Telescoping Languages

or

High Performance Computing for Dummies – II

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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- Shortage of programmers
  - 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

- Enable end−users to program
  - language should be high level
  - should provide domain−specific features
  - must have effective and efficient compilers

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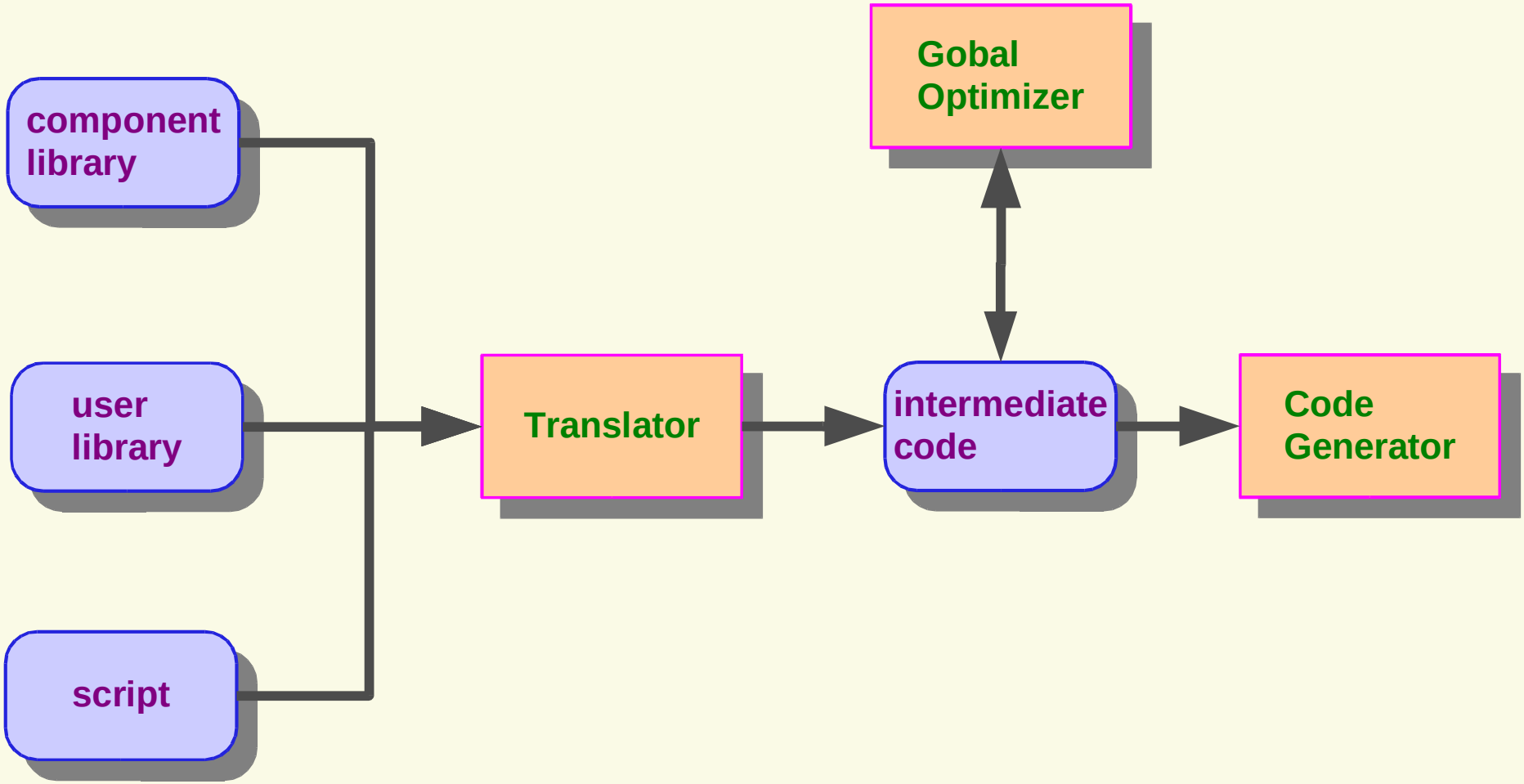
- Enable end−users to program
  - language should be high level
  - should provide domain−specific features
  - must have effective and efficient compilers
- Scripting systems like MATLAB exist
  - very popular with end−users
  - lack effective and efficient compilers

Fundamental Observations

- Libraries extremely important
  - cannot treat libraries as black boxes
  - lib sources may not be available to end users
- Compiling user scripts must be fast
  - should follow principle of no surprise

Existing Approaches:

based on transforming to lower level languages



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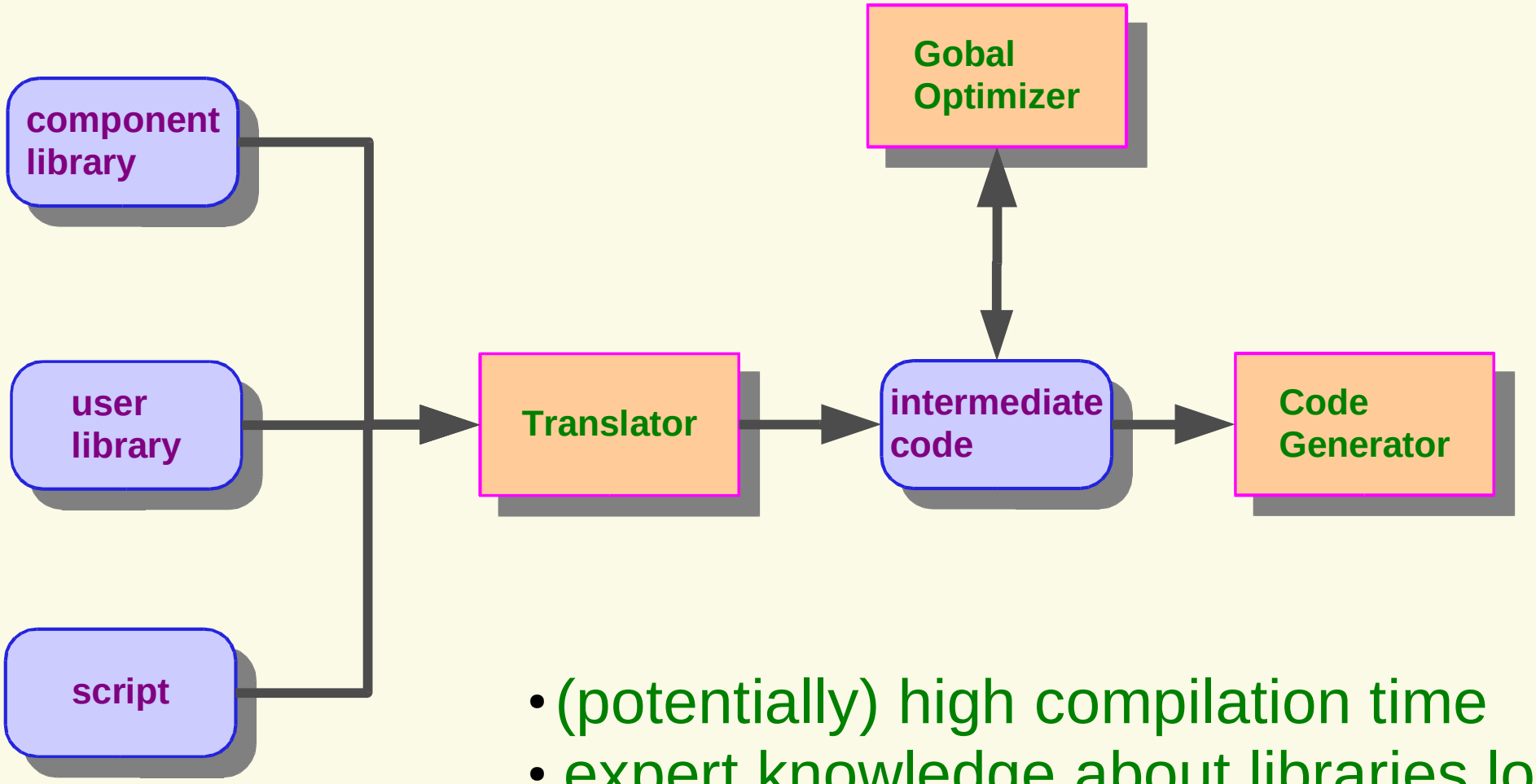

- (potentially) high compilation time
- expert knowledge about libraries lost

Expert Knowledge

Example 1

```
function result = matrix_op (input_1, input_2, step)

i = 1
for j = 1:N
   result(i) = result(i) + input_1(j)*input_2(j)
   i = i + step
end
```

Expert Knowledge

Example 1

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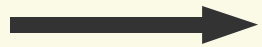
```

Example 2

```
 ....
 x = sin (a);
 y = cos (a);
 ....
```

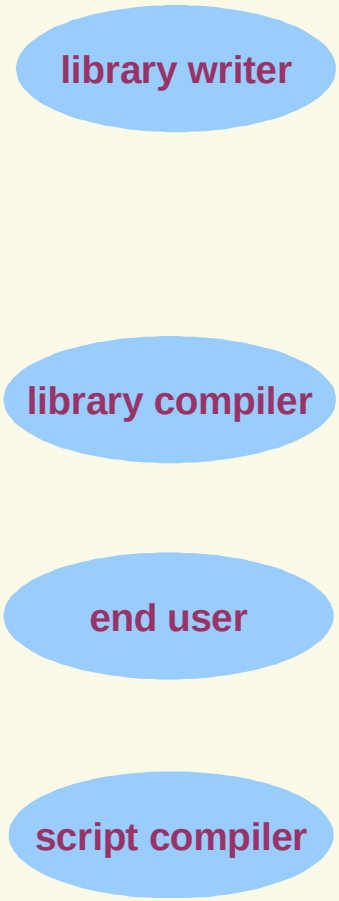


```
 ....
 [x, y] = sincos (a);
 ....
```

Desiderata

- Utilize expert knowledge on libraries
- Fast compilation of user−scripts
- Still achieve high performance

Telescoping Languages Approach



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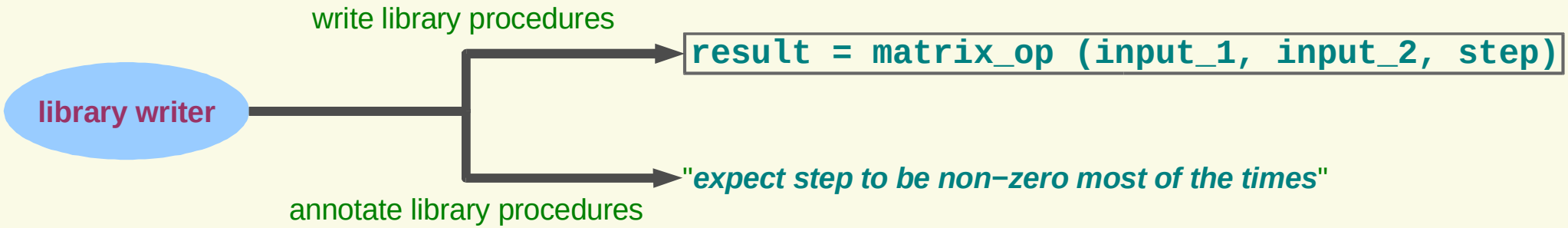
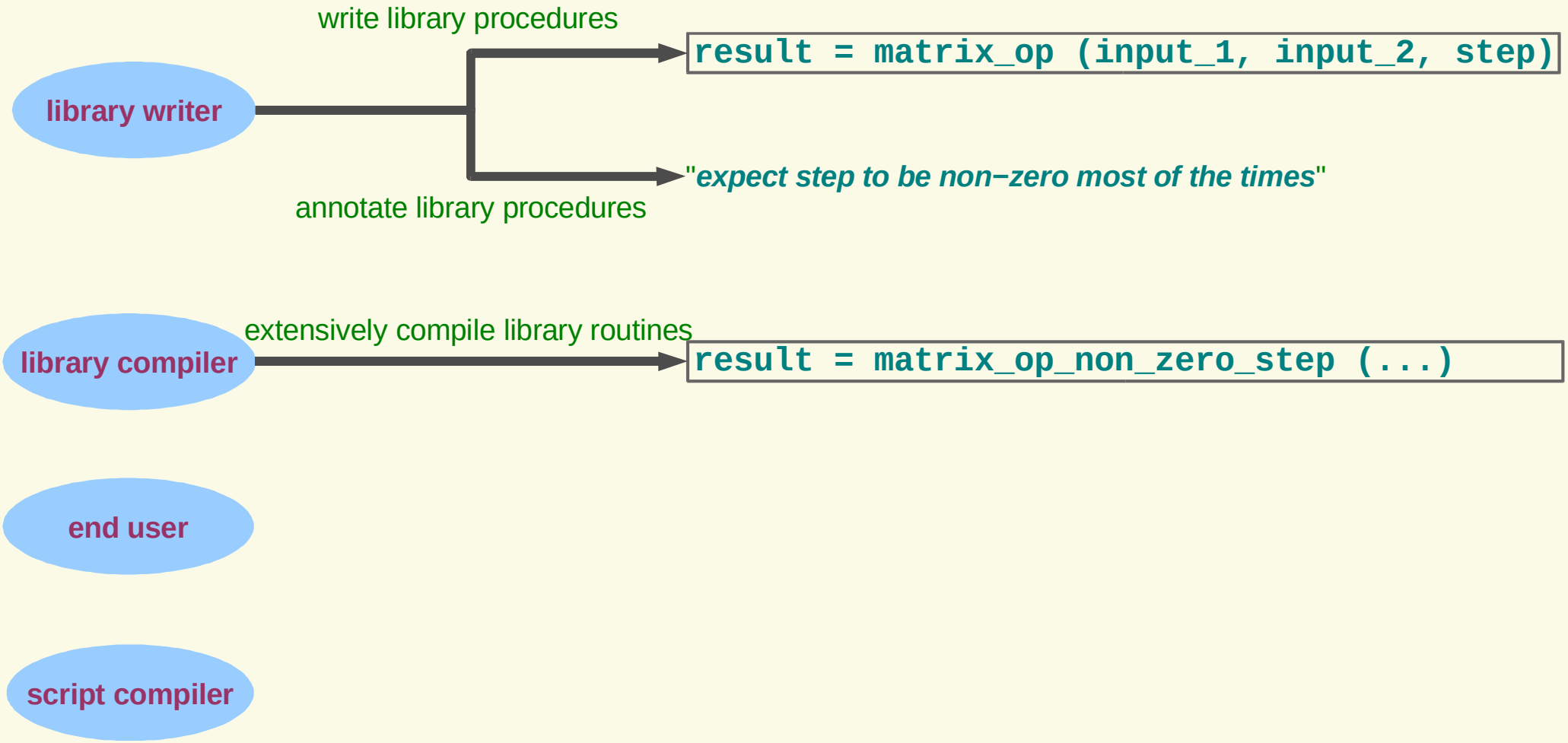


library compiler

end user

script compiler

Telescoping Languages Approach



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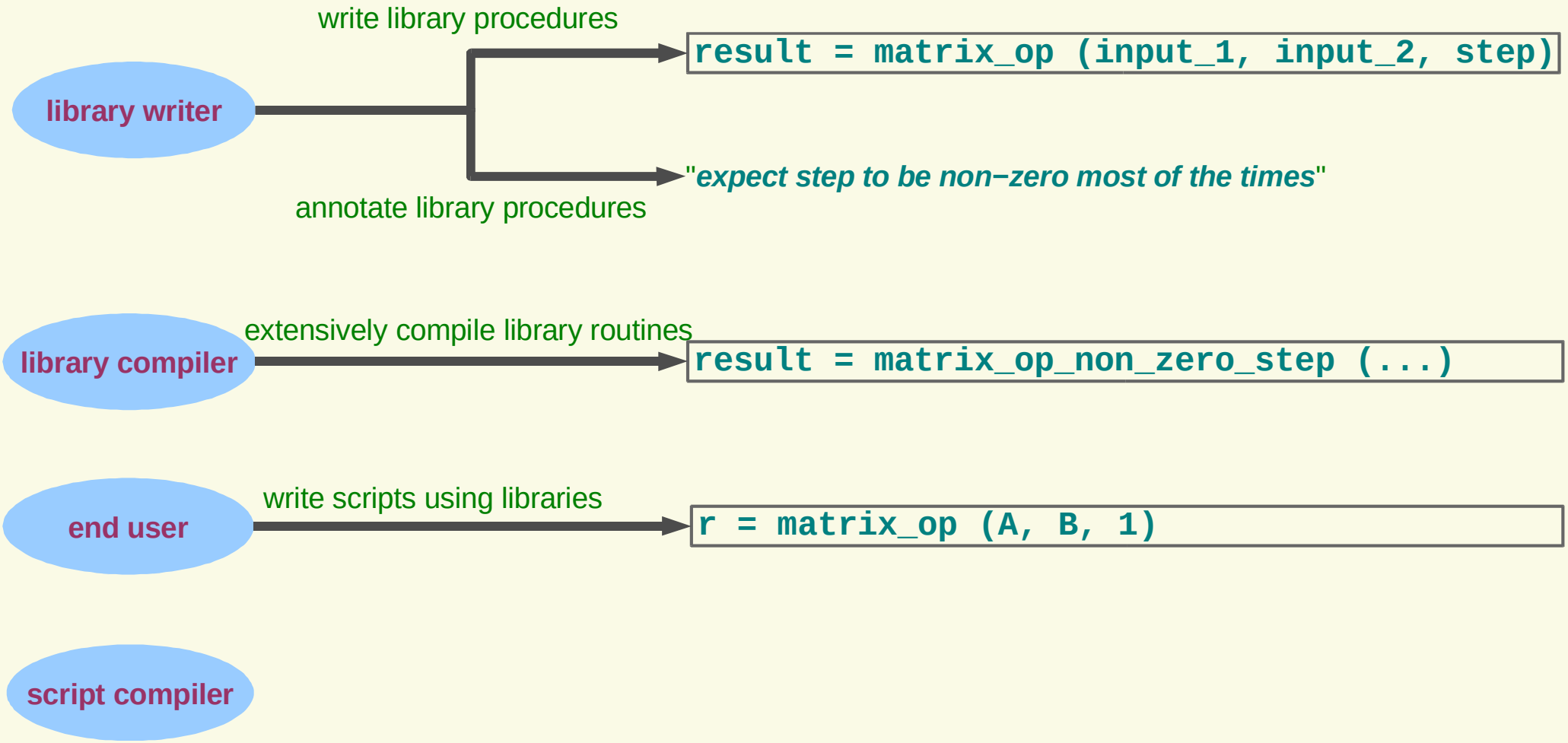
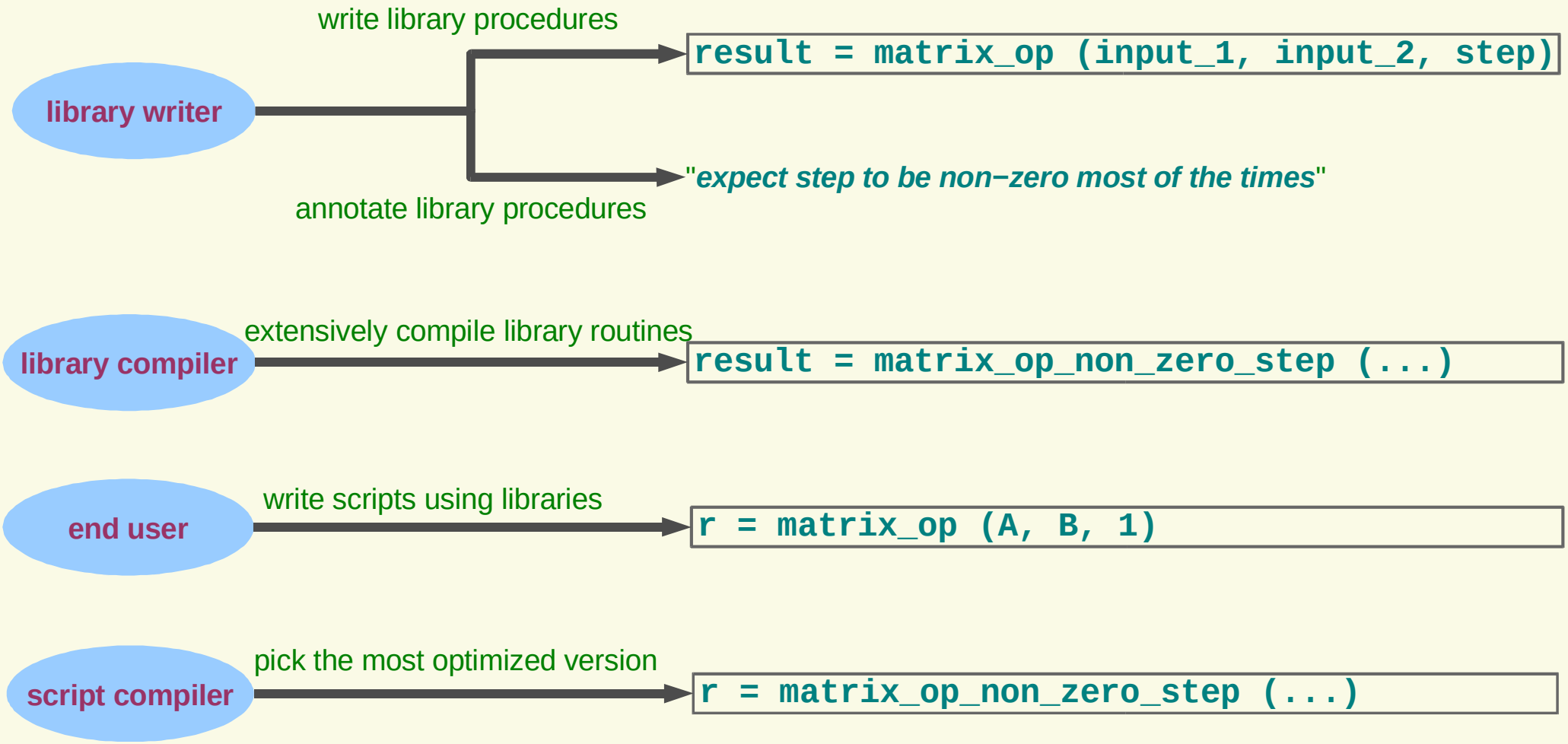
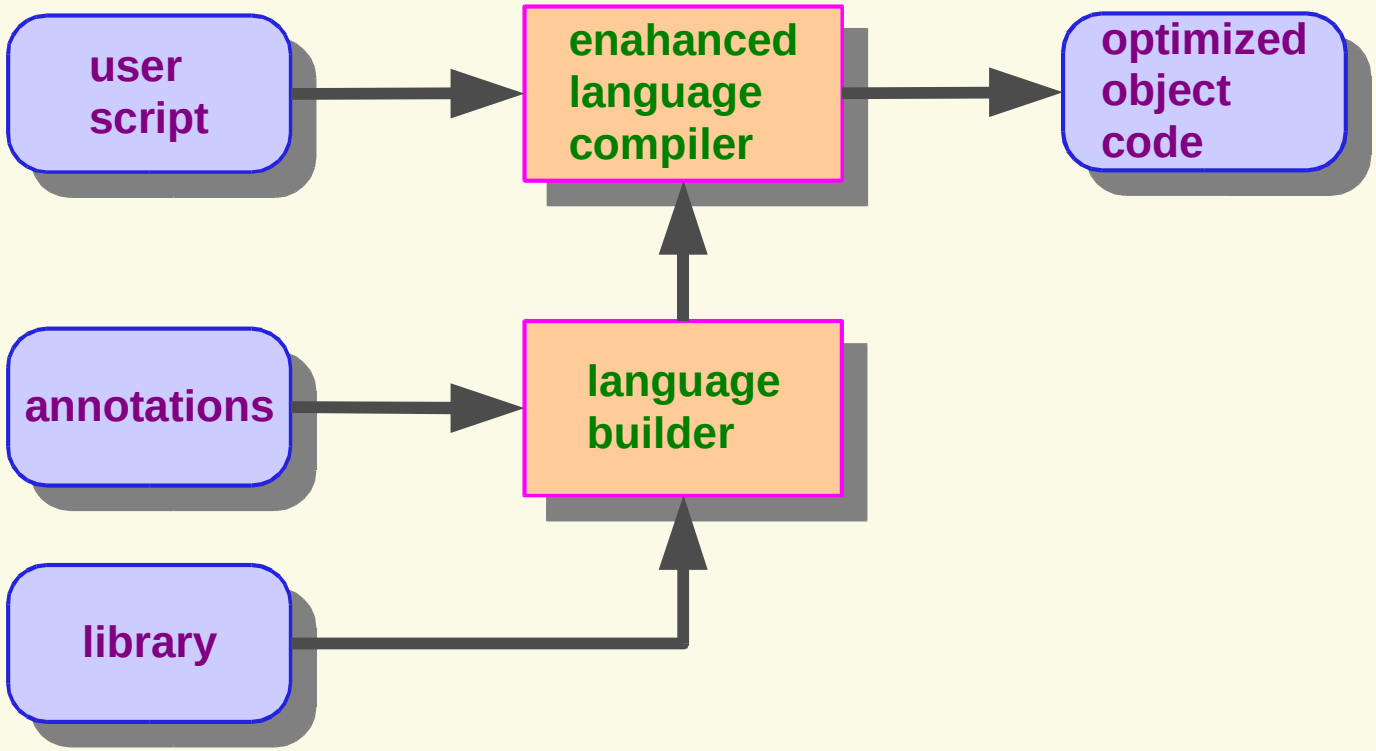


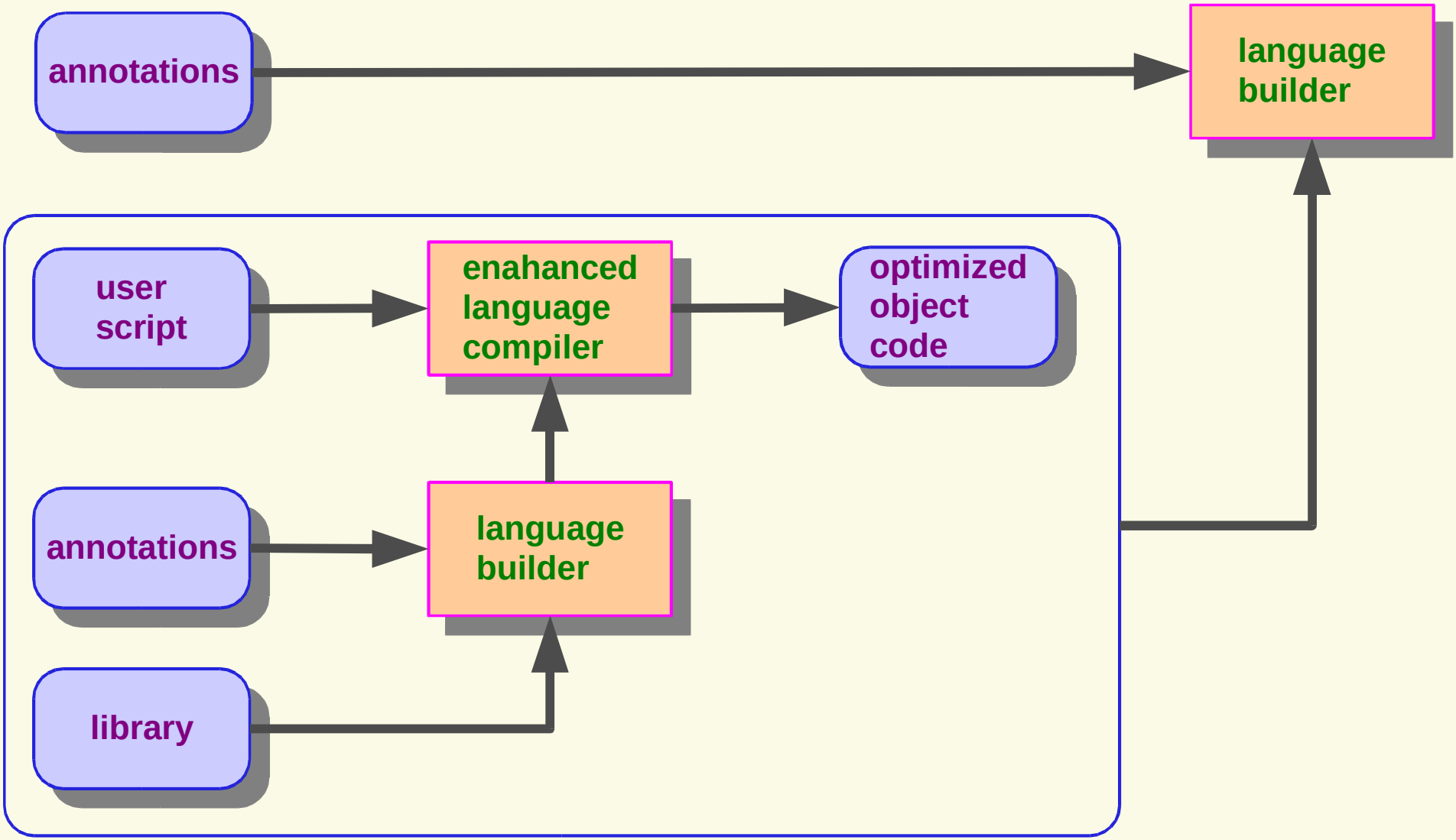
Telescoping Languages Approach



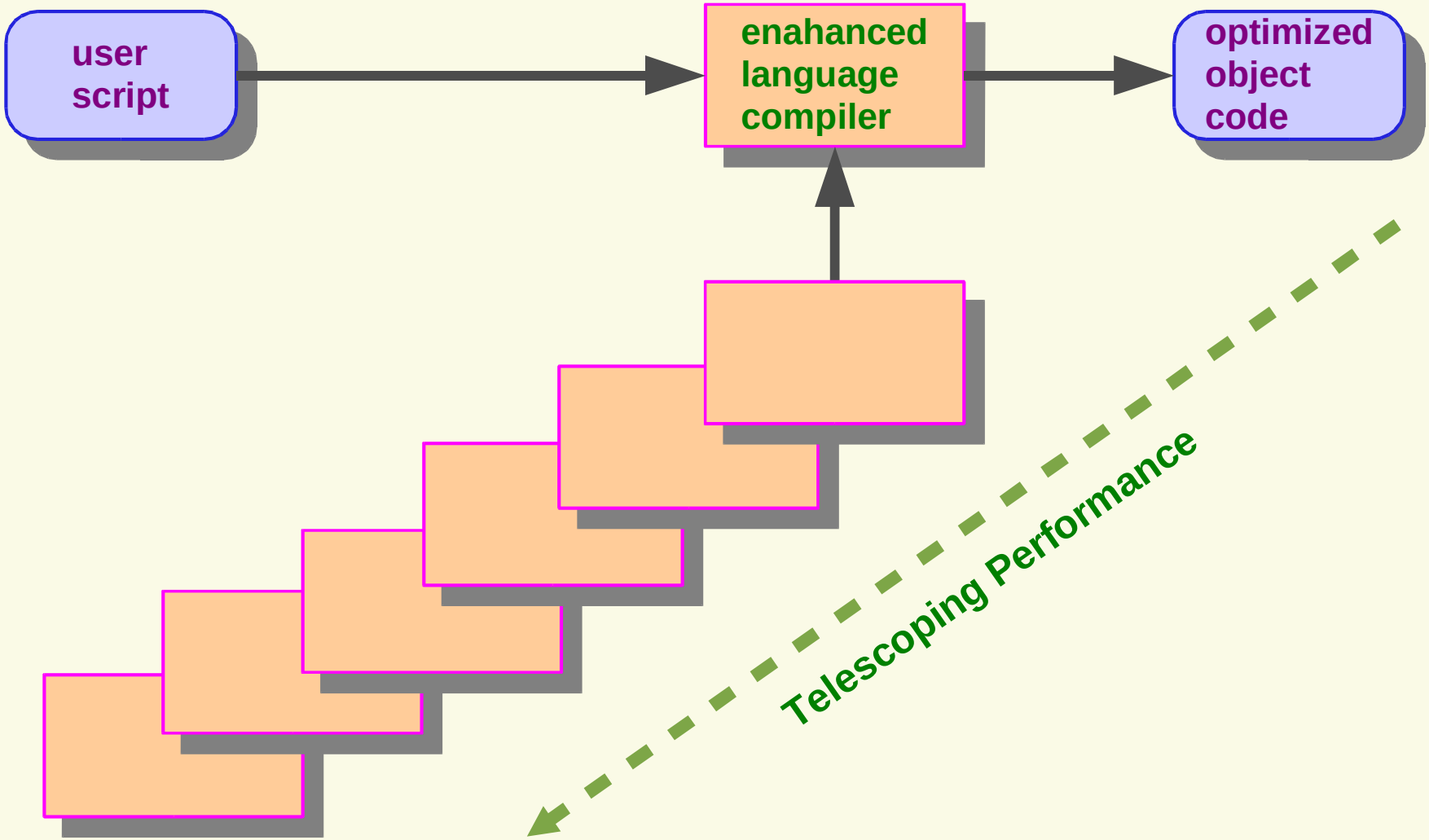
Telescoping Languages Approach



Telescoping Languages Approach



Telescoping Performance



Strength Reduction

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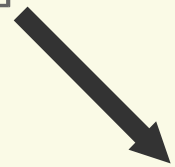

```
x = n0 * c;
for i = n0:n0+N
  ....
  y = g(x);
  x = x + c;
  ....
end
```

Procedure Strength Reduction

- Procedure called inside loop
  - several arguments typically invariant
  - move invariant computations into init part
  - do incremental computations inside loop

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for i = 1:N
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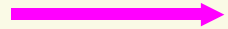

```
f_init (c1, c2, c3)
for i = 1:N
    f_iter (i)
end
```

Procedure Strength Reduction

```
....

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, l, 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
....
```

Procedure Strength Reduction

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jakes_mp1_init (16500, 160, num_paths);
for ii = 1:200
  chan = jakes_mp1_iter (ii);

  ....

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   ....
  end
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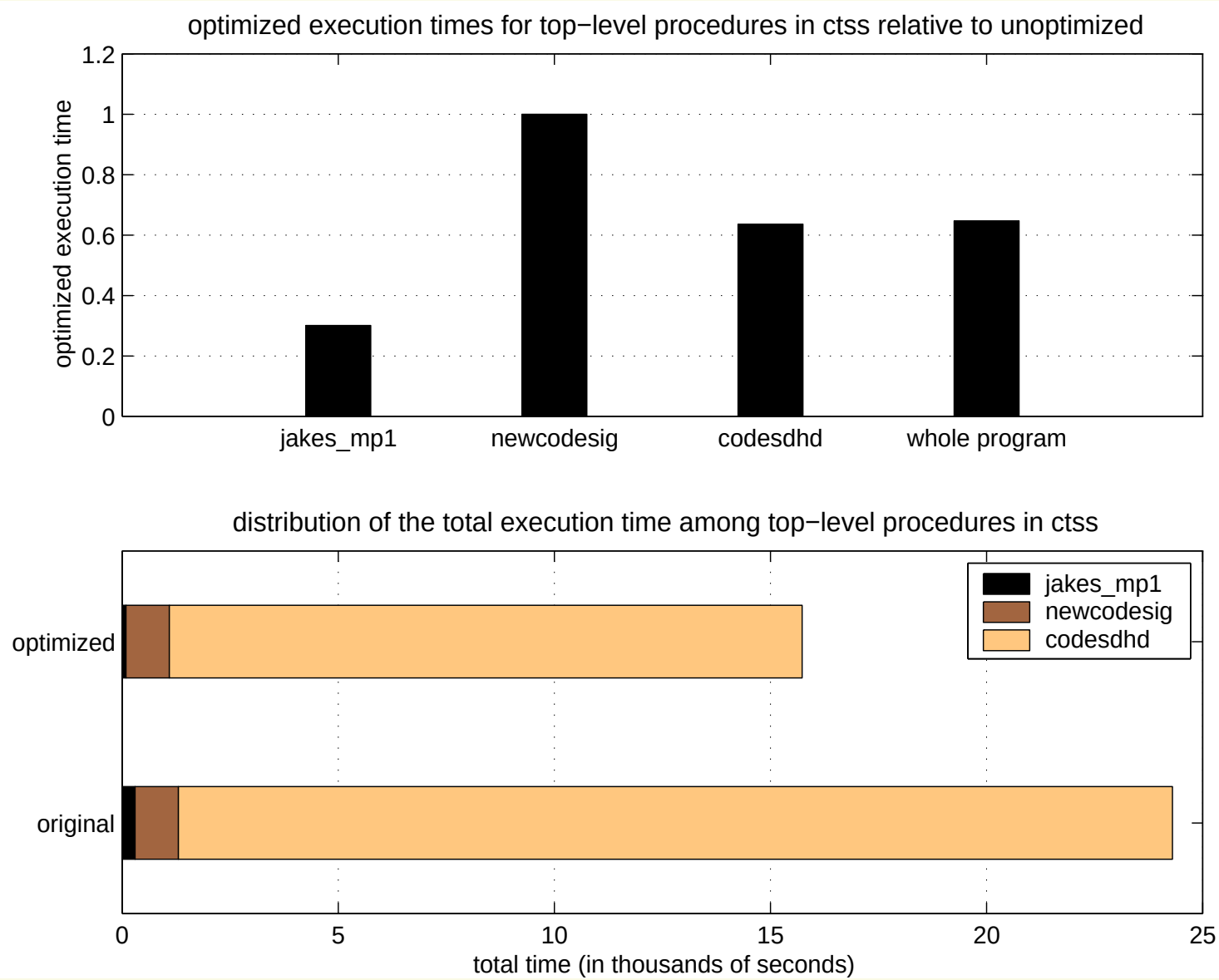
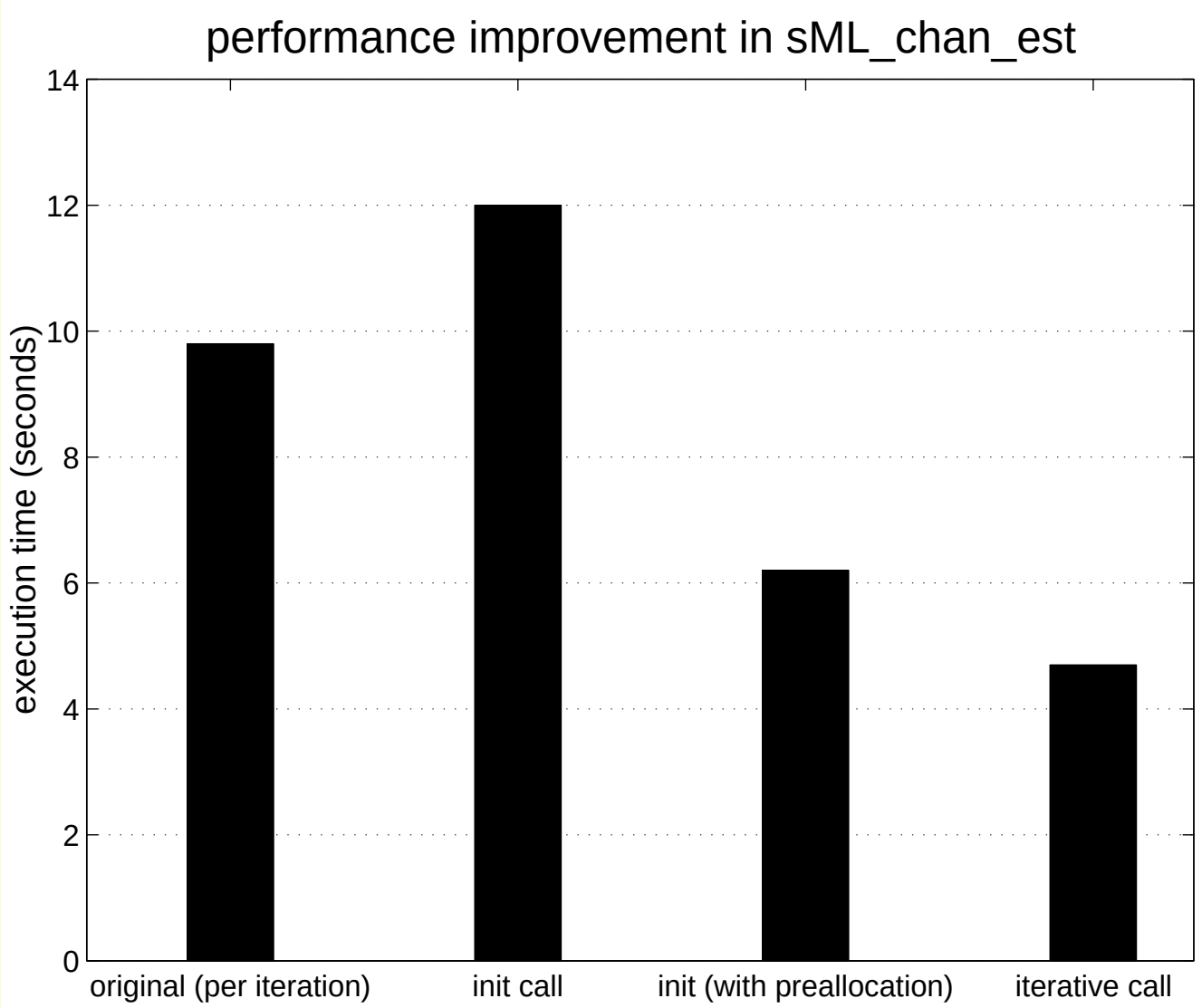
....
```

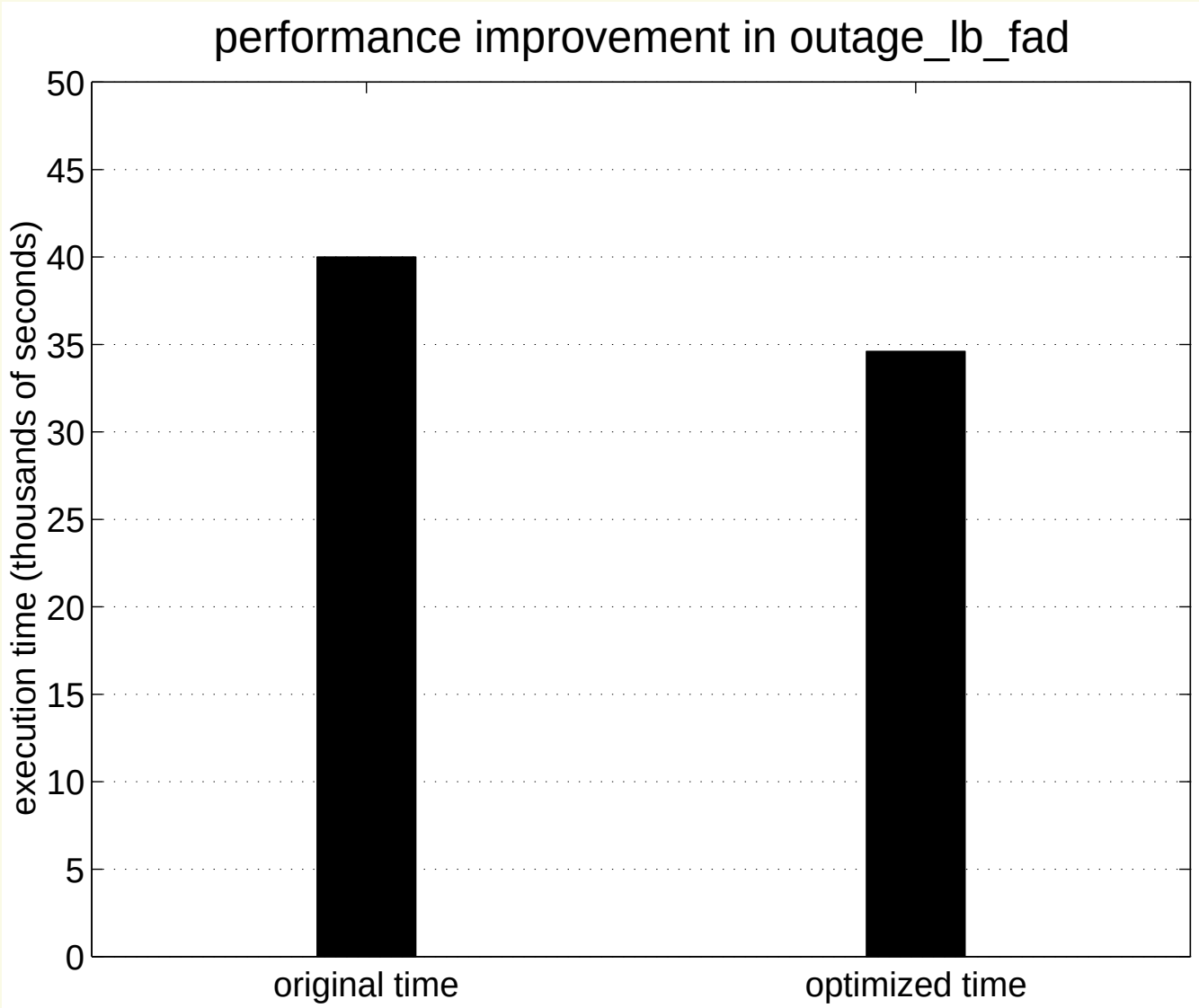
ctss: strength reduction



chan_est: strength reduction



outage_lb_fad: strength reduction



Conclusion

- Telescoping Languages approach
  - enable end−users write high perf. programs
  - libraries optimized as primitive operations
  - fast compilation of user scripts
- Procedure Strength Reduction
  - 10% – 50% gain