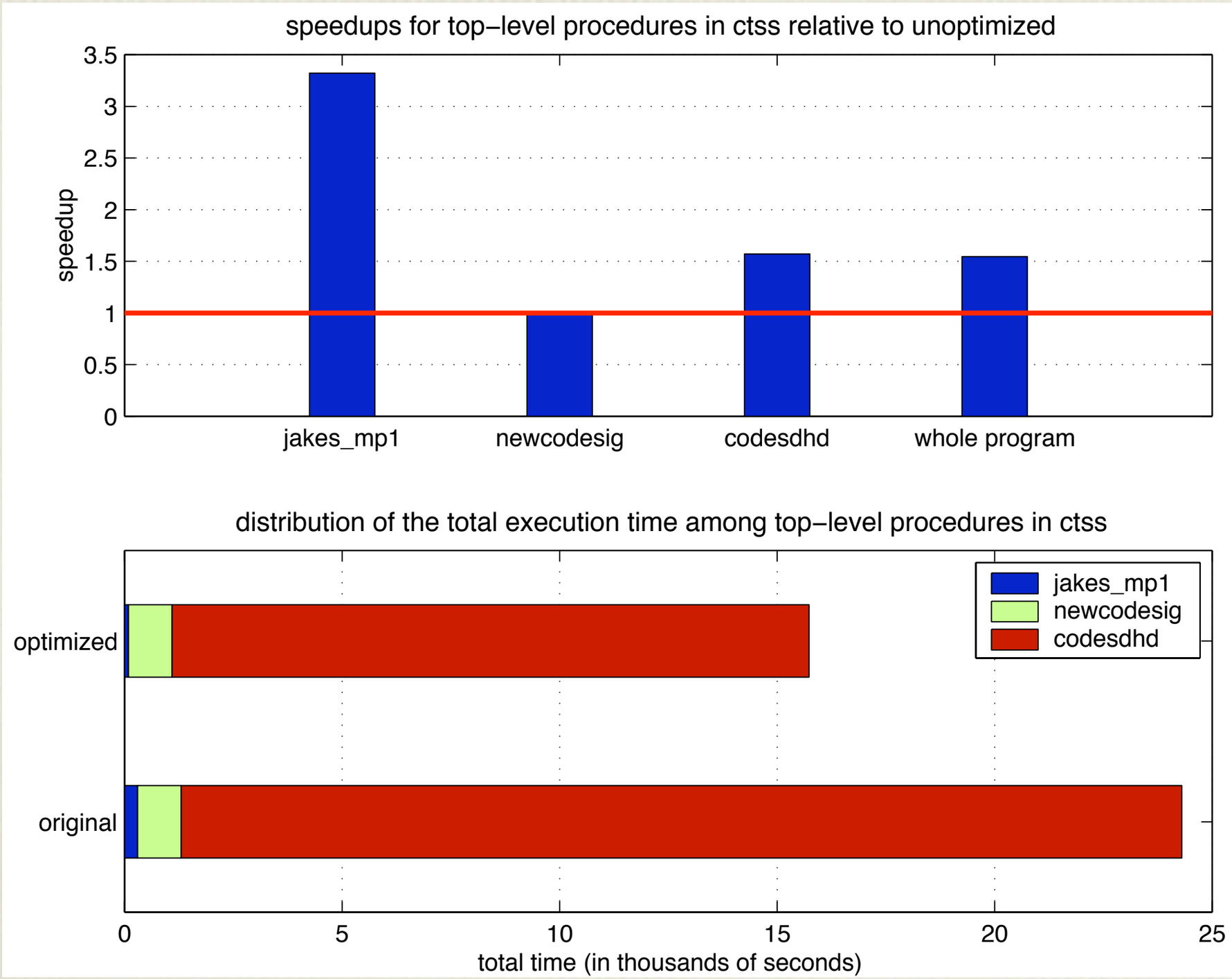
Optimizing Libraries

```
tmp = jakes_mp1_init (16500, 160, num_paths);
for ii = 1:200
  ...
  chan = jakes_mp1_iter (ii, tmp);
  ...
  ...
  for snr = 2:2:20
     ...
     [s,x,ci,h,L,a,y,n0] = newcodesig (NO, I, num_paths, M, snr, chan, sig_pow_paths);
     [o1,d1,d2,d3,mf,m] = codesdhd (y, a, h, NO, Tm, Bd, M, B, n0);
     ...
  end
  ...
end
```

Optimizing Libraries

```
tmp1 = jakes_mp1_init (16500, 160, num_paths);
[h,L,tmp2] = newcodesig_init_1 (NO, I, num_paths, M, sig_pow_paths);
[m, tmp3] = codesdhd_init (a, h, NO, Tm, Bd, M);
for ii = 1:200
  ...
  chan = jakes_mp1_iter (ii, tmp1);
  ...
  ...
  [a, tmp4] = newcodesig_init_2 (chan, tmp2);
  for snr = 2:2:20
    ...
    [s,x,ci,y,n0] = newcodesig_iter (snr, tmp4);
    ...
    [o1,d1,d2,d3,m] = codesdhd_iter (y, tmp3);
    ...
  end
  ...
end
```

Procedure Strength Reduction



Library Identities

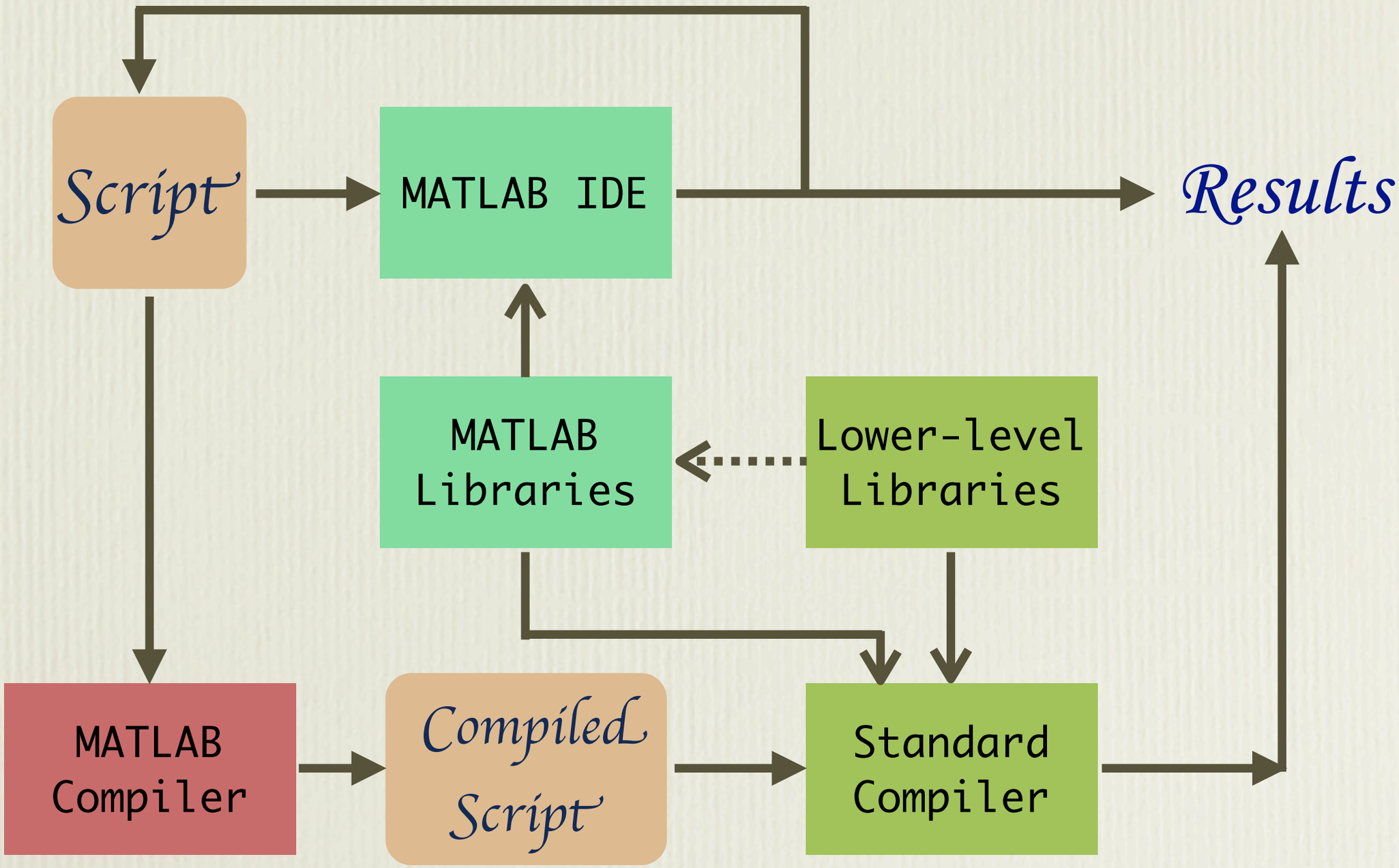
```
function [s, r, j_hist] = min_sr1 (xt, h, m, alpha)
  ...
  while ~ok
     ...
     invsr = change_form_inv (sr0, h, m, low_rp);
     big_f = change_form (xt-invsr, h, m);
     ...
     while iter_s < 3*m
        ...
        invdr0 = change_form_inv (sr0, h, m, low_rp);
        sssdr = change_form (invdr0, h, m);
        ...
     end
     ...
     invsr = change_form_inv (sr0, h, m, low_rp);
     big_f = change_form (xt-invsr, h, m);
     ...
     while iter_r < n1*n2
        ...
        invdr0 = change_form_inv (sr0, h, m, low_rp);
        sssdr = change_form (invdr0, h, m);
        ...
     end
      ...
end
```

Lessons

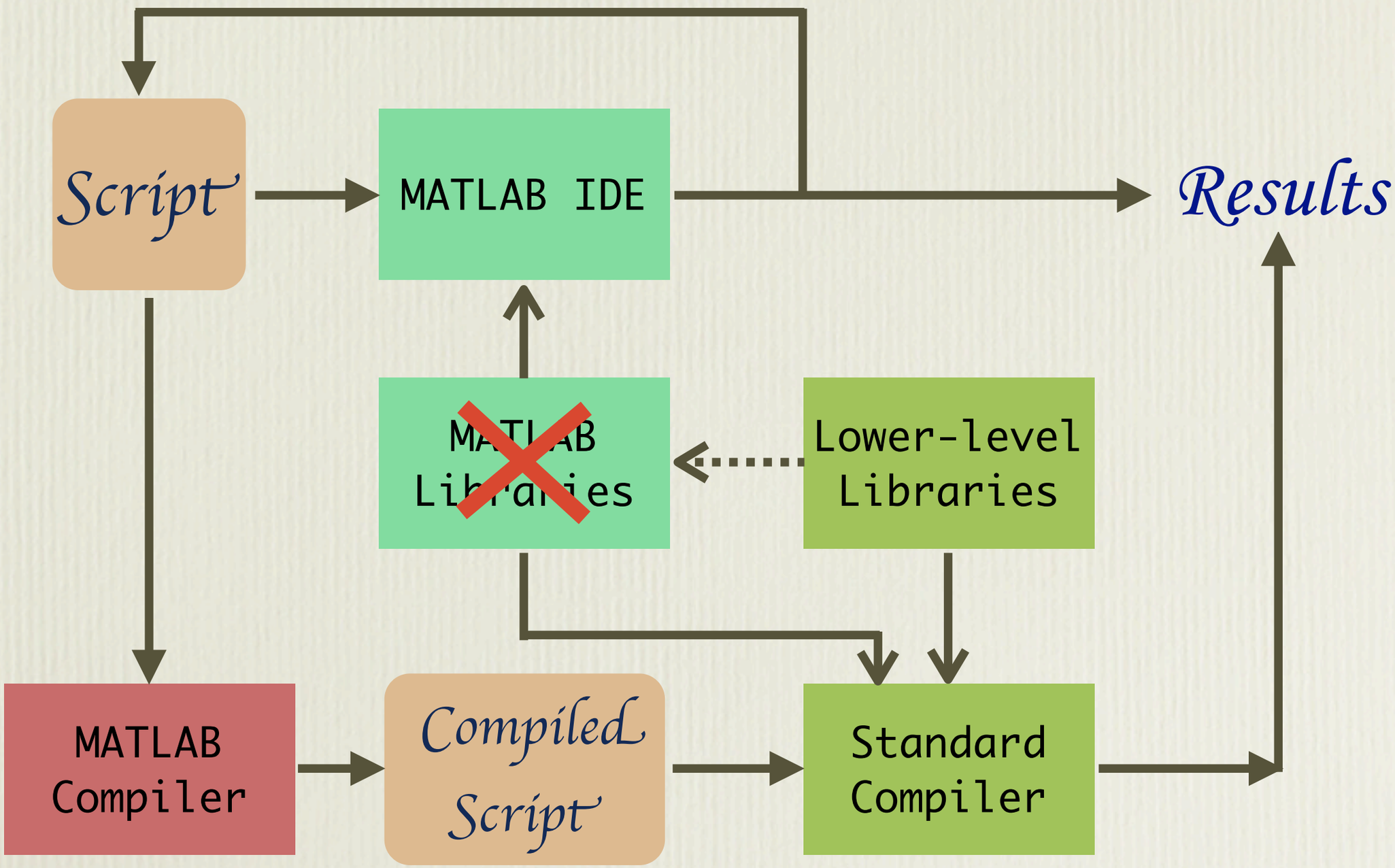
Two Types of Lessons

- Computer science
  - compilation (top-down vs bottom-up)
  - type inference strategy
- Software engineering
  - high-level compiler development

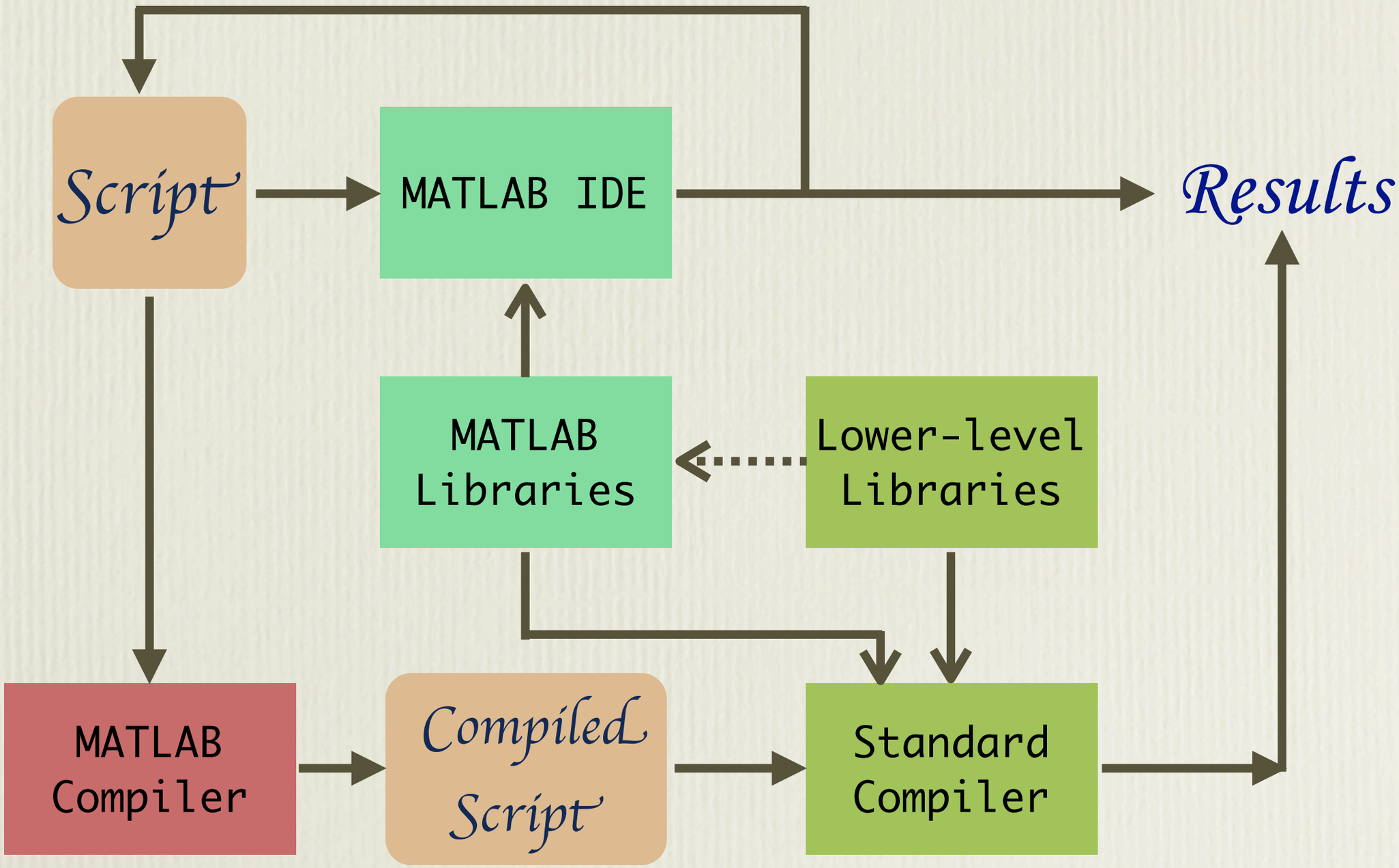
Compilation Strategy



Compilation Strategy



Compilation Strategy



Type Inference

Type = (intrinsic type, array size)

intrinsic type = integer, real, complex, etc.

array size = <d_1, d_2, d_3, ...>

- Heavily overloaded operators
  - backward propagation of very limited use
- Rich array subscripting semantics
  - arrays as subscripts
  - dynamically resizable arrays
  - "end" keyword

Subscripting in MATLAB

- Standard subscripting
  - A(10), A(j+1, i), A(B(i))
  - A(1:100)
- MATLAB subscripts: above plus ...
  - A(B), A(B,C) where B and C are arrays
  - A(end), A(end+2)
  - A(x, y) where A is a 3-D array

Type Inference: Solution

- Program transformation-based strategy
  1. Expose type disambiguation in source language
  2. Evaluate types through concrete interpretation
- Advantages
  - Availability of the power of MATLAB

```
z(1:2:end, 1:2:end, 1:2:end) = zn;
z = dlaplacian(z, [1,1/2,1/4,1/8]);
z = z(1:end-2, 1:end-2, 1:end-2);
```

```
a_0 = ParaM_compute_end_val(ParaM_size_z, 3, 1);
b_0 = ParaM_compute_end_val(ParaM_size_z, 3, 2);
c_0 = ParaM_compute_end_val(ParaM_size_z, 3, 3);
z(1:2:a_0, 1:2:b_0, 1:2:c_0) = zn;
d_0 = 1 / 2;
e_0 = 1 / 4;
f_0 = 1 / 8;
z = dlaplacian(z, [1, d_0, e_0, f_0]);
h_0 = g_0 - 2;
g_0 = ParaM_compute_end_val(ParaM_size_z, 3, 1);
j_0 = i_0 - 2;
i_0 = ParaM_compute_end_val(ParaM_size_z, 3, 2);
l_0 = k_0 - 2;
k_0 = ParaM_compute_end_val(ParaM_size_z, 3, 3);
z = z(1:h_0, 1:j_0, 1:l_0);
```

Type Inference: Solution

- Program transformation-based strategy
  1. expose type disambiguation in source language
  2. evaluate types through concrete interpretation
- Advantages
  - availability of the power of MATLAB
  - continuous spectrum of possibilities

Engineering

- C++ as the language of choice
  - wide availability
  - "portable"
  - modular (?)
- A "high-level" language for writing compilers
  - Stratego (University of Utrecht, the Netherlands)

Status and Plan

Compiler Implementation

- Moved infrastructure to Stratego
  - shared with Ohio-State, Rice, UCSB
- Robust handling of difficult subscripting cases
  - exception: cell subscripting
- Type inference
  - exception: cells, structs

Plan: Compiling MATLAB

- Implement the hybrid compilation strategy
- Identify libraries
  - C++ generics or C / Fortran
    - study undertaken by Youngsang to evaluate the performance tradeoffs
  - Octave, Andrew Lumsdaine's concepts-based
- Implement "high-level" transformations
  - annotation language

Plan: Parallelizing MATLAB

- Model: distributed data
  - distributed data ⇒ parallel operations
  - replicated data ⇒ sequential operations
- Implementation
  - dependence analysis
  - cost-based analysis of data distributions
  - library development

Thank You