Optimizing Strategies for Telescoping Languages: Procedure Strength Reduction and Procedure Vectorization

presentation by

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joint work with

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Motivation

- Shortage of programmers
  - increasing application demands
  - rapidly changing architectures
  - need programmers for scientific applications too

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  - increasing application demands
  - rapidly changing architectures
  - need programmers for scientific applications too
- High Performance programming is hard
  - increasingly a specialized activity
  - more complex architectures
  - more high performance applications

One Solution

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  - language should be high level
  - should provide domain−specific features
  - must have effective and efficient compilers

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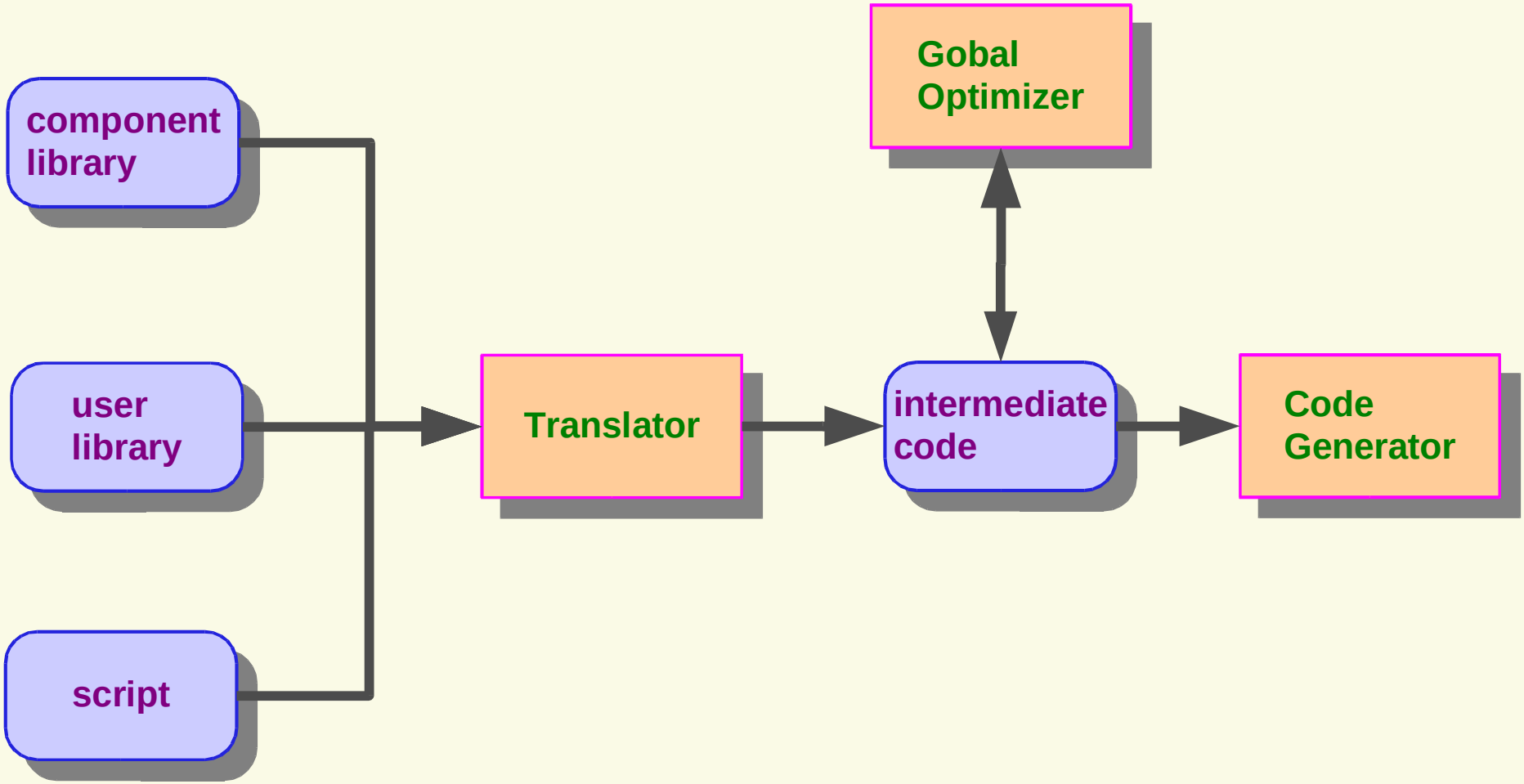
  - language should be high level
  - should provide domain−specific features
  - must have effective and efficient compilers
- Scripting systems like MATLAB exist
  - very popular with end−users
  - lack effective and efficient compilers

Existing Approaches:

based on transforming to lower level languages



Existing Approaches:

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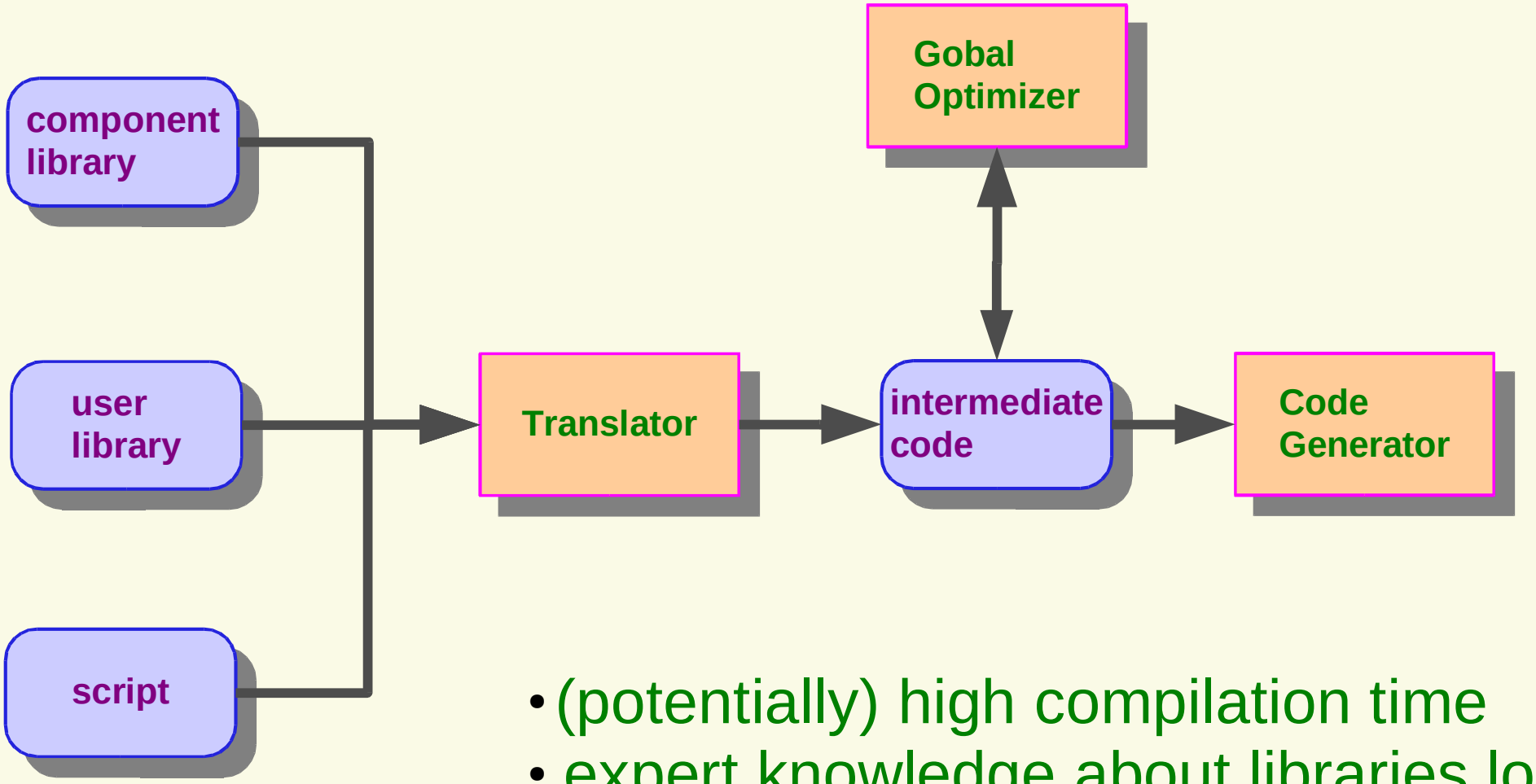
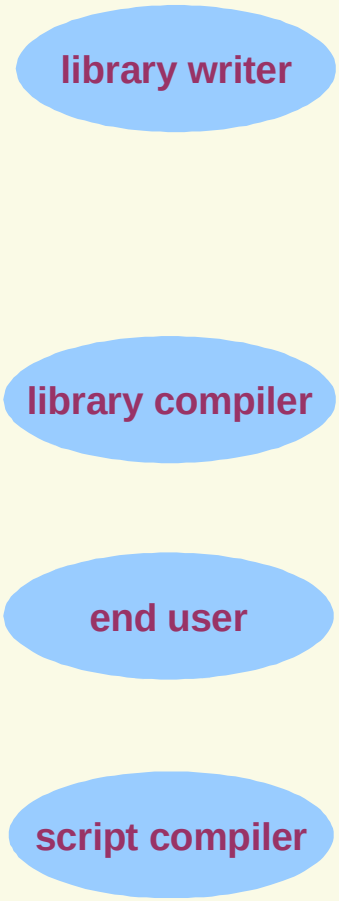


- (potentially) high compilation time
- expert knowledge about libraries lost

Telescoping Languages Approach



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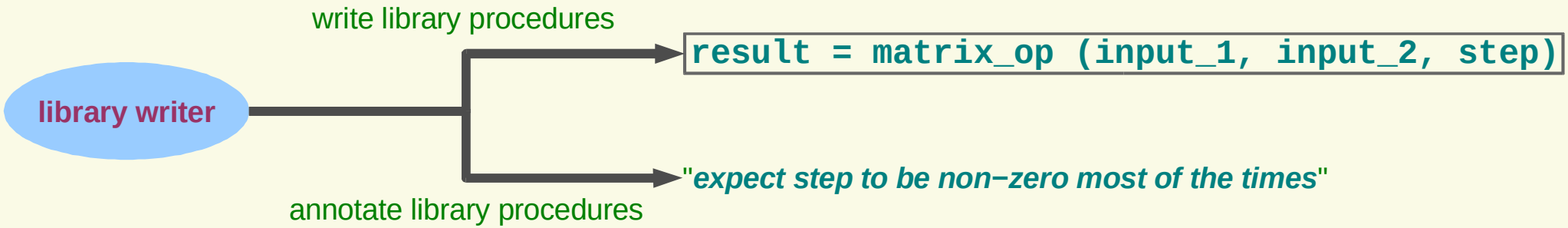
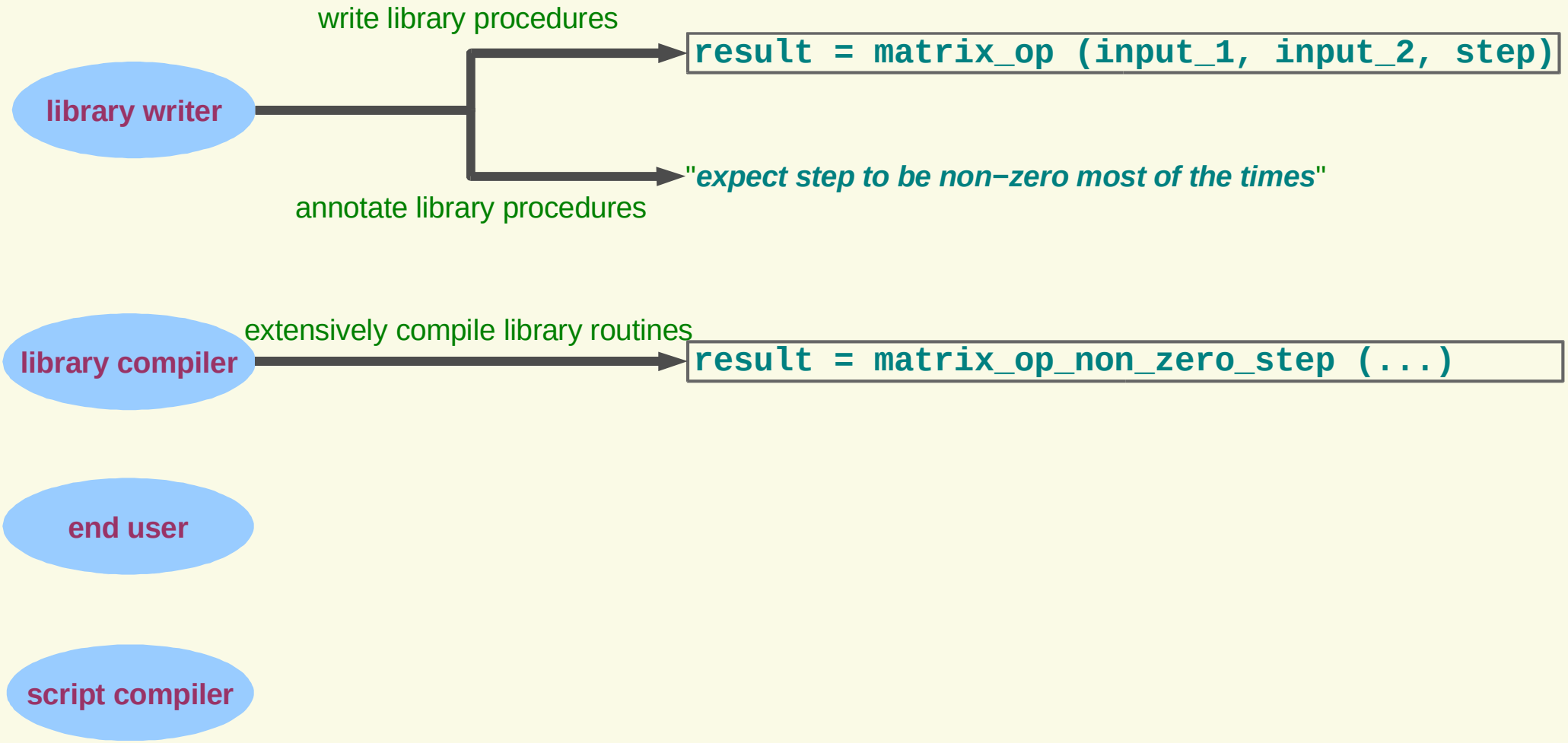


library compiler

end user

script compiler

Telescoping Languages Approach



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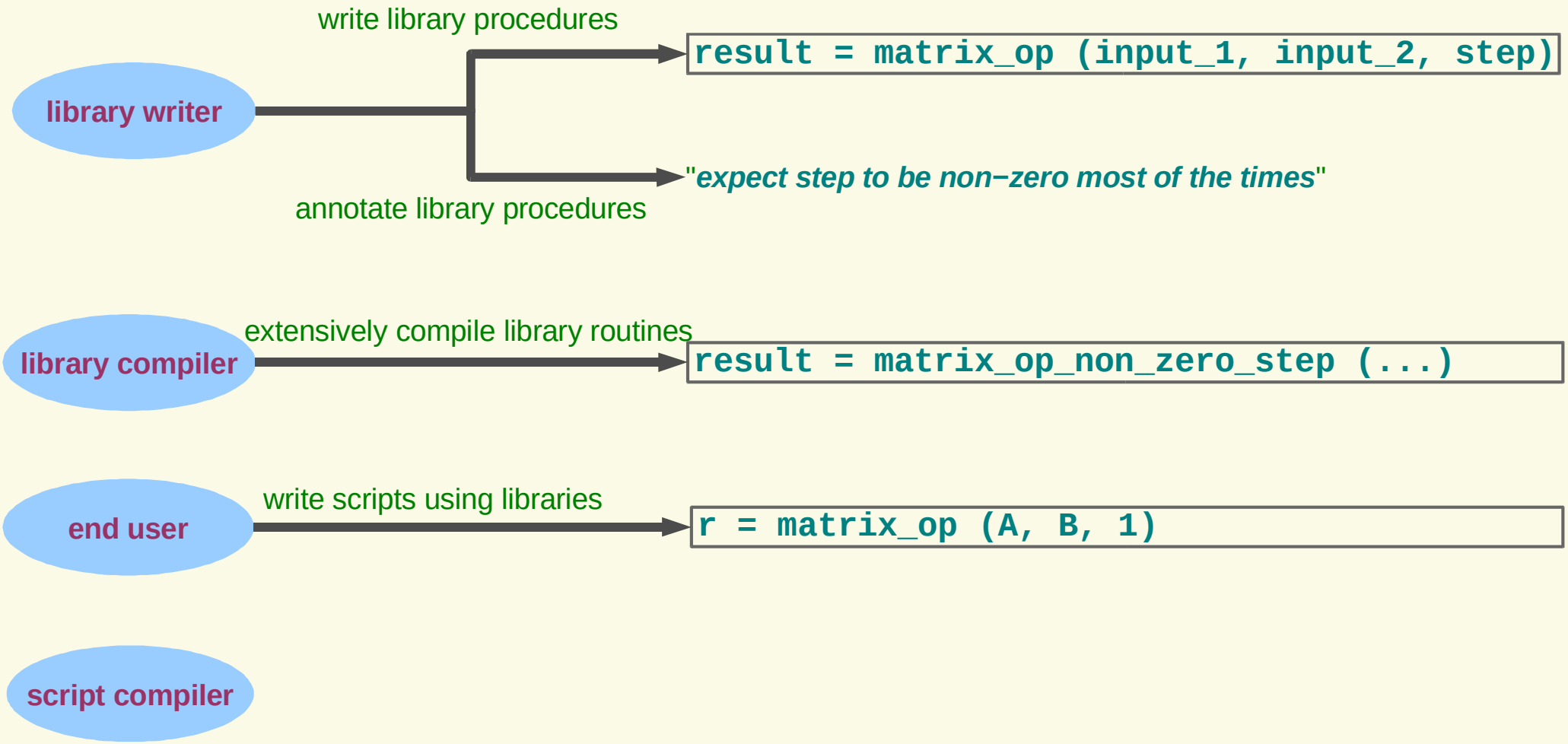

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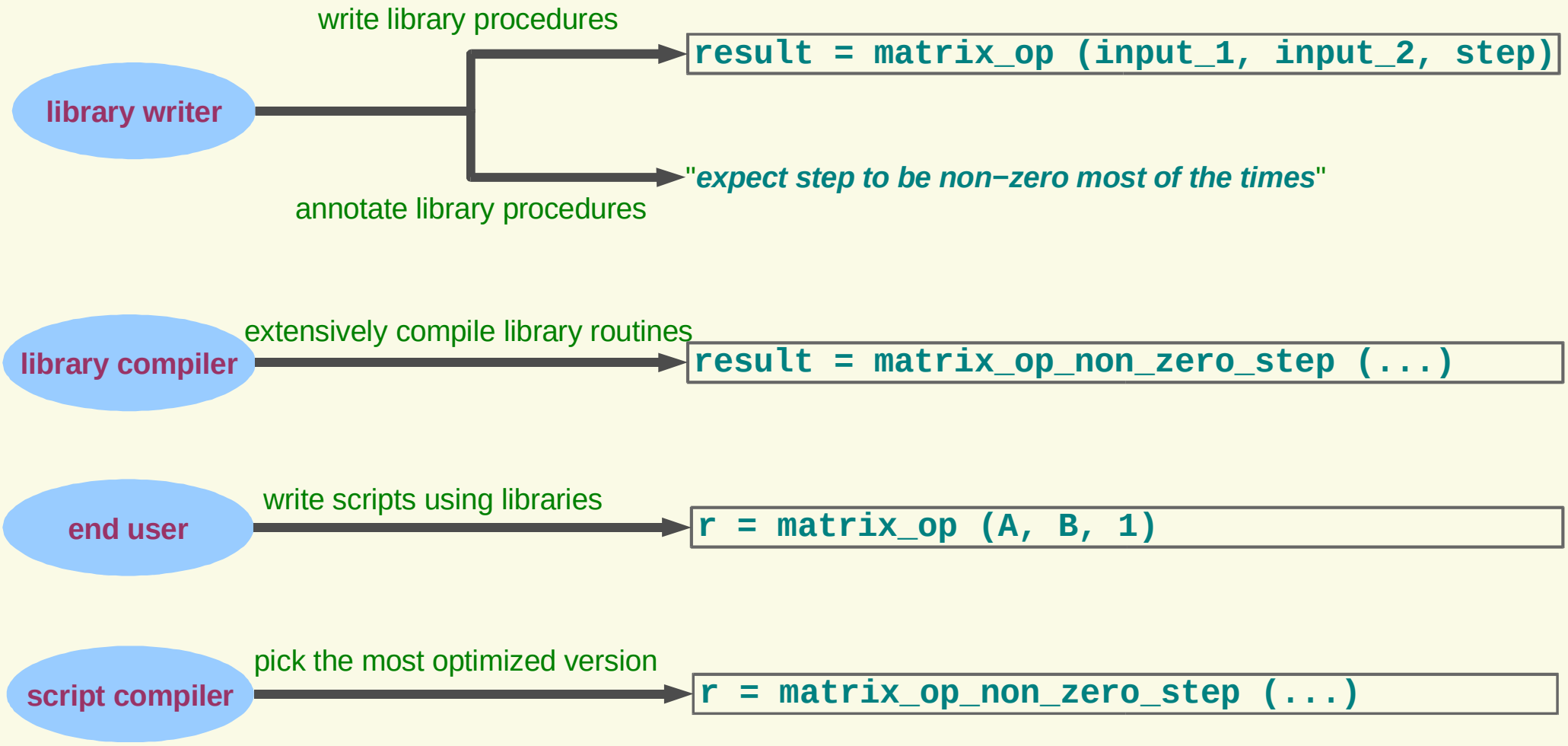

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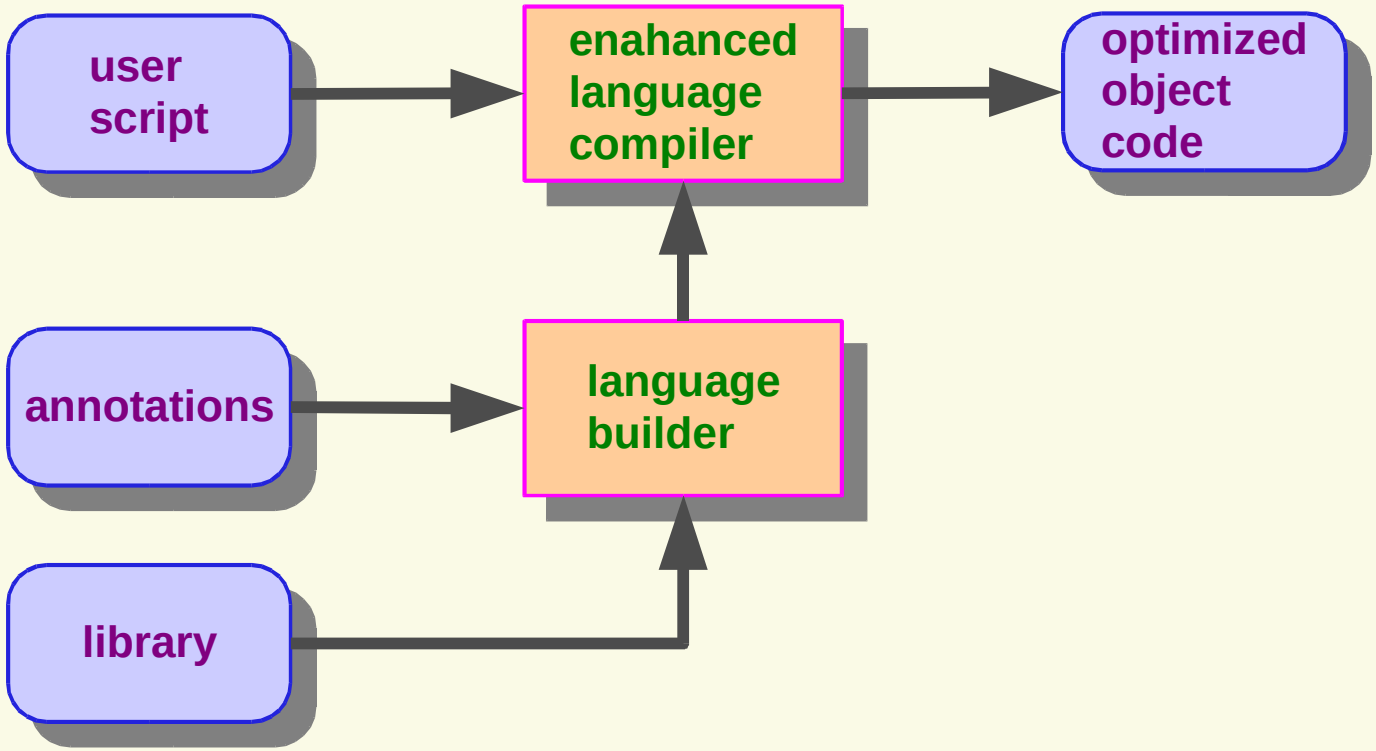

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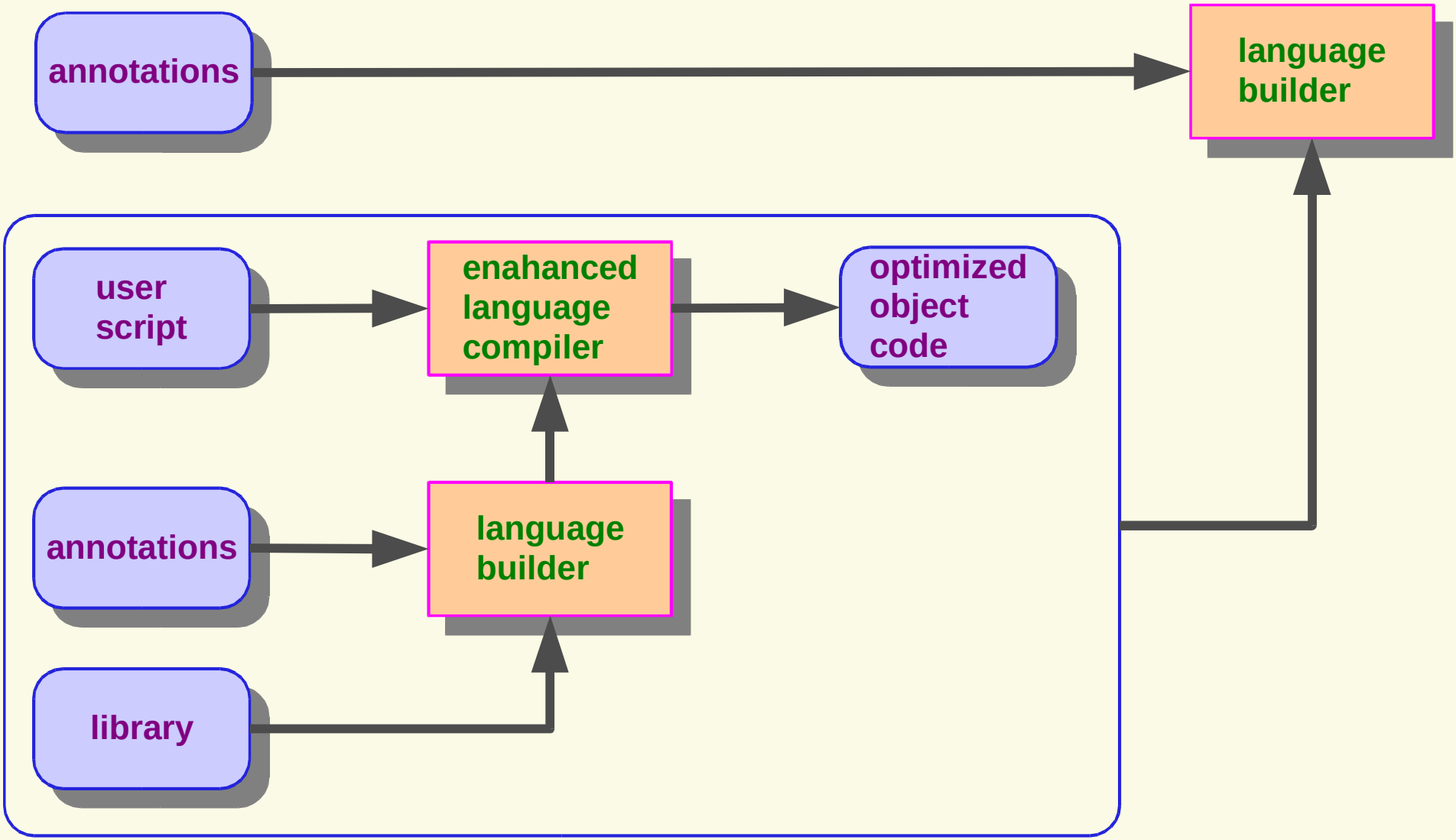

Application to DSP

- Digital Signal Processing is an important application area
- Matlab extremely popular with DSP researchers
- Researchers frequently rewrite their code in C / C++
  - to fit it onto embedded systems
  - to be accepted in their community

Study of DSP Applications

- Real DSP applications used in the ECE dept.
- Long running (several hours)
- Transformed by hand
- Run under Matlab environment

Relevant Optimizations

- Vectorization
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  - using the **`zeros`** call

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Novel Optimizations

- Procedure Strength Reduction
- Procedure Vectorization

Strength Reduction

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for i = n0:n0+N
  ....
  x = i * c;
  y = g(x);
  ....
end
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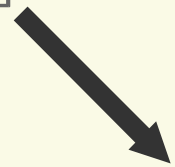

```
x = n0 * c;
for i = n0:n0+N
  ....
  y = g(x);
  x = x + c;
  ....
end
```

Procedure Strength Reduction

- Motivation
  - procedure calls inside loop
  - several arguments typically invariant
- Key
  - move invariant computations into init part
  - do incremental computations inside loop

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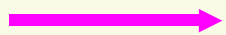

```
f_init (c1, c2, c3)
for i = 1:N
    f_iter (i)
end
```

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for i = 1:N
    f (c1, c2, i, A[i])
end
 ....
function f (a1, a2, a3, a4)
   <body of f>
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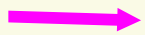
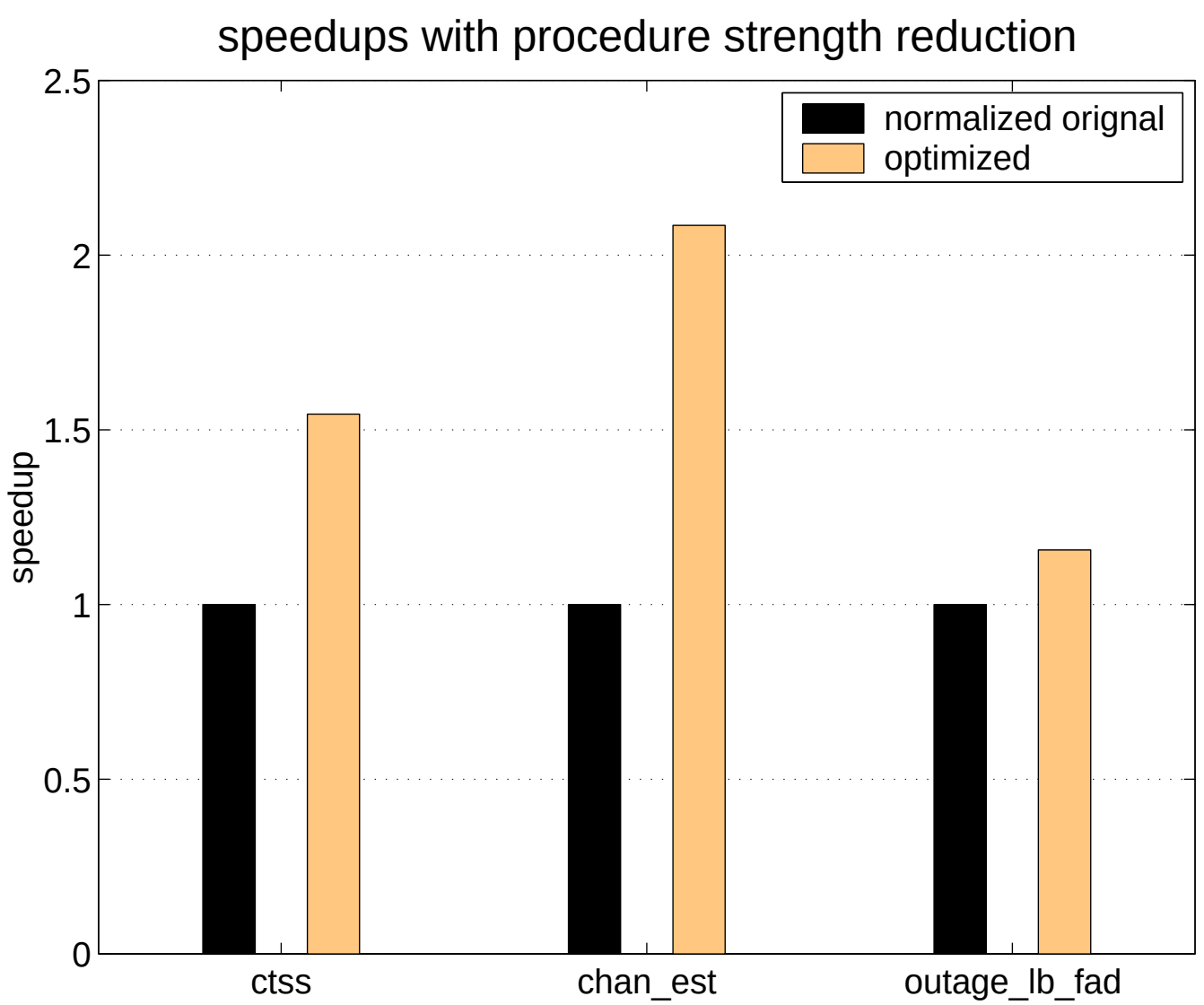
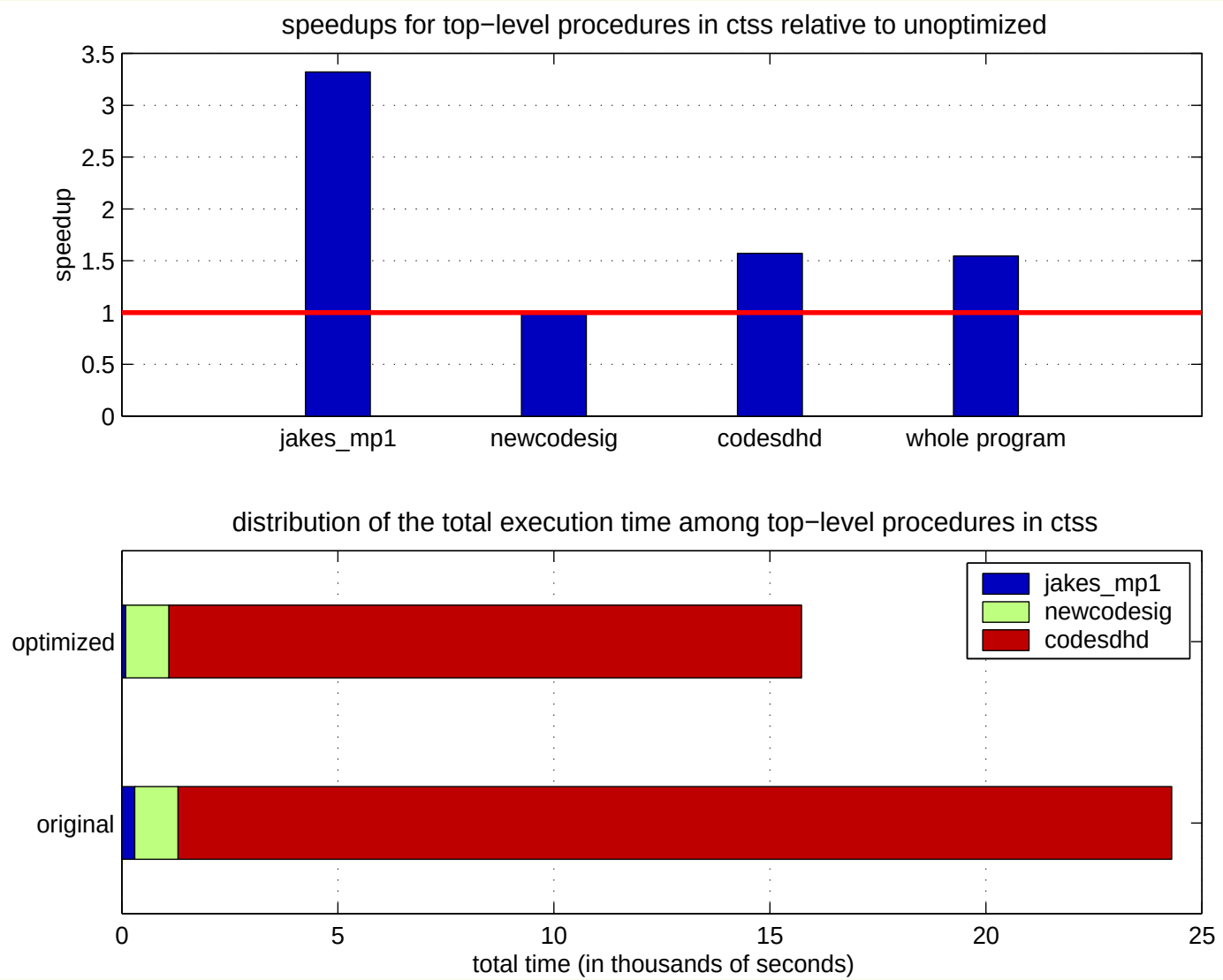


```
f_vect (c1, c2, [i:N], A[1:N])
 ....
function f_vect (a1, a2, a3, a4)
  for i = 1:N
     <body of f>
  end
```

Evaluation Results: Procedure Strength Reduction



ctss: Procedure Strength Reduction



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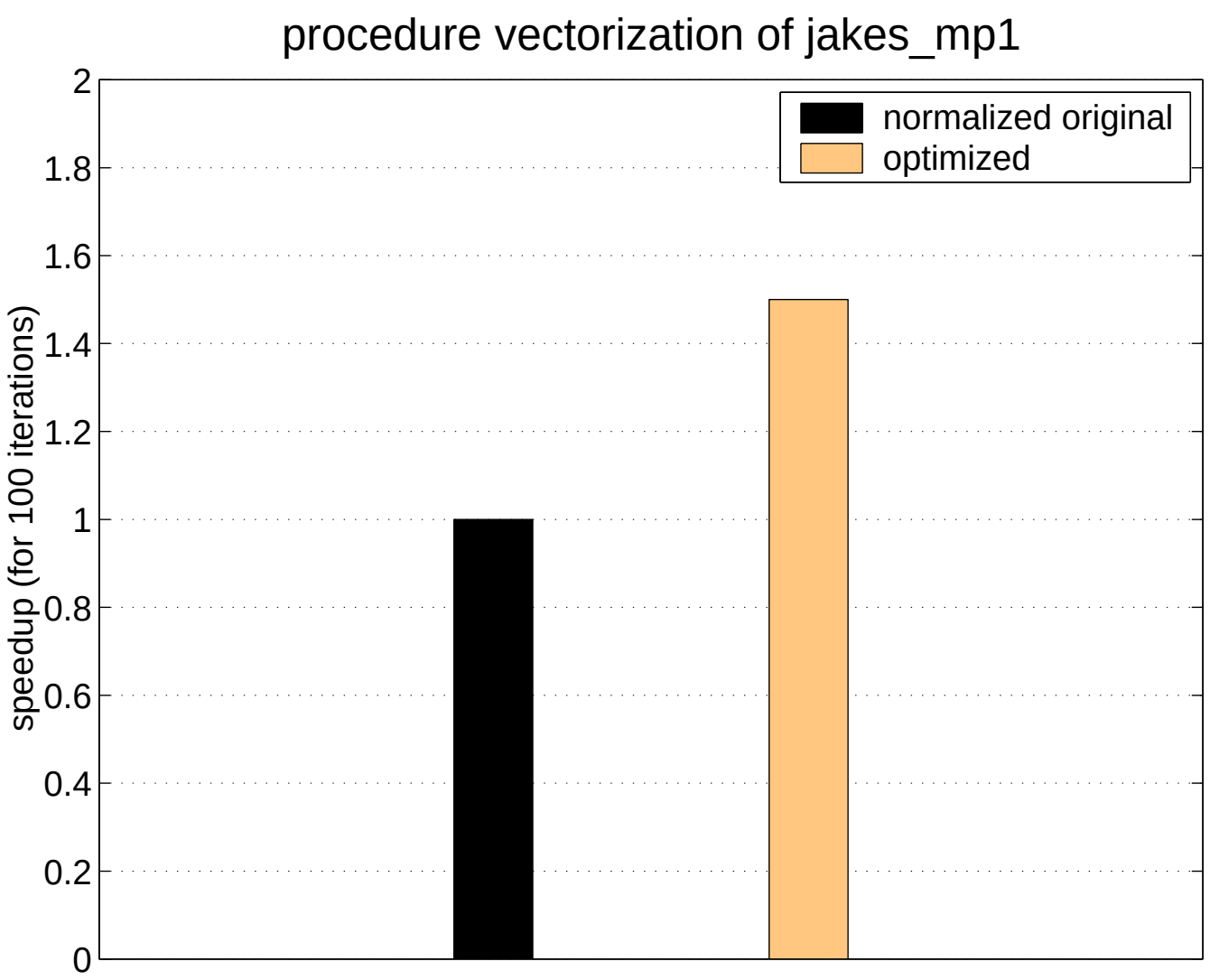
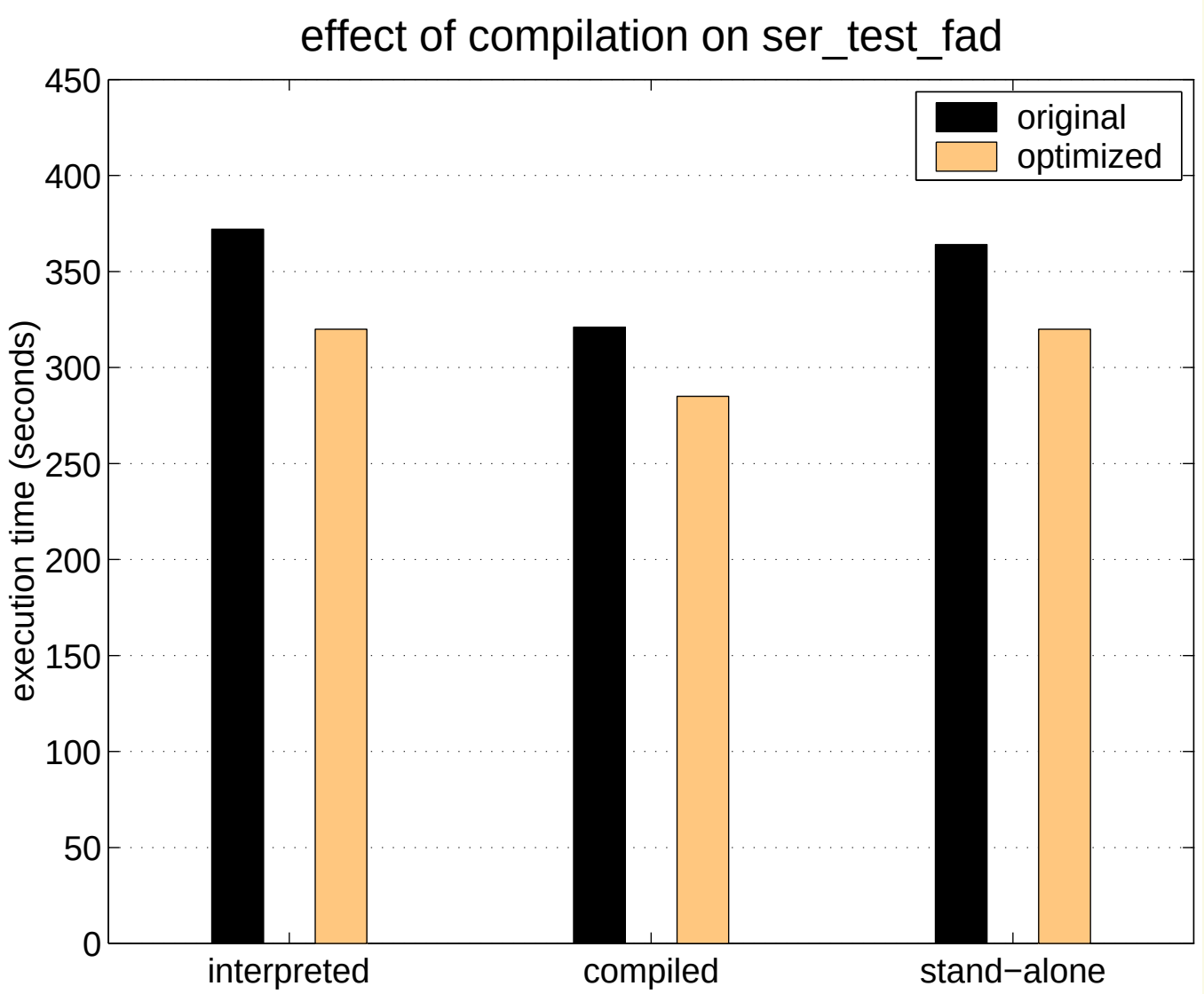


outage_lb_fad: Effect of Compilation



Conclusion

- Telescoping Languages approach
  - libraries optimized as primitive operations
  - fast compilation of user scripts
- Application to DSP programs
  - identified relevant optimizations
    - vectorization, common sub−expression elimination, pre−allocation
  - two novel optimizations
    - procedure strength reduction and procedure vectorization
    - 10% – 50% application level gain