Dynamic X10

Resource-Aware Programming for Higher Efficiency

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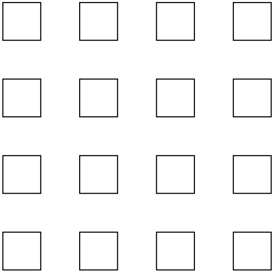
Motivation



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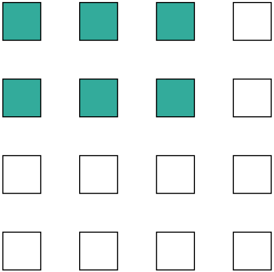

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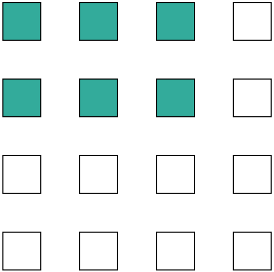

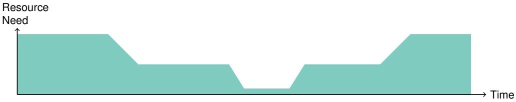

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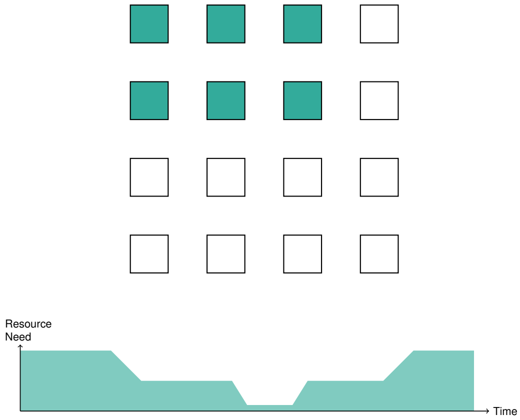
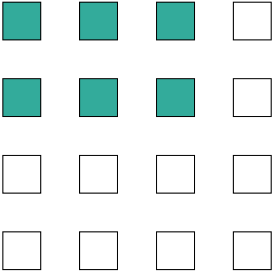


- Static exclusive resource allocation decreases overall efficiency

Dynamic Exclusive Resource Allocation

- Allocate resources exclusively
- But make the allocation dynamically changeable (i.e., at run-time)

⇒ Resizable claims



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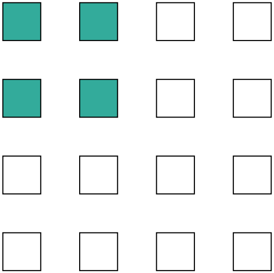

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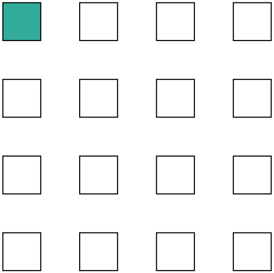

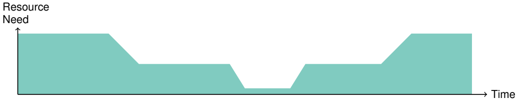

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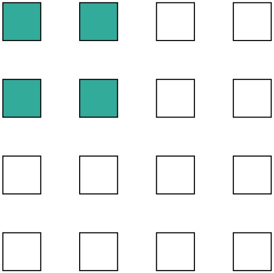

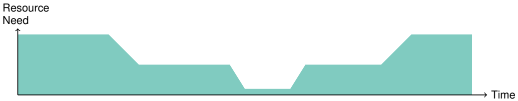

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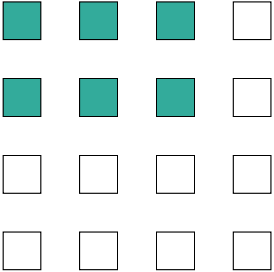
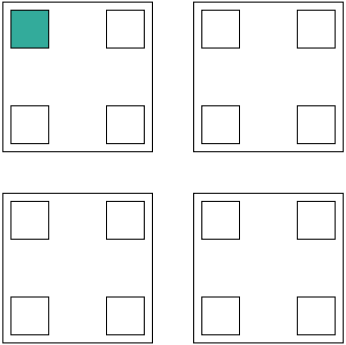


Scope of This Talk

Dynamic X10: framework for programming with resizable claims

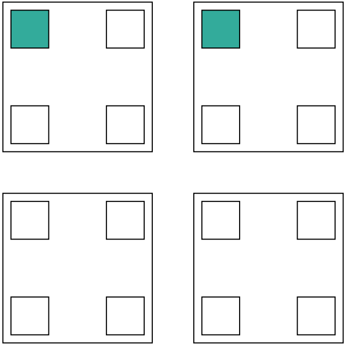
- Integration into existing X10: what needs to change?
- Resource management for improving global efficiency
- Brief evaluation of programming effort for developers

Claim Concept and X10



- Claim: set of cores with exclusive access
  - In general: different kinds of resources
- Application's view is restricted to resources in its claim

Claim Concept and X10



- Claims can be resized with method `reinvade()`
- Claims can span multiple shared-memory domains
  $\Rightarrow$ can contain multiple places

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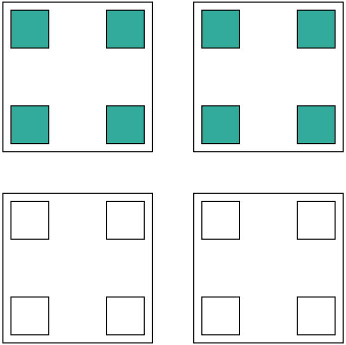

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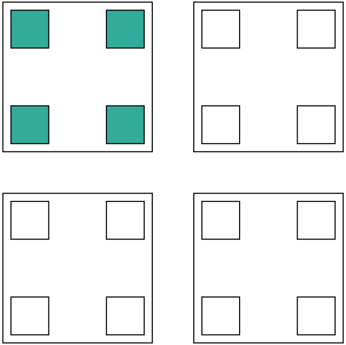
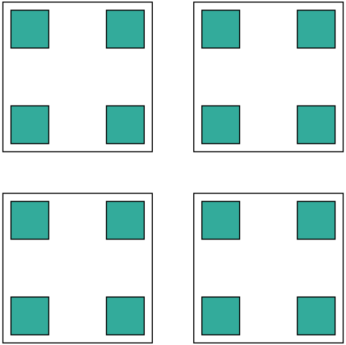


- Claims can be resized with method `reinvade()`
- Claims can span multiple shared-memory domains
  $\Rightarrow$ can contain multiple places
- Dynamic X10: places can *appear* and *disappear* at runtime

Claim Concept and X10

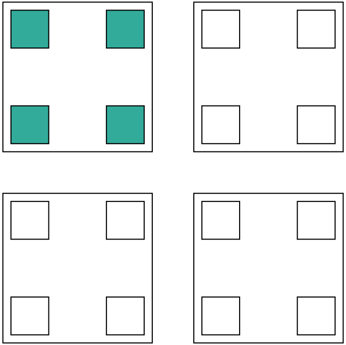


- Natural Embedding: Traditional X10 program behaves like Dynamic X10 program running inside claim containing all cores

Isolation using Multiple Claims

- Alternative to resizing existing claim: creating a *new* claim
- Useful property: isolation
  - Concurrent resizing requests using `reinvade()` $\Rightarrow$ bad
- Method to create and destroy claims: `invade()` and `retreat()`

Multiple Claims and X10



Multiple Claims and X10

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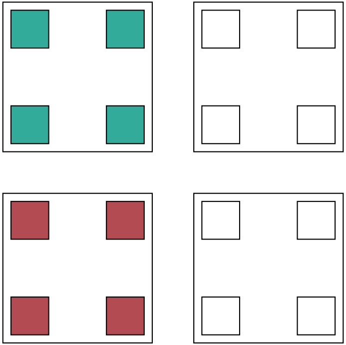

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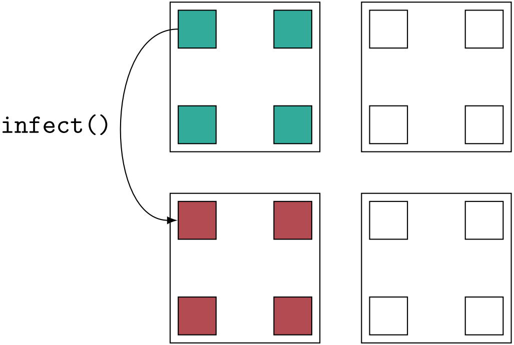

`infect()` ≙ `at` on claim-level

- Closure as argument (with deep copy semantics)
- Closure runs *inside* the new claim
- Navigation inside new claim with `at` and `async`

Example Usage

```
val claim = Claim.getCurrentClaim();
claim.reinvade(...);
at (here.next()) async { /* do work */ };
val newClaim = Claim.invade(...);
newClaim.infect(() => { /* do more work */ });
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Question: Who changes the allocation? And how?

The application

- No information about other claims

⇒ Does not optimize well in multi-application scenario

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Question: Who changes the allocation? And how?

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The operating system

- Not enough information about applications

⇒ Does not optimize well in multi-application scenario

Constraints

- Idea: pass application-specific information to OS

⇒ `invade()`/`reinvade()` take resource description: *constraints*

- Modeled as class hierarchy in X10, can be combined using `&&` and `||`
- Most important: `PEQuantity` and `ScalabilityCurve`

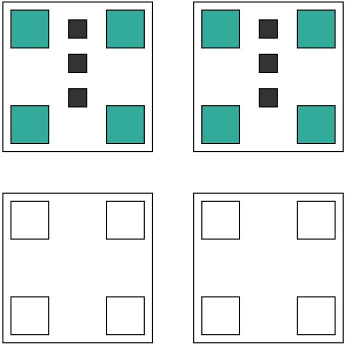
```
Claim.invade(new PEQuantity(1, 3)
             && new ScalabilityCurve([130, 150, 160]));
```

- Scalability information via offline experiments or online monitoring

Necessary X10 Adaptions

1. Static fields $\rightarrow$ methods
   - `Place.MAX_PLACES` $\rightarrow$ `Place.maxPlaces()` to query current claim
2. Adapt method implementations
   - `Place.places()` must query current claim
3. Usage of `DistArray`s

DistArrays



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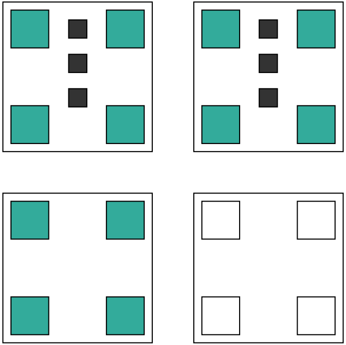

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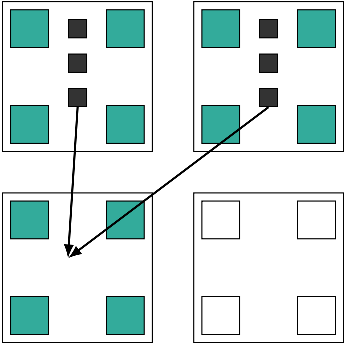
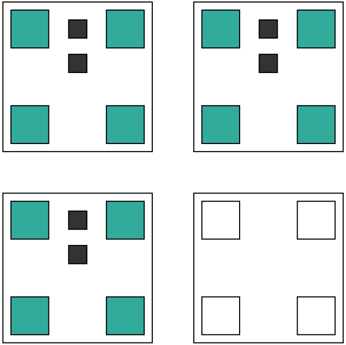


- Create new `DistArray`, move data (library routine)

DistArrays



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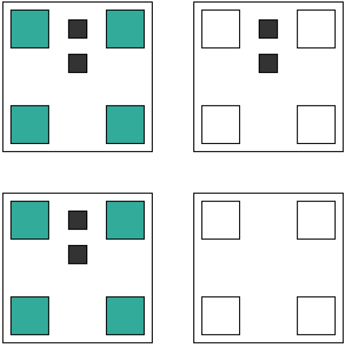

- What if we lose places? ⇒ data inaccessible

DistArrays

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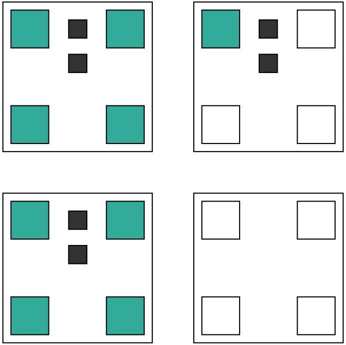
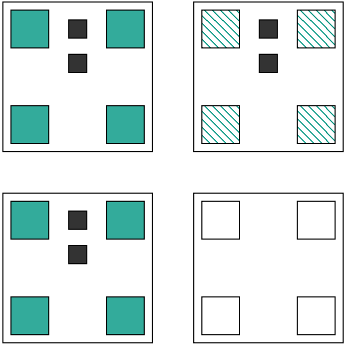


Solution 1: “Sticky claims”

- Forbid losing places
- Simple, but severely restricts reallocation $\Rightarrow$ decreased efficiency

DistArrays



Solution 2: Give opportunity to redistribute

- Requires programmer effort
- More flexible resource reallocation

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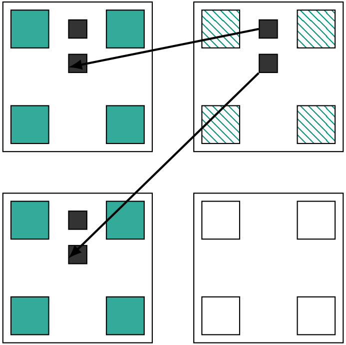

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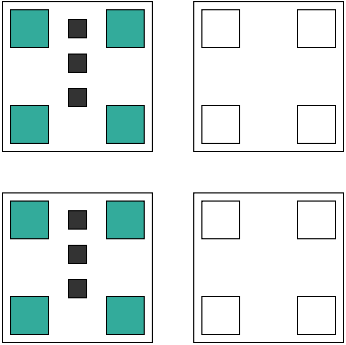

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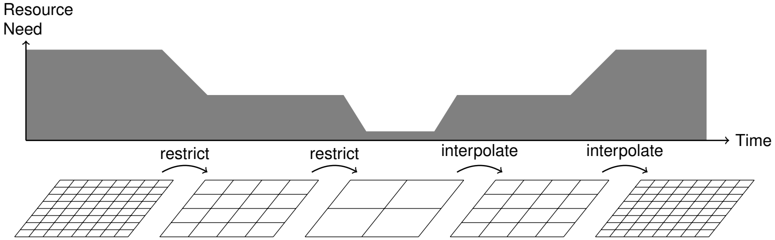
Preliminary Evaluation: Multigrid



- Prototype implementation of Dynamic X10
- Multigrid: Calls `reinvade()` when resizing grid
  - Uses grid size to compute number of cores
- Prototype uses sticky claims $\Rightarrow$ no disappearing places
- `DistArray` redistribution after `reinvade()`
- $\approx$ 50 lines of additional code compared to traditional X10

Conclusion

We have:

- Integrated claim concept and dynamic exclusive allocation into X10
- Adapted X10 to deal with varying number of places
- Shown that constraints can solve resource management problem
- Implemented a first version of “Dynamic X10”
- Given a preliminary evaluation of programming effort

Backup: Shared Memory Systems

Neither exclusive, nor static resource allocation:

- Resource virtualization: threads instead of CPUs
- Threads multiplexed onto physical cores

Not for free:

- #threads $\gg$ #cores
- Cache issues
- Scheduler has no application-specific knowledge (e.g., barrier synchronization)

Backup: Invasive Computing

- Dynamic X10 implemented in the scope of “Invasive Computing” project
- Looks at future tiled many-core architectures ($>$ 1000 cores)
  - Share characteristics of supercomputers
- Custom operating system
  - Claims as central data structure
  - Claim-aware scheduler