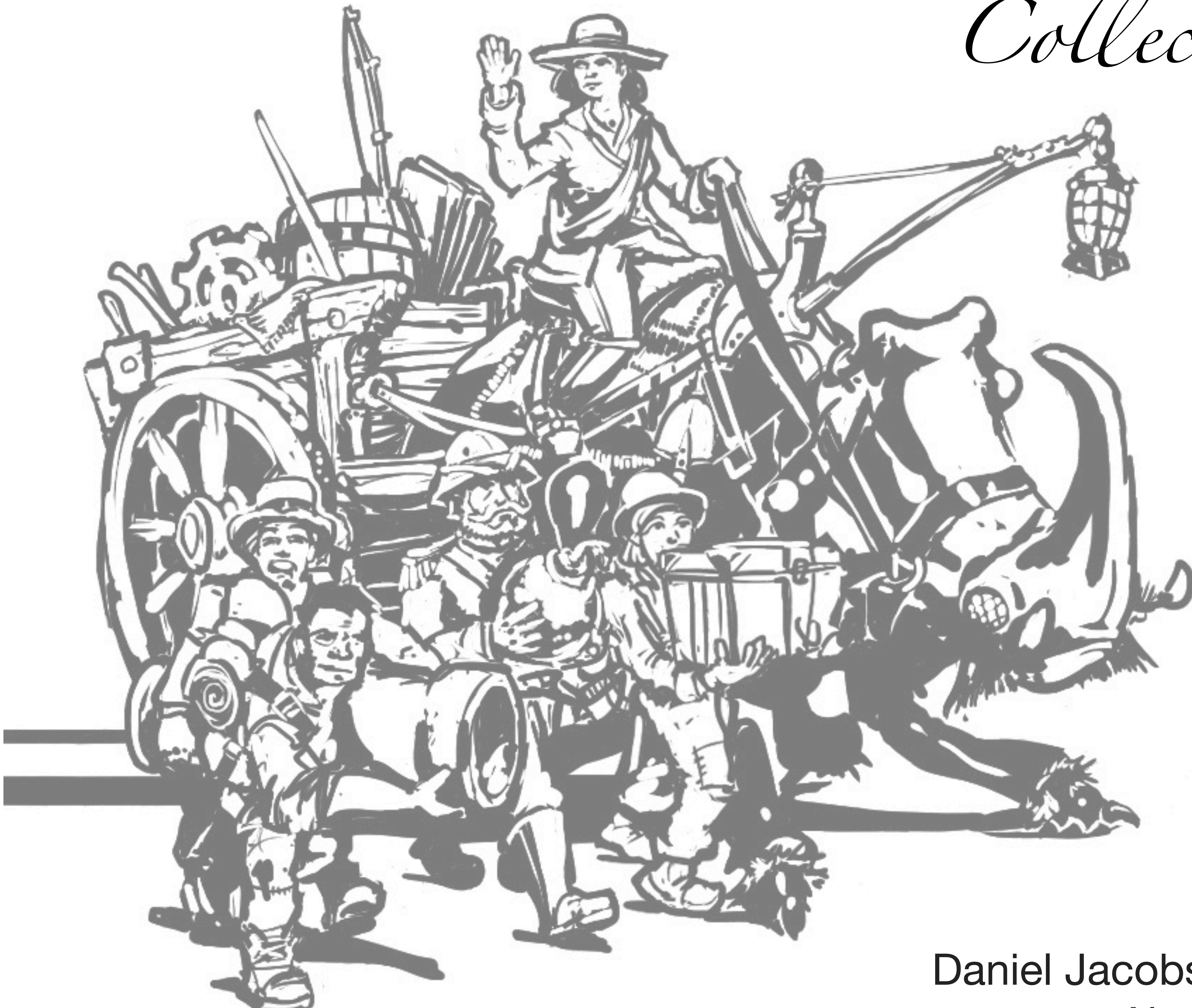


Collection-focused Parallelism

Micah J Best | **UBC**
Nicholas Vining | **UBC**
Daniel Jacobsen | **Gaslamp Games**
Alexandra Fedorova | **SFU**

Clockwork Empires

Clockwork Empires

Mental Models

Argument

Realization

Experience

Mental Models

Argument

Realization

Experience

Mental Models

Argument

Realization

Experience

Gaslamp Games

SFU

Mental Models

Argument

Realization

Experience

Mental Models

Argument

Realization

Experience

Mental Models

Argument

Realization

Sub-collections are a good candidate for the **basic unit of parallelism**

Experience

Mental Models

Mental Models

How do we think about parallelism?

Mental Models

How do we think about parallelism?

Mental Models

The "Undergrad Model"

Mental Models

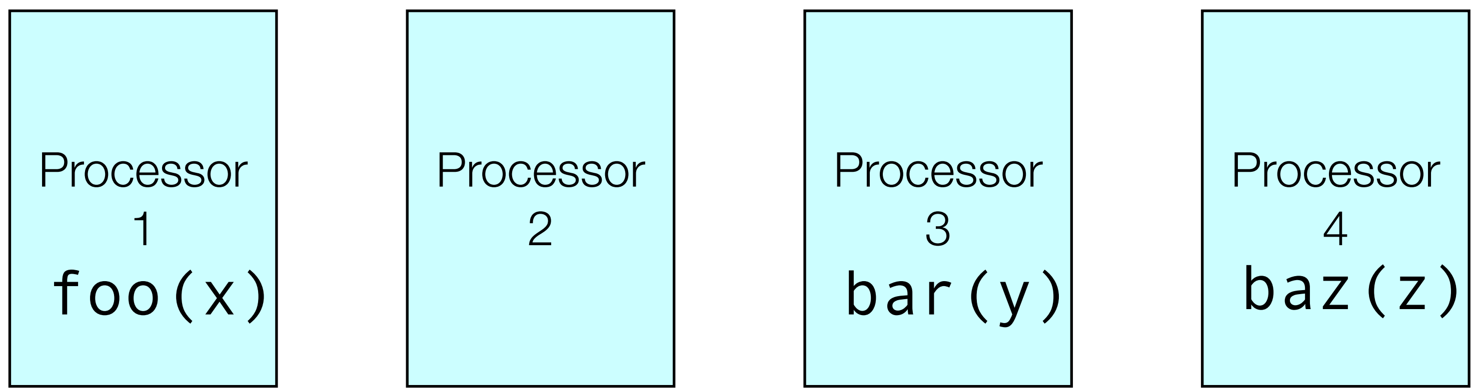
The “Undergrad Model”

Processor 1	Processor 2	Processor 3	Processor 4

```
int main(int argc,char **argv)
{
    foo(x)

    bar(y)

    baz(z)

}
```

Mental Models

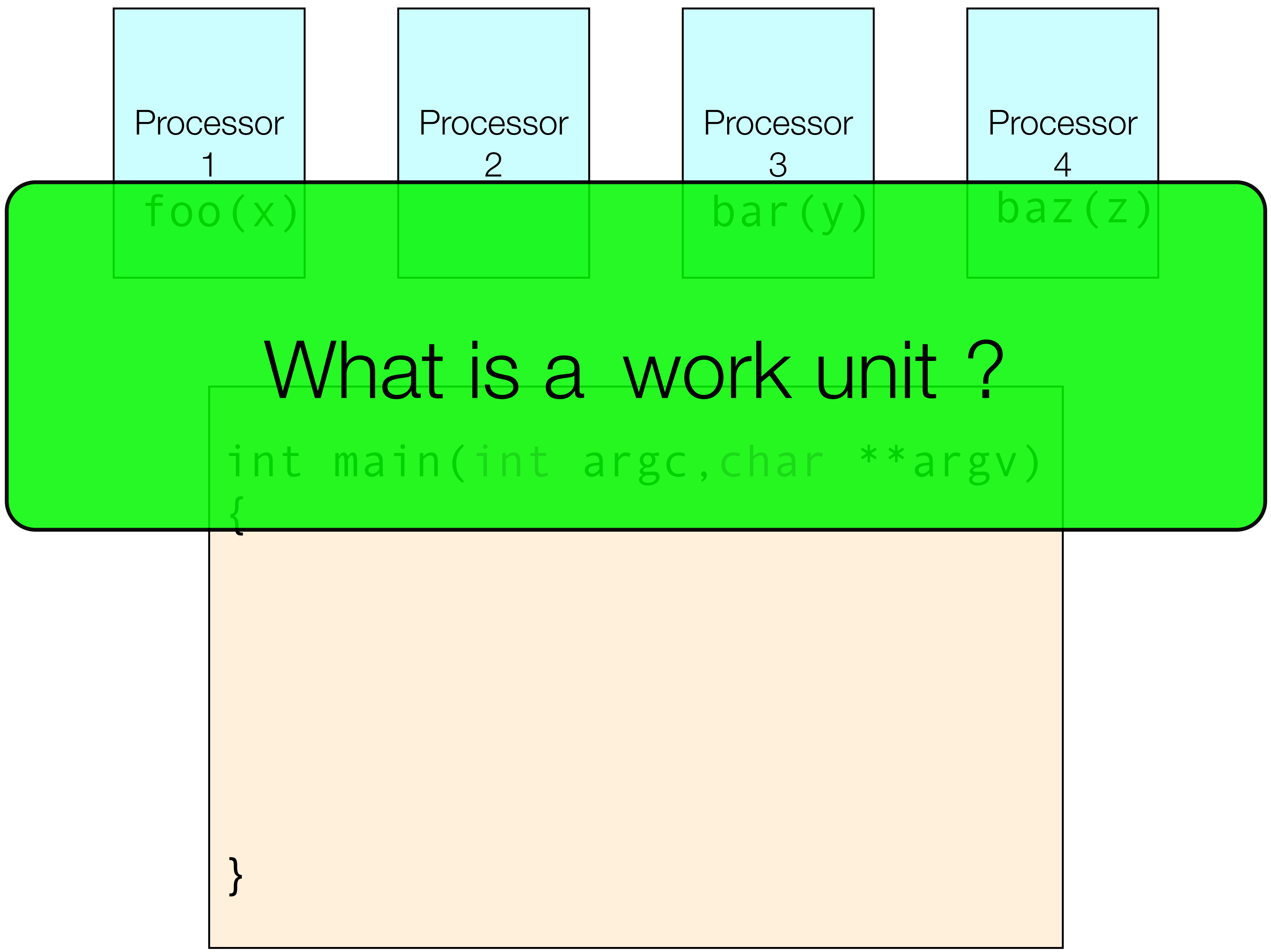
The "Undergrad Model"




```
int main(int argc,char **argv)
{





}
```

Mental Models

The “Undergrad Model”



Mental Models

Mental Models

L1 Cache hit: ~**1-3** cycles

L2 Cache hit: **10s** of cycles

Main Memory Access: **100s** of cycles

Mental Models

L1 Cache hit: ~**1-3** cycles

L2 Cache hit: **10s** of cycles

Main Memory Access: **100s** of cycles

Cloud Access: Many many many many many cycles

Mental Models

L1 Cache hit: ~**1-3** cycles

L2 Cache hit: **10s** of cycles

Main Memory Access: **100s** of cycles

Cloud Access: Many many many many many cycles

deadlock

livelock

load balancing

starvation

state conflicts

Mental Models

L1 Cache hit: ~**1-3** cycles

L2 Cache hit: **10s** of cycles

Main Memory Access: **100s** of cycles

Cloud Access: Many many many
many many cycles

deadlock

livelock

load balancing

starvation

state conflicts

branch misprediction

UBC

Gaslamp Games

SFU

Schedule Data, Not Code

Schedule Data, Not Code

What if we pick up the other end of the stick?

Schedule Data, Not Code

What if we pick up the other end of the stick?

Schedule Data, Not Code

What if we pick up the other end of the stick?

Processor 1

Processor 2

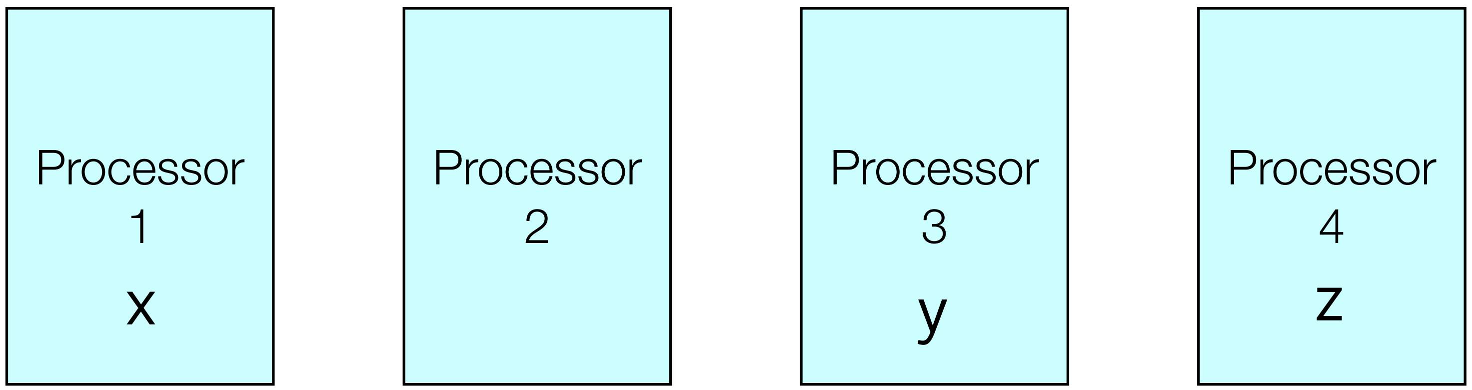
Processor 3

Processor 4

```
int main(int argc,char **argv)
{
    foo(x)

    bar(y)

    baz(z)

}
```

Schedule Data, Not Code

Schedule Data, Not Code




```
int main(int argc,char **argv)
{



}
```

Data is in Collections

Code is static

Data is dynamic

Data is in Collections

Code is static

Data is dynamic

But data never travels alone.

Data is in Collections

almost always

generally

Code is static

Data is dynamic

rarely

But data ~~never~~ travels alone.

Data is in Collections

almost always

generally

Code is static

Data is dynamic

rarely

But data ~~never~~ travels alone.

It comes in collections.

Data is in Collections

almost always

generally

Code is static

Data is dynamic

rarely

But data ~~never~~ travels alone.

It comes in collections.

We rarely use a whole collection at once.

Collections

Collections

What is a work unit?

Collections

What is a work unit?

The smallest set of subcollections needed for processing in making forward progress in the application.

Mental Models

Argument

Realization

Experience

Mental Models

Argument

Realization

Experience

Realization Problems

Realization Problems

How do we efficiently deal with sub-collections?

Realization Problems

How do we efficiently deal with sub-collections?

How do we structure programs?

Realization Problems

How do we efficiently deal with sub-collections?

How do we structure programs?

How do we derive schedules?

Synchronization via Scheduling (SvS)

Basic Idea:

Basic Method:

Synchronization via Scheduling (SvS)

Basic Idea: Know what data a task is going to access before it executes and use this information to make scheduling decisions.

Basic Method:

Synchronization via Scheduling (SvS)

Basic Idea: Know what data a task is going to access before it executes and use this information to make scheduling decisions.

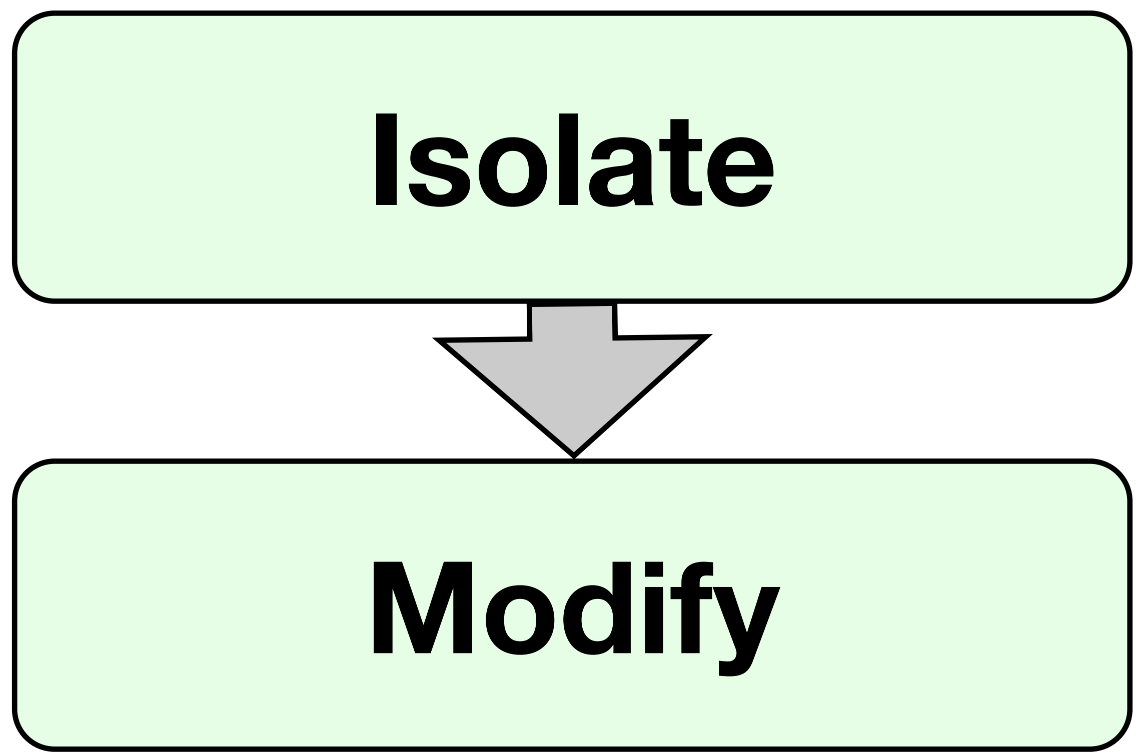
Basic Method: Derive a compact representation (a single bit string) of the 'space' of potential access for quick comparisons during scheduling.

Software Patterns (IMR)

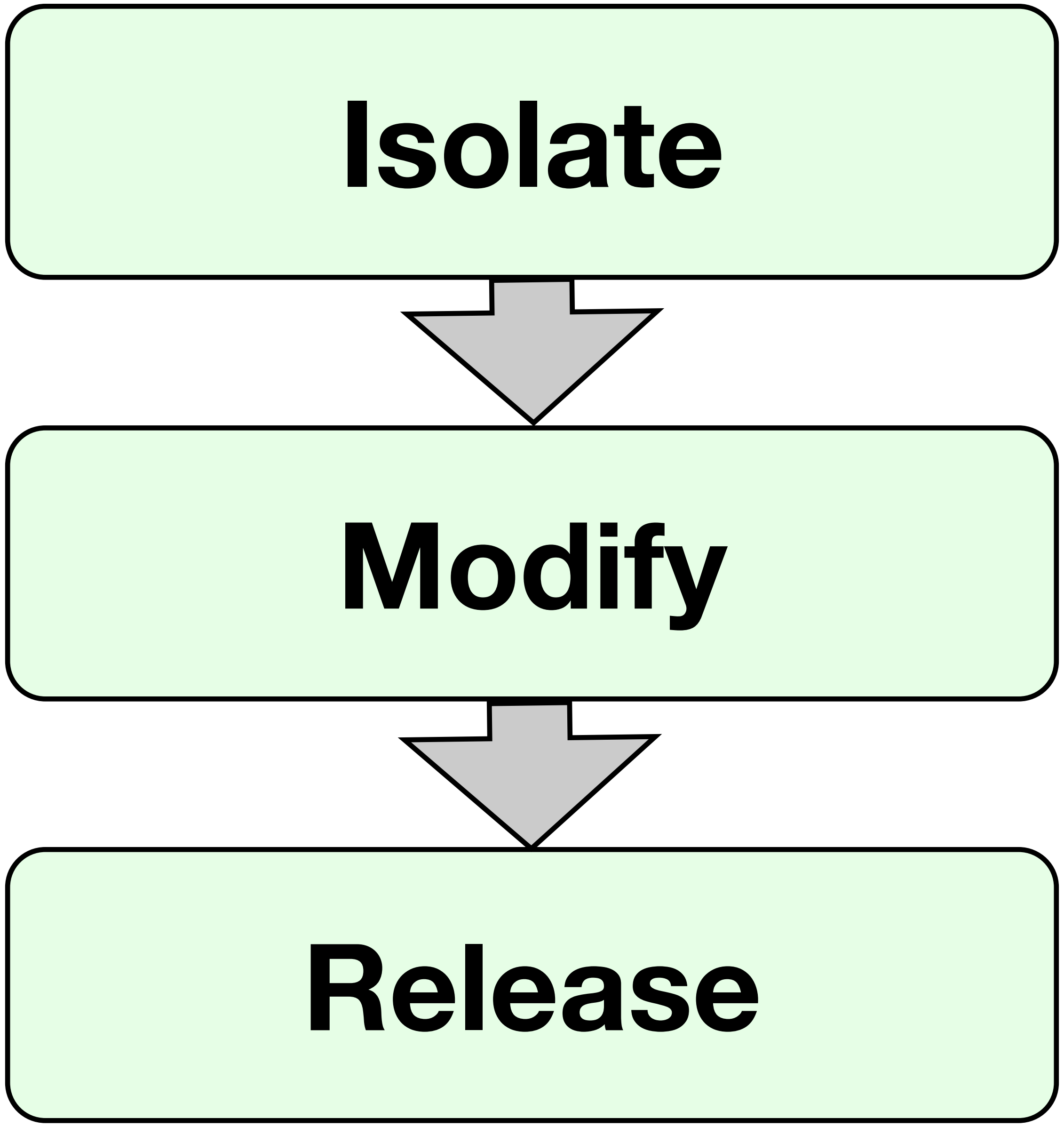
Software Patterns (IMR)

Isolate

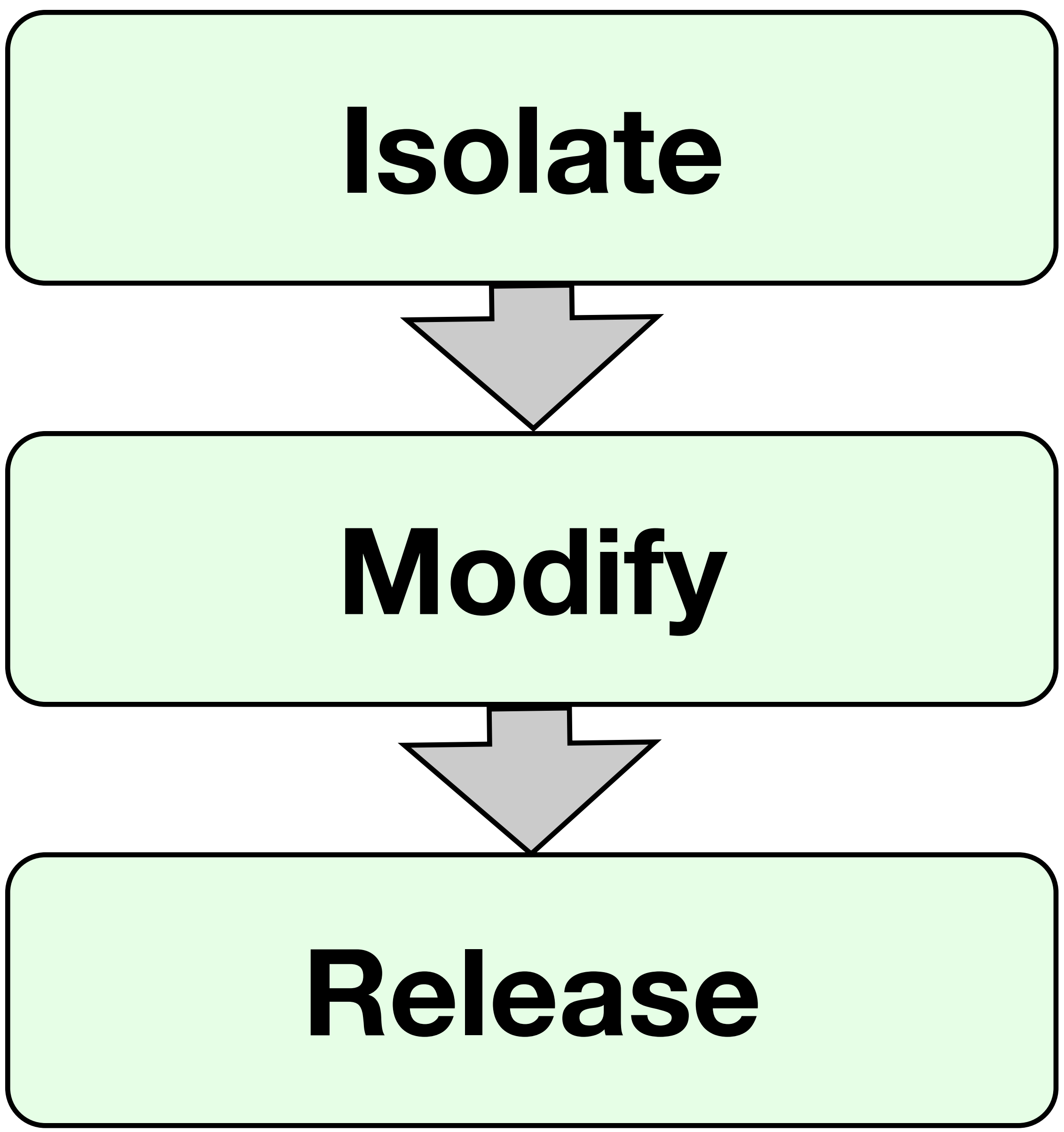
Software Patterns (IMR)



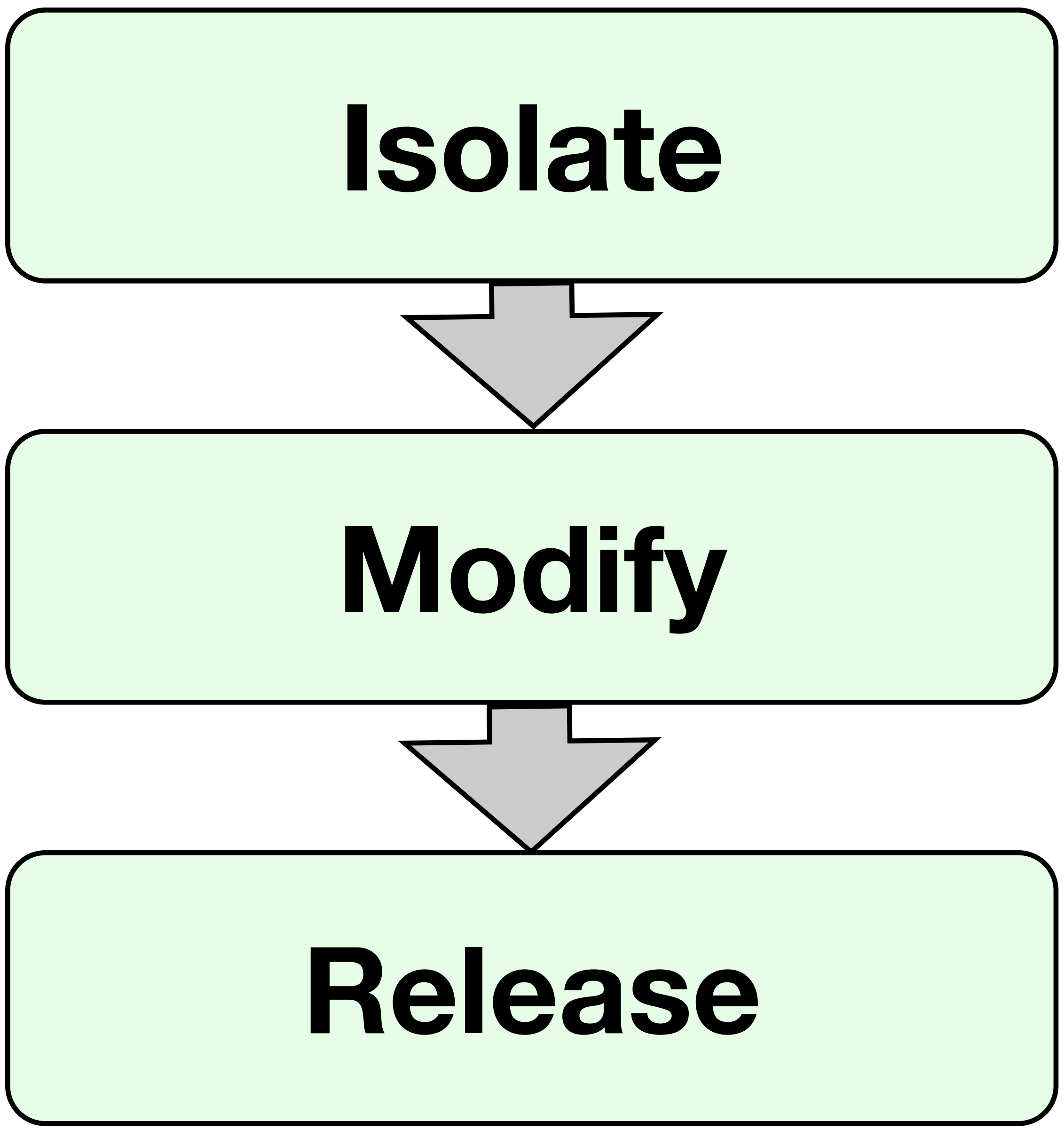
Software Patterns (IMR)



Software Patterns (IMR)

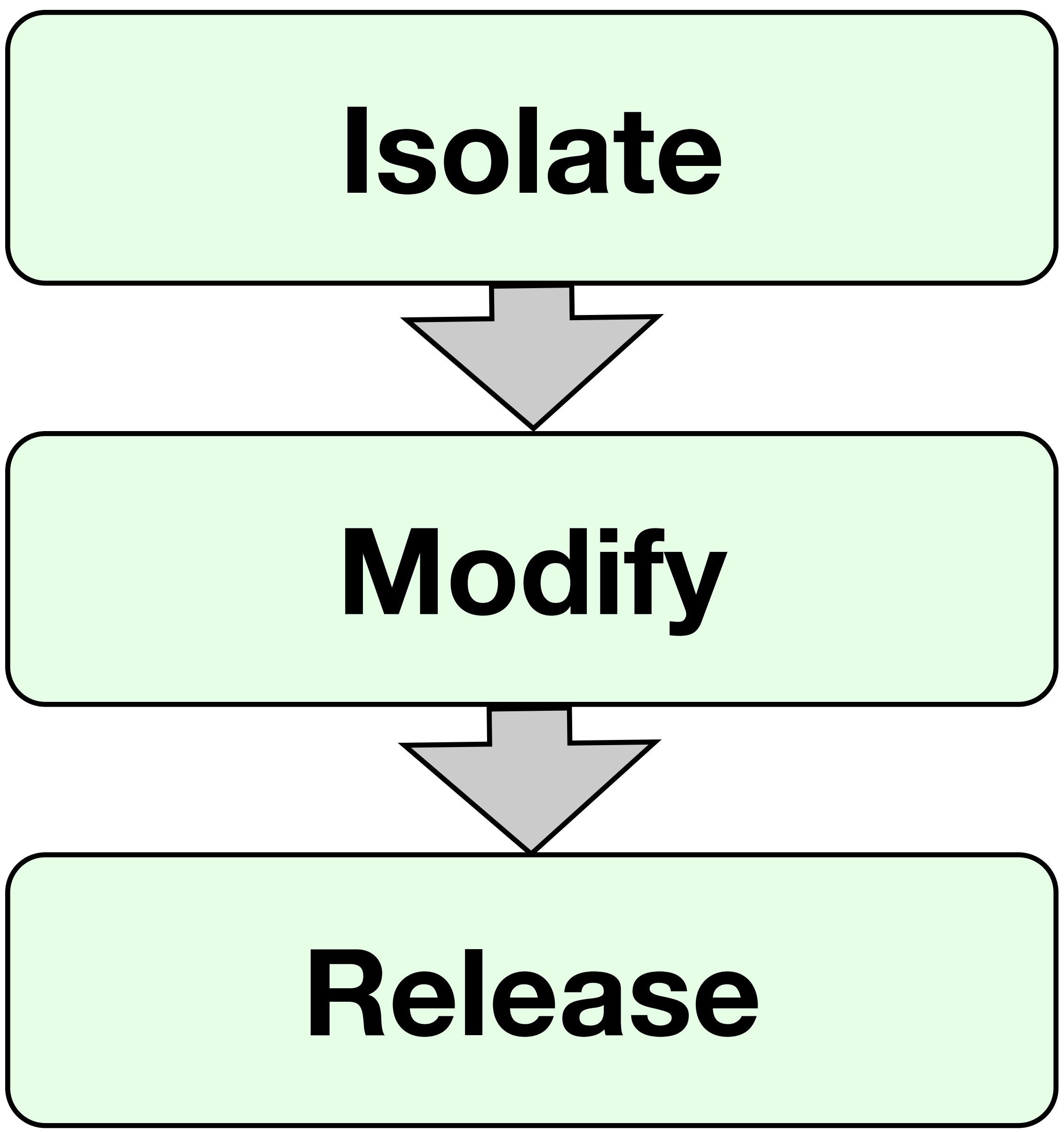


Software Patterns (IMR)



Stencil Patterns

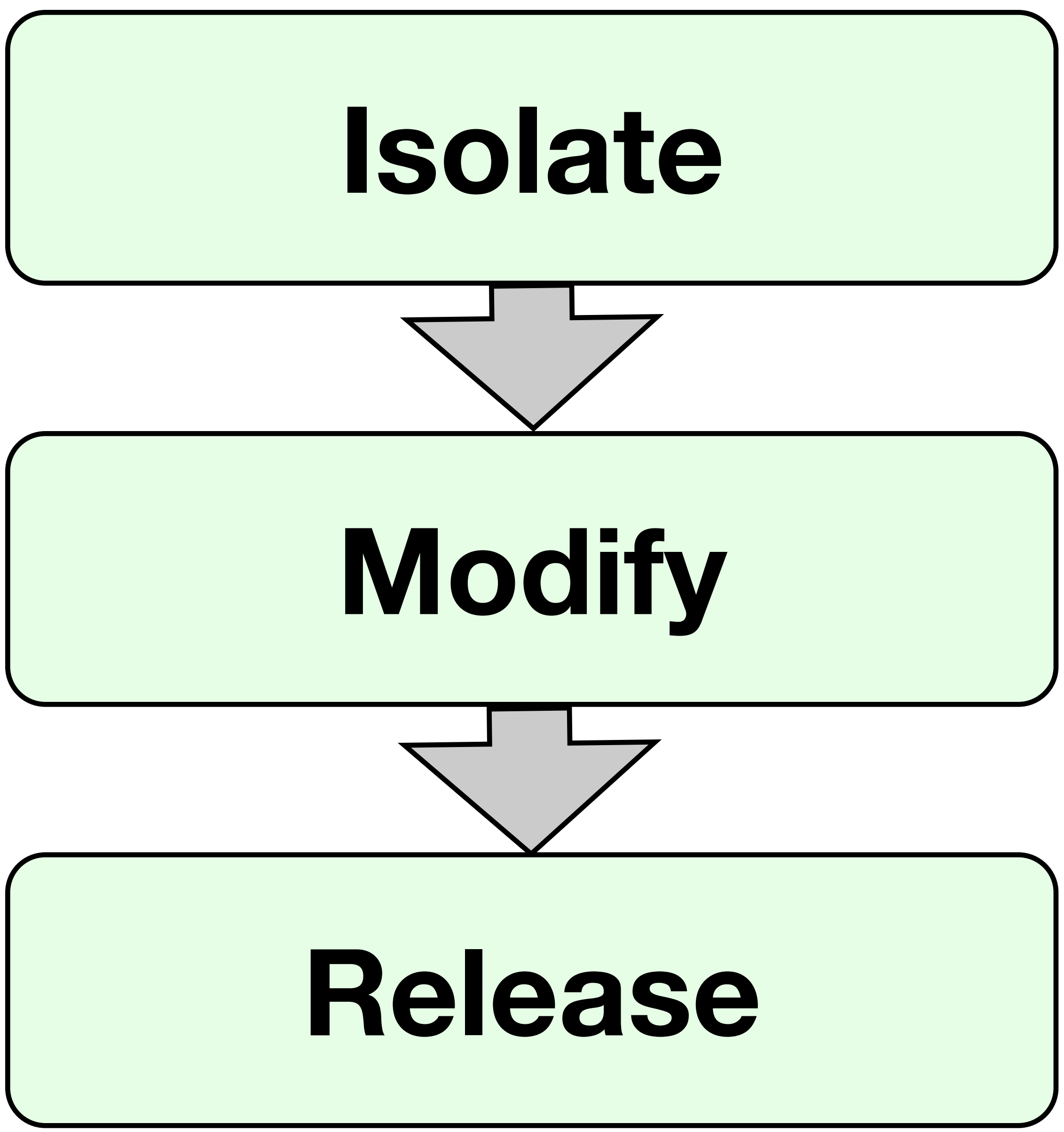
Software Patterns (IMR)



Stencil Patterns

List modification

Software Patterns (IMR)



Stencil Patterns

List modification

Tree Modification

Gaslamp Games

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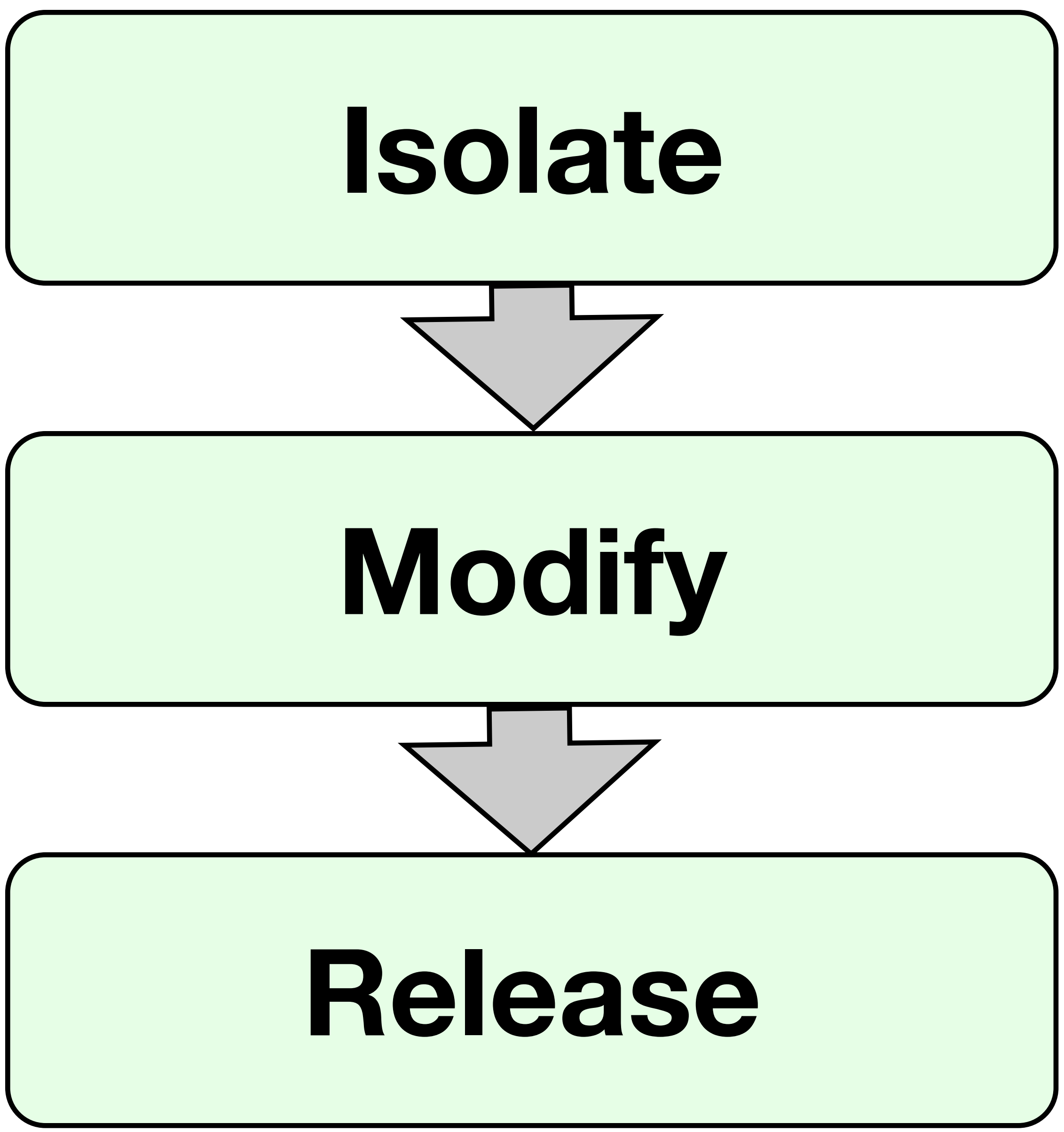
Software Patterns (IMR)



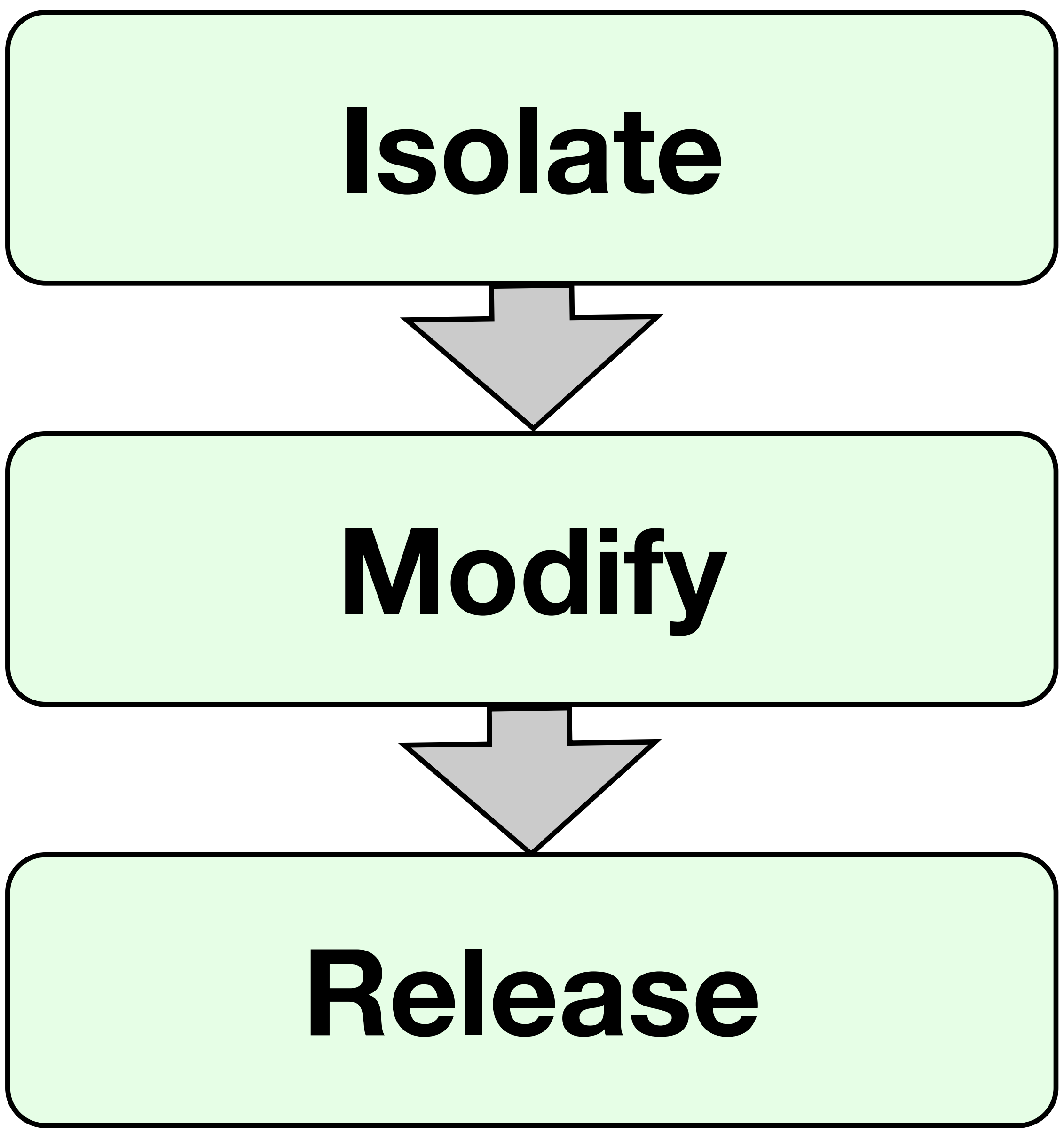
Stencil Patterns

List modification

Tree Modification

Graph Modification

Software Patterns (IMR)



Stencil Patterns

List modification

Tree Modification

Graph Modification

... more

Programming Support

Programming Support

‘First class’ collections

Programming Support

‘First class’ collections

Actor Model

Programming Support

‘First class’ collections

Actor Model + Messages

Programming Support

‘First class’ collections

Actor Model + Messages + Queries

Mental Models

Argument

Realization

Experience

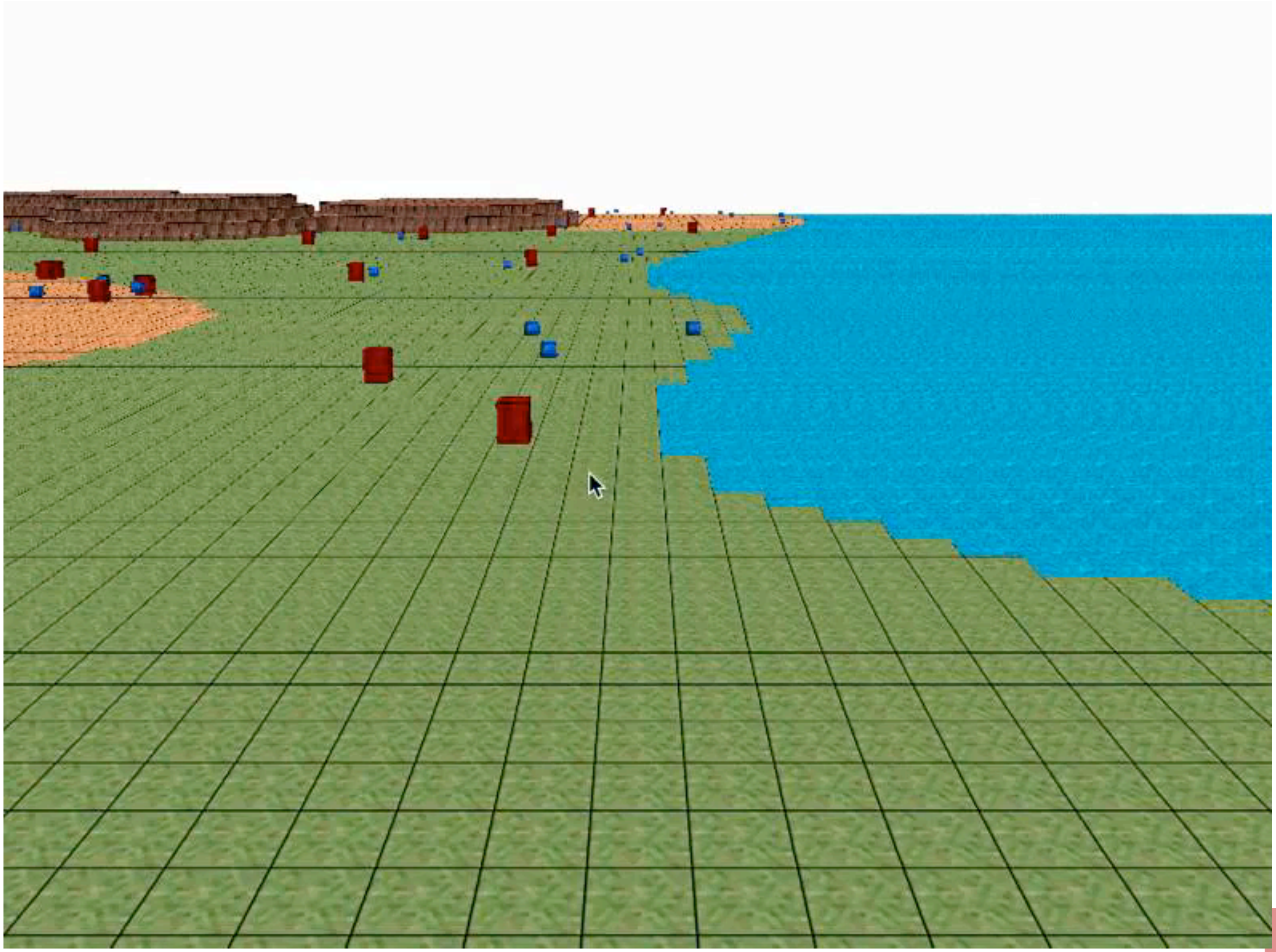
Mental Models

Argument

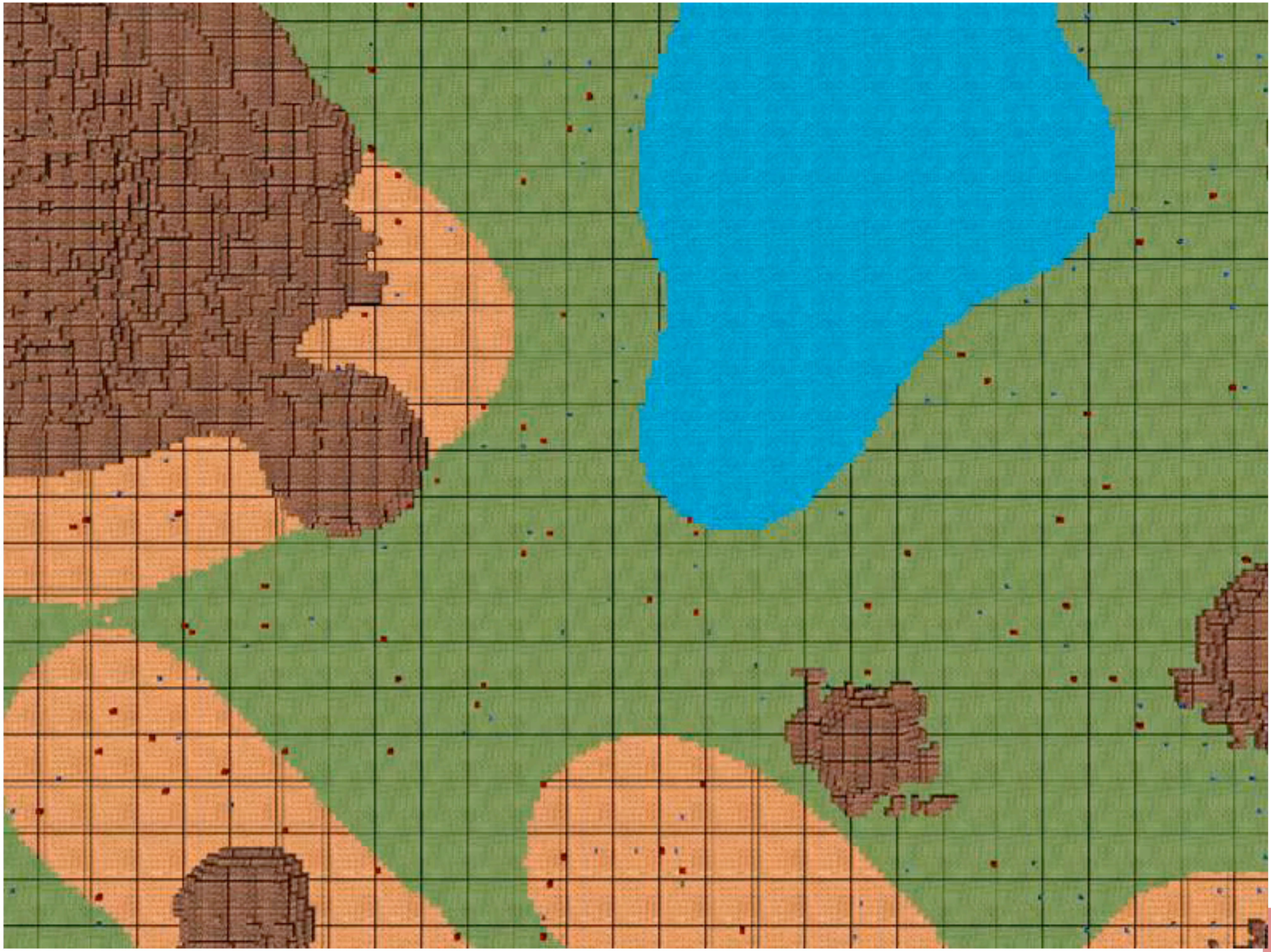
Realization

Experience

Experiments: spatialDictionary



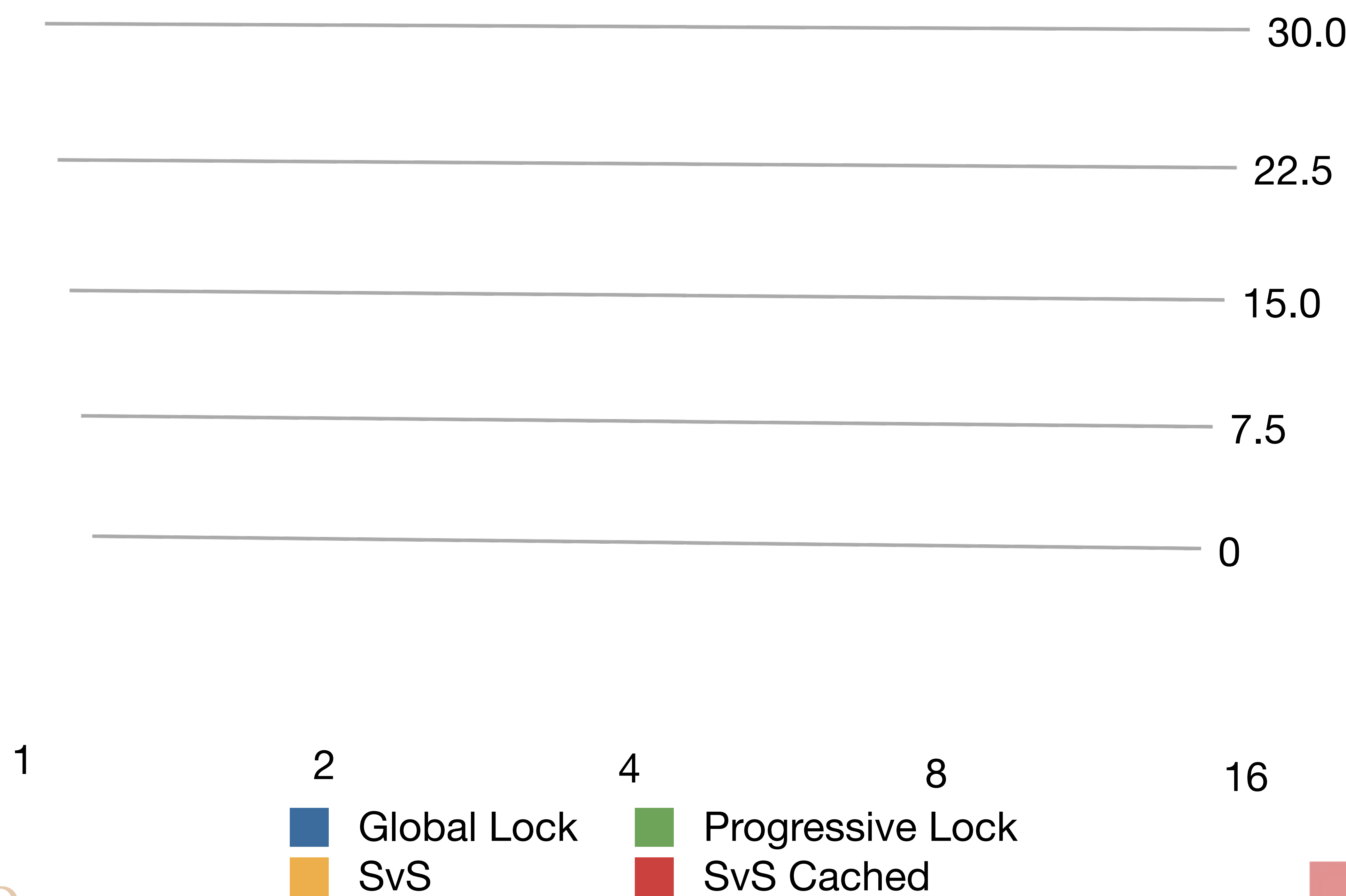
Experiments: spatialDictionary



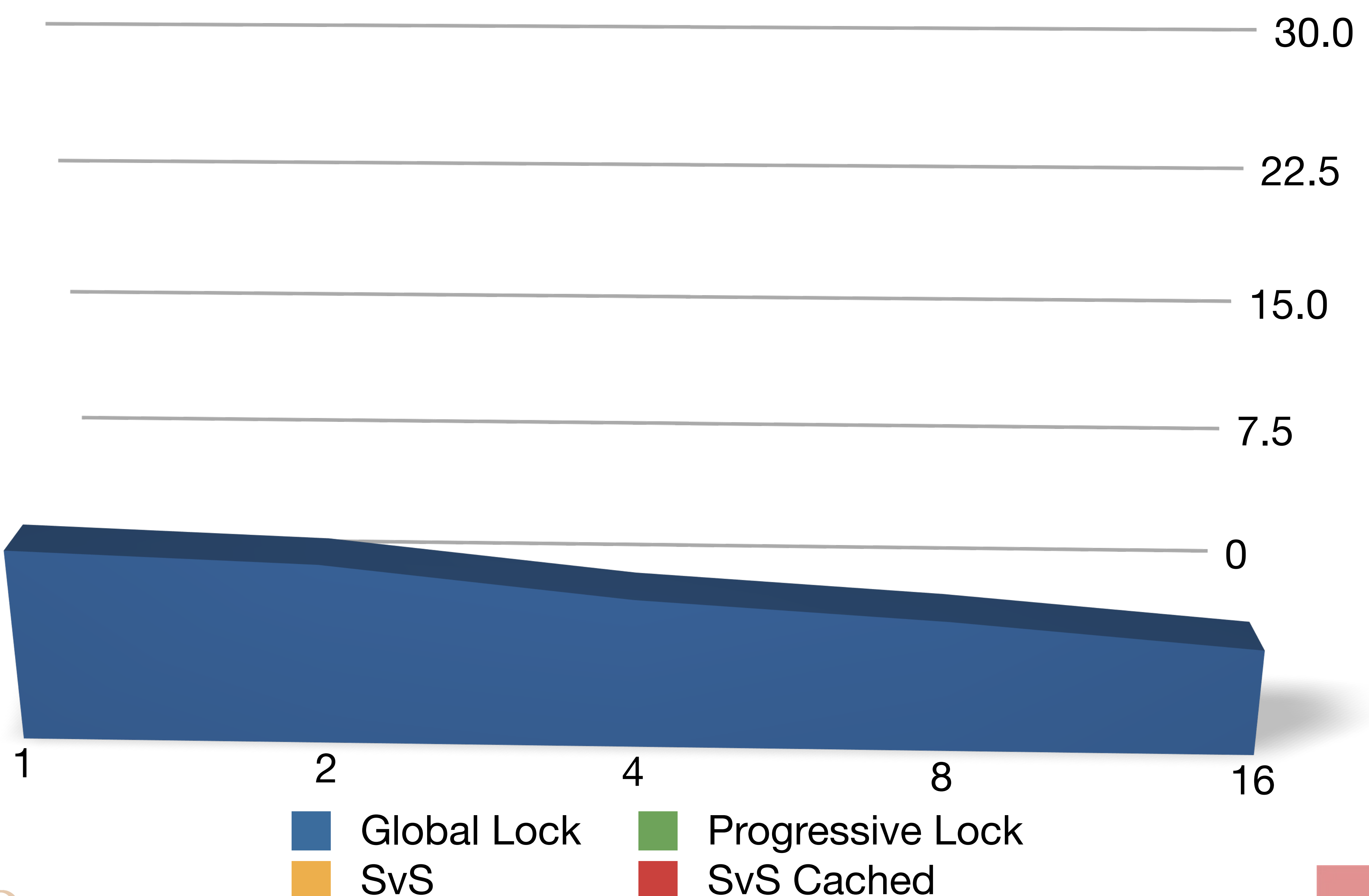
Experiments: spatialDictionary

Global Lock
Progressive Lock
SvS
SvS Cached

Experiments: spatialDictionary



Experiments: spatialDictionary



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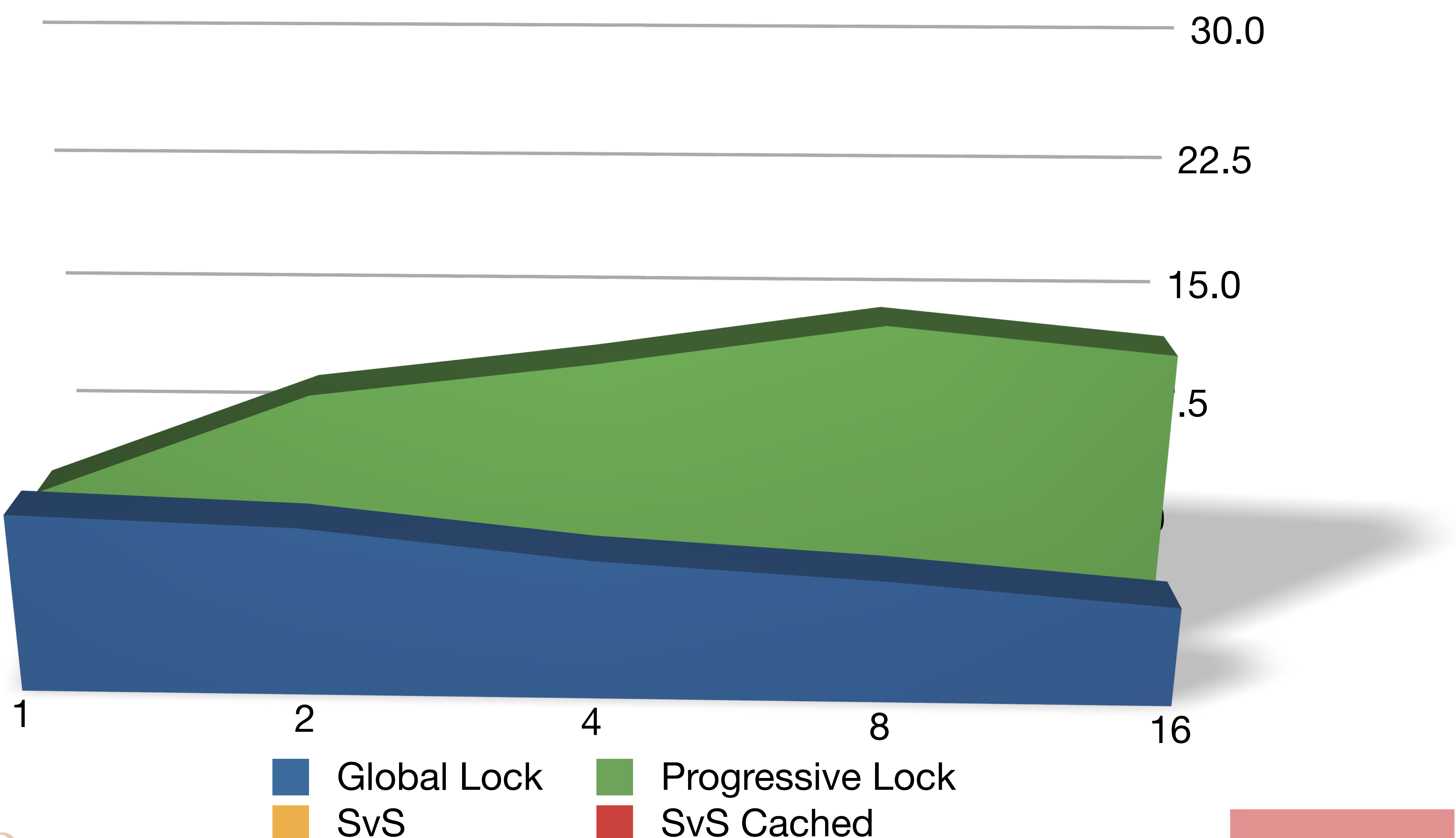
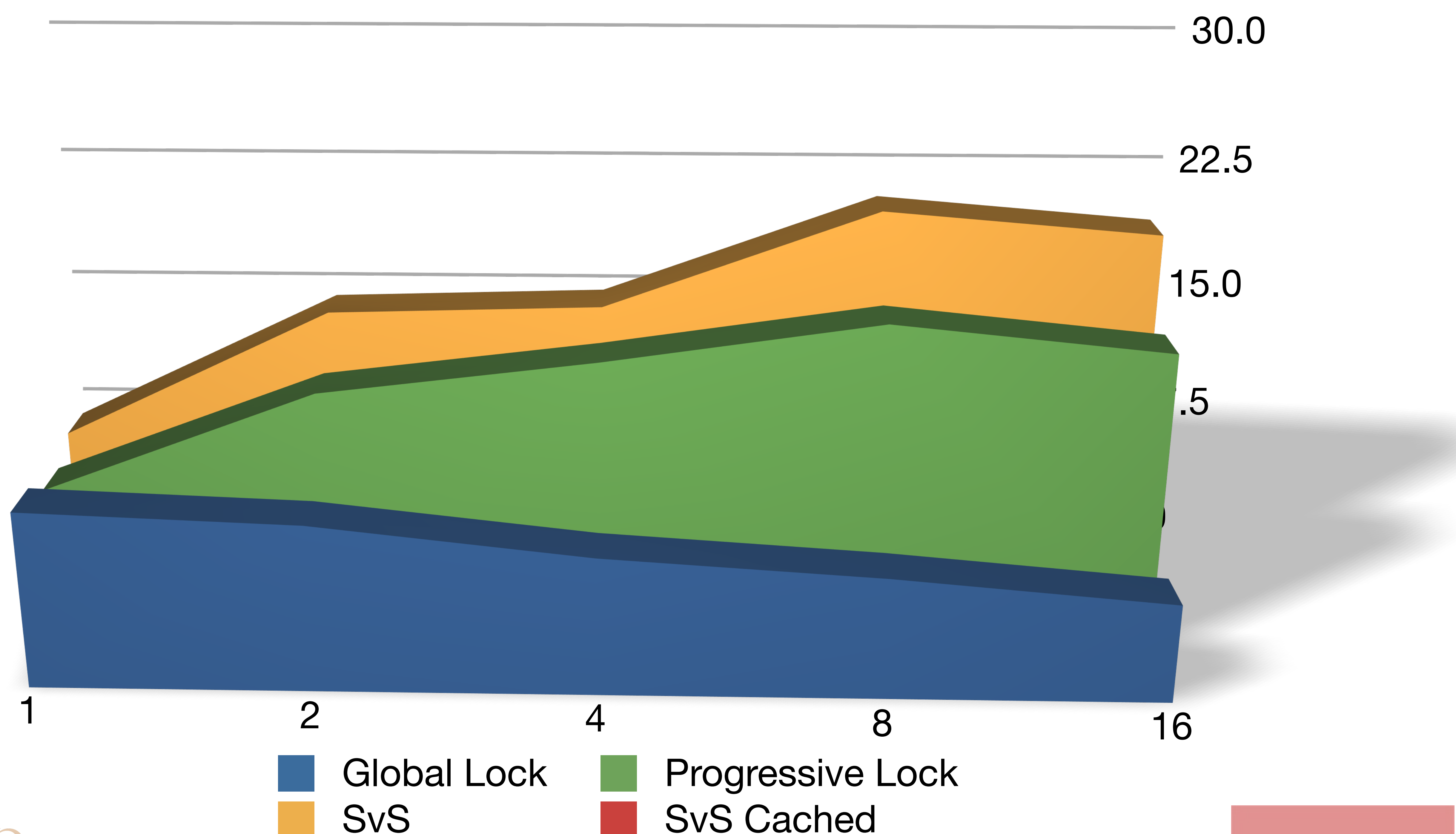
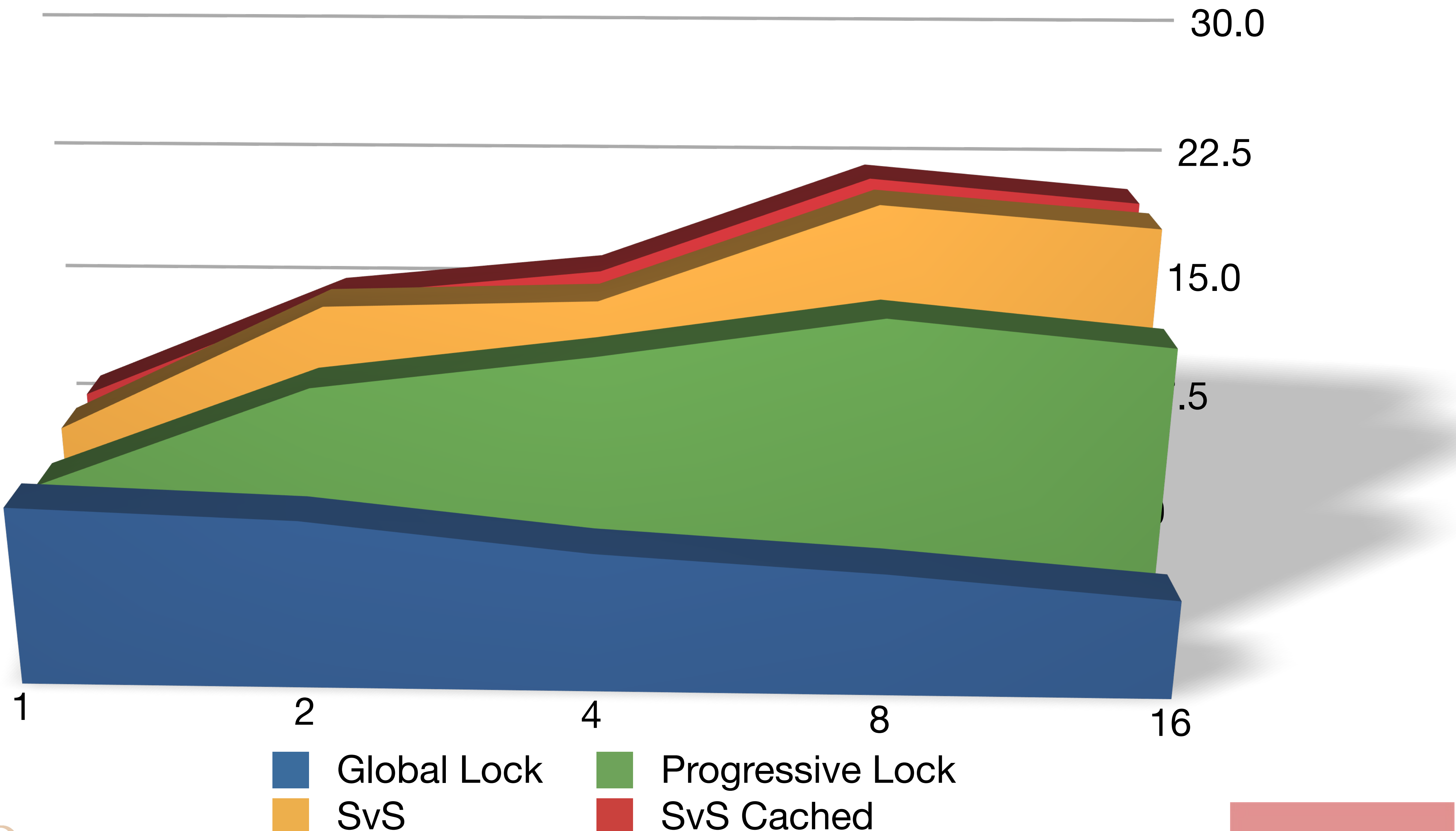
Experiments: spatialDictionary



Experiments: spatialDictionary



Experiments: spatialDictionary



Future Work

Future Work

Optimized scheduling

Future Work

Optimized scheduling

Robust query support

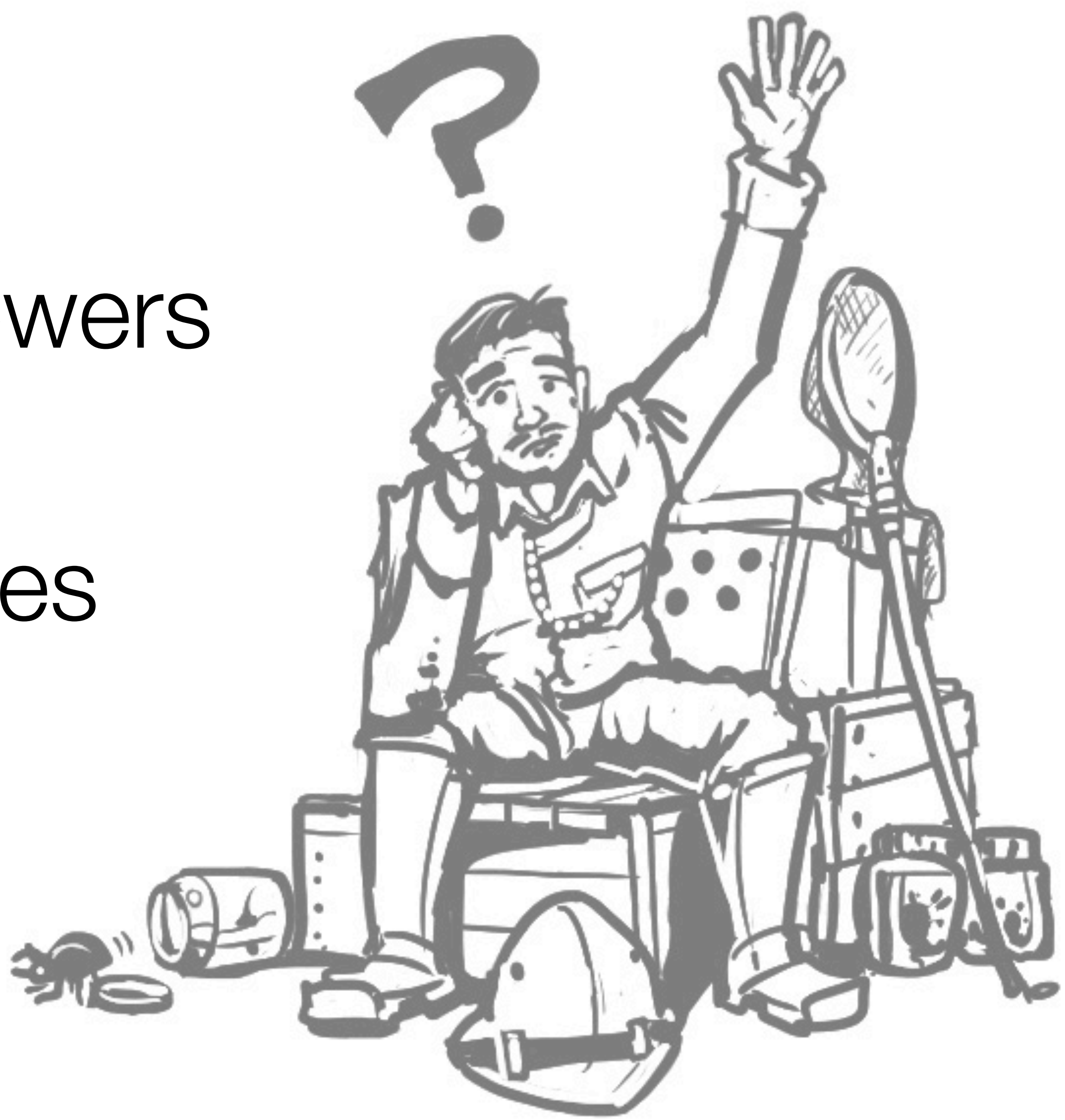
Questions

Questions

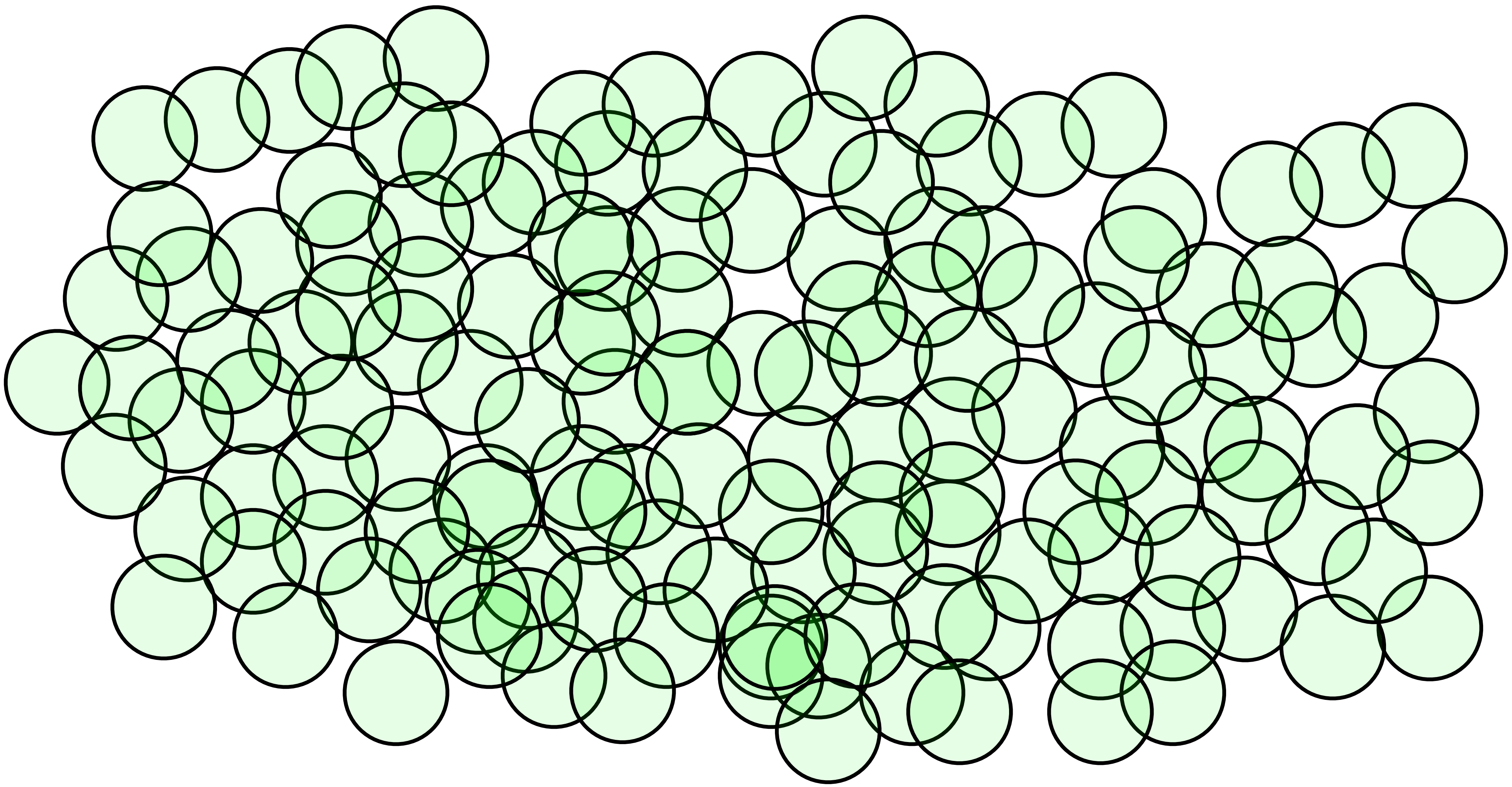
Thanks to

Anonymous reviewers

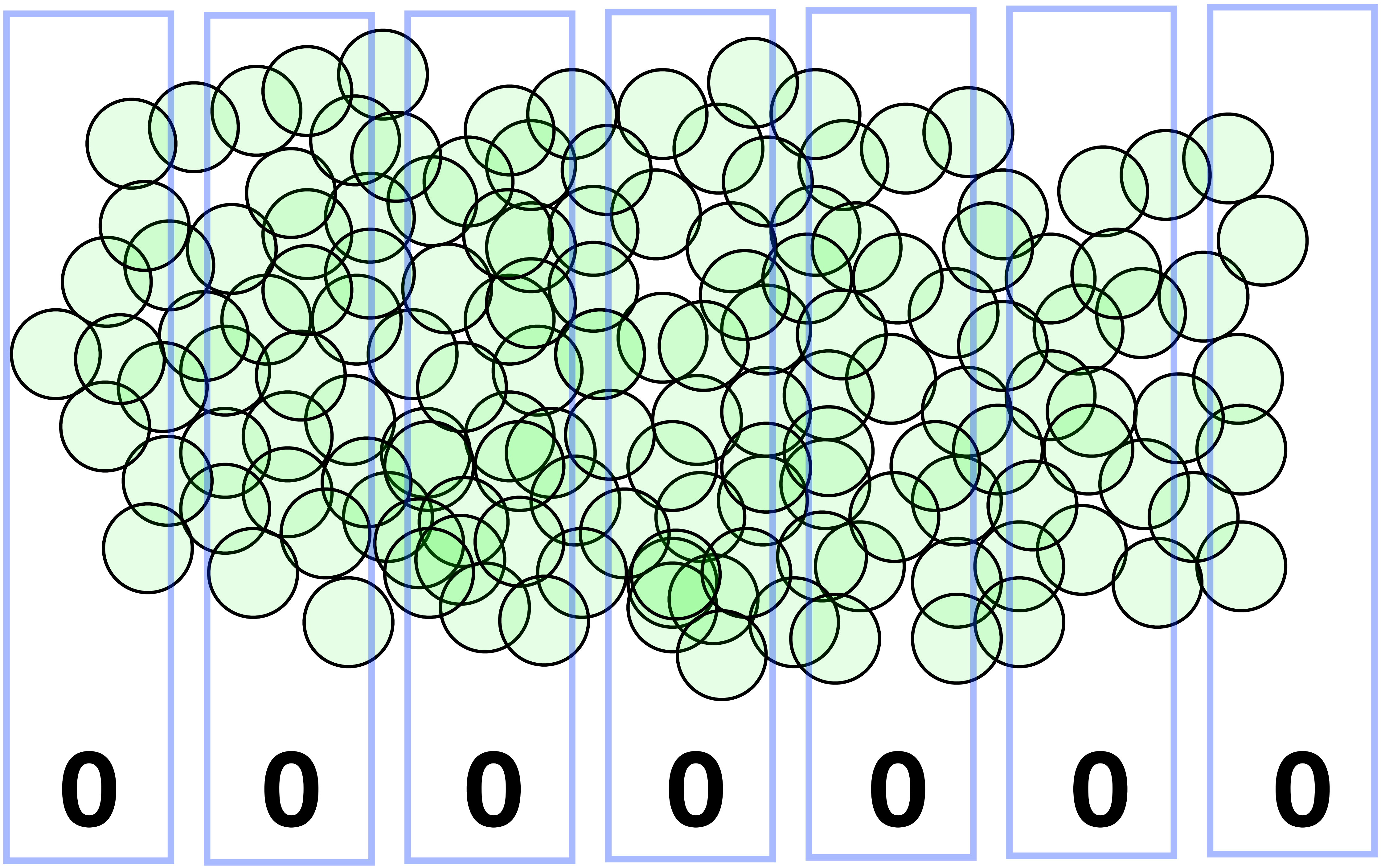
Gaslamp Games



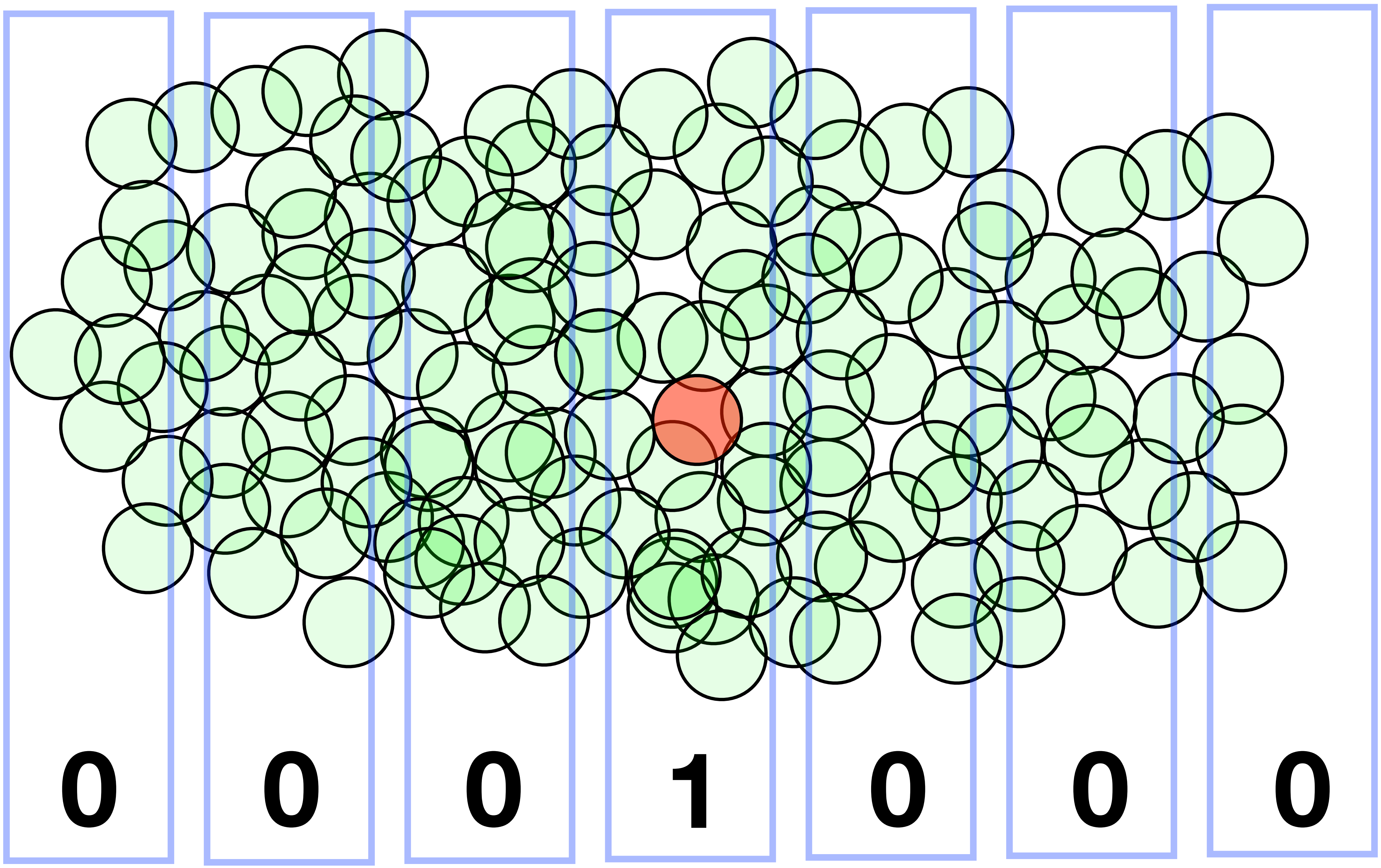
SvS - Signatures



SvS - Signatures



SvS - Signatures



SvS - Signatures

SvS - Signatures

composable

SvS - Signatures

composable

quick to compute and compare

SvS - Signatures

composable

only false positives for intersection

quick to compute and compare

SvS - Signatures

composable

easy to make arbitrarily precise

only false positives for intersection

quick to compute and compare

SvS - Signatures

composable

easy to make arbitrarily precise

only false positives for intersection

quick to compute and compare

separate evaluation of data items from synchronization

Preliminary Stuff

Preliminary Stuff

```
     inXspan( int x, int s ) : Cell I [  | I.x - x | <= s ]
     inYspan( int y, int s ) : Cell I [  | I.y - y | <= s ]
inRadius( ivec2 C, int r ) : Cell I [ inXspan<C> ( C.x, r )  and
                             inYspan<C>( C.y, r ) ]
```

Super preliminary warning!