Aggregate Programming
Part 3: Application Examples

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Aggregate Programming Stack

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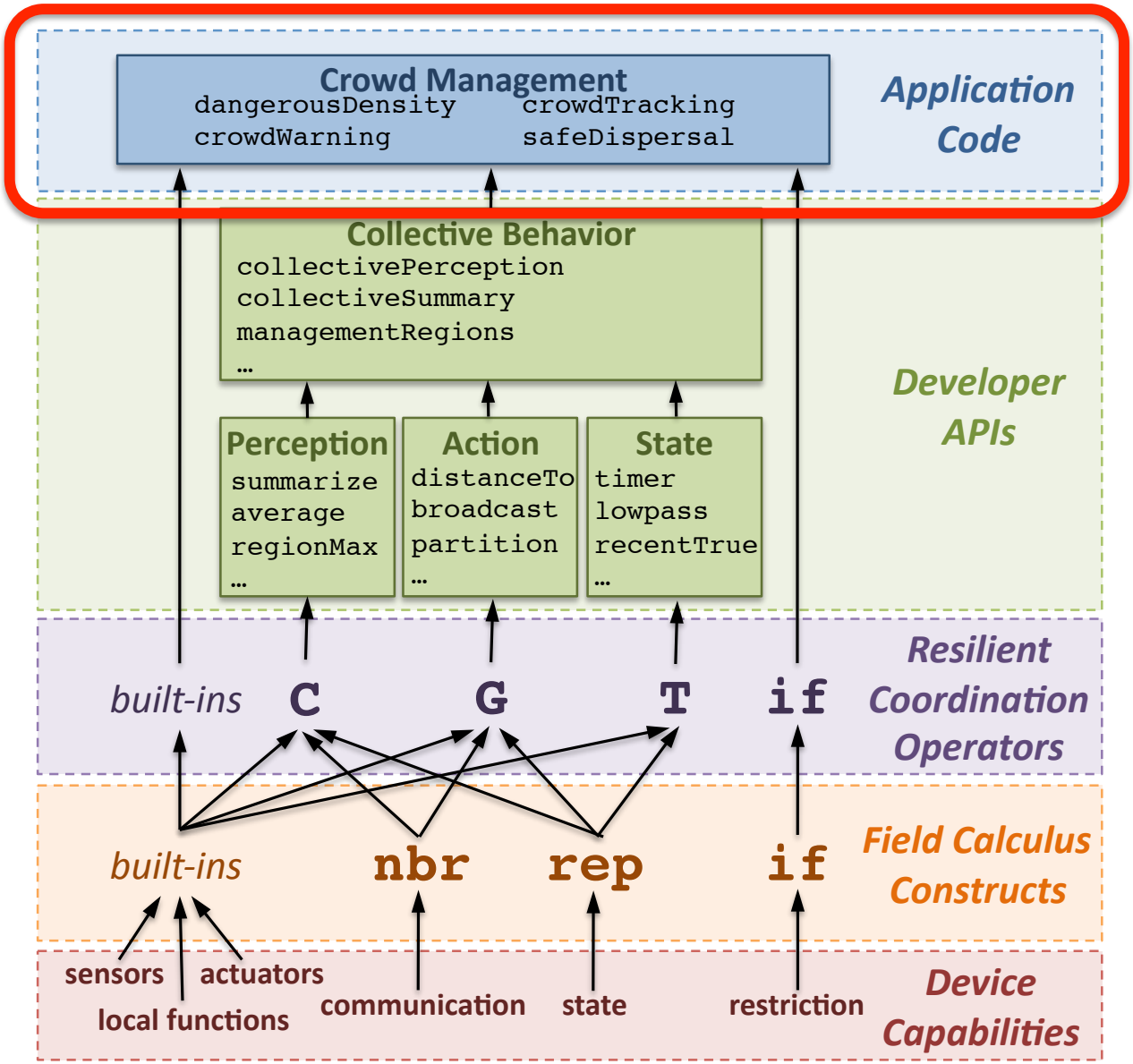

Crowd Safety Services

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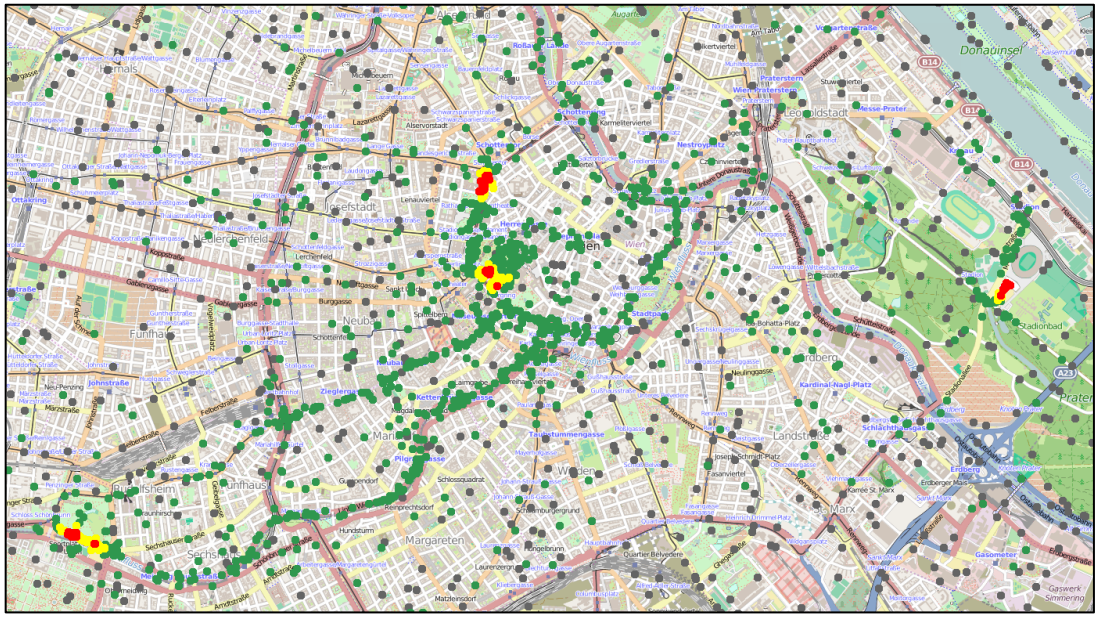
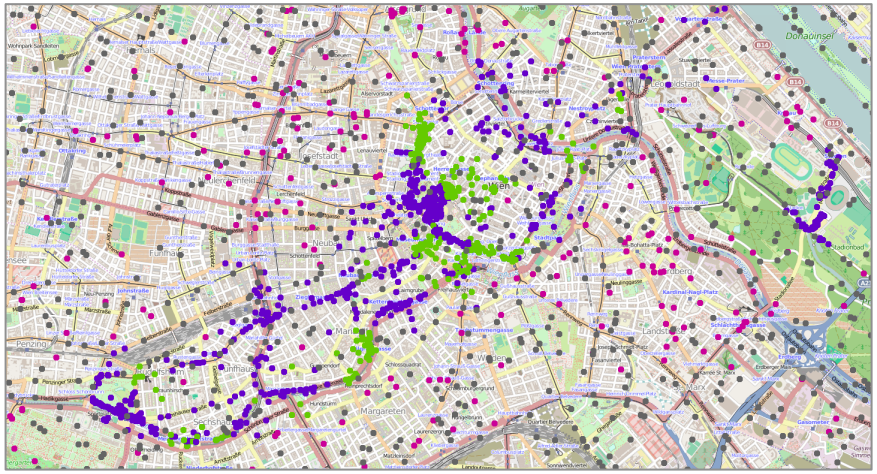
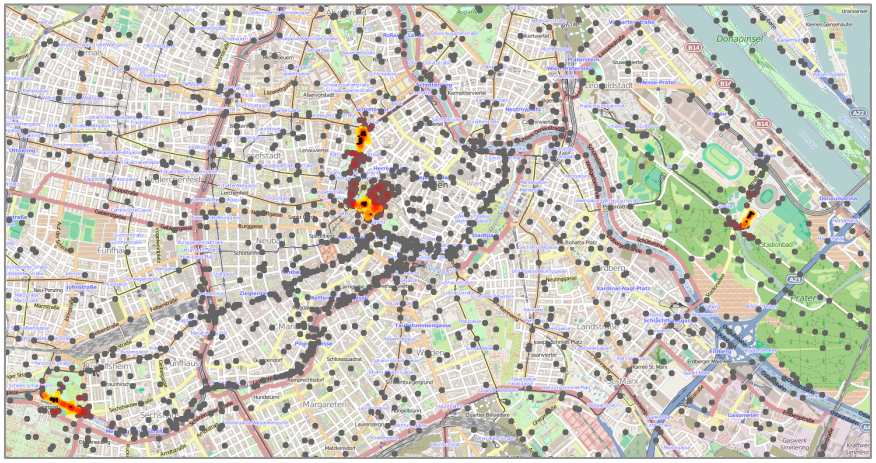


```
def dangerousDensity(p, r) {
  let mr = managementRegions(r*2, () -> { nbrRange });
  let danger = average(mr, densityEst(p, r)) > 2.17 &&
               summarize(mr, sum, 1 / p, 0) > 300;
  if(danger) { high } else { low }
}
def crowdTracking(p, r, t) {
  let crowdRgn = recentTrue(densityEst(p, r)>1.08, t);
   if(crowdRgn) { dangerousDensity(p, r) } else { none };
}
def crowdWarning(p, r, warn, t) {
  distanceTo(crowdTracking(p,r,t) == high) < warn
}
```

Dissemination of new versions



Pre-emptive modulation of priorities



Dependency-Directed Recovery

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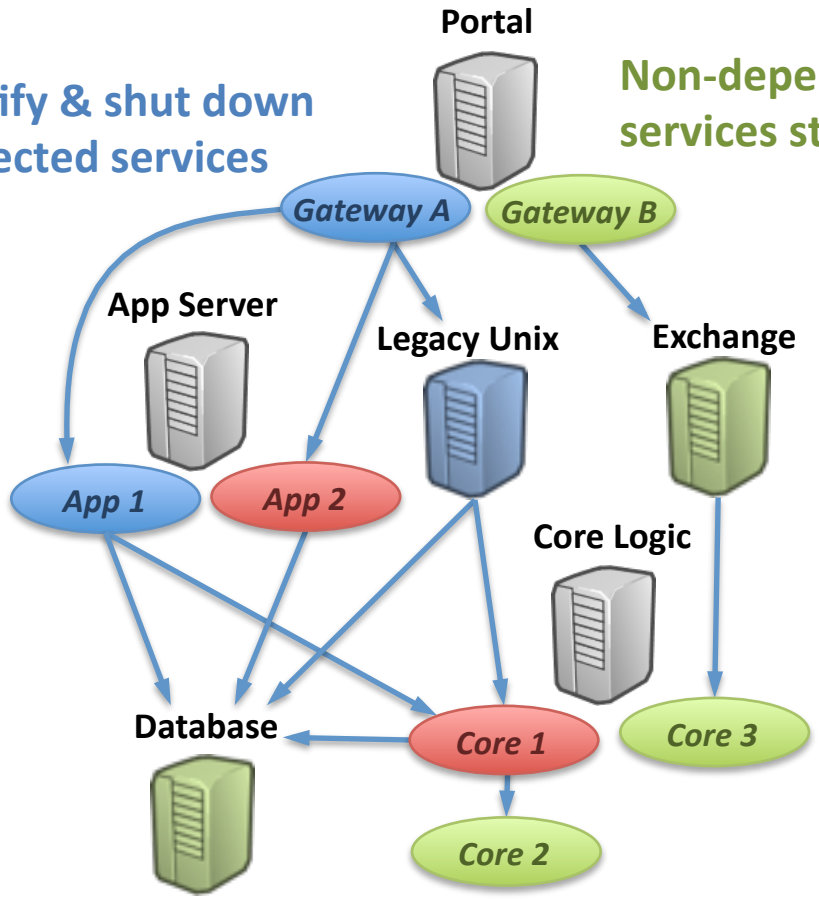
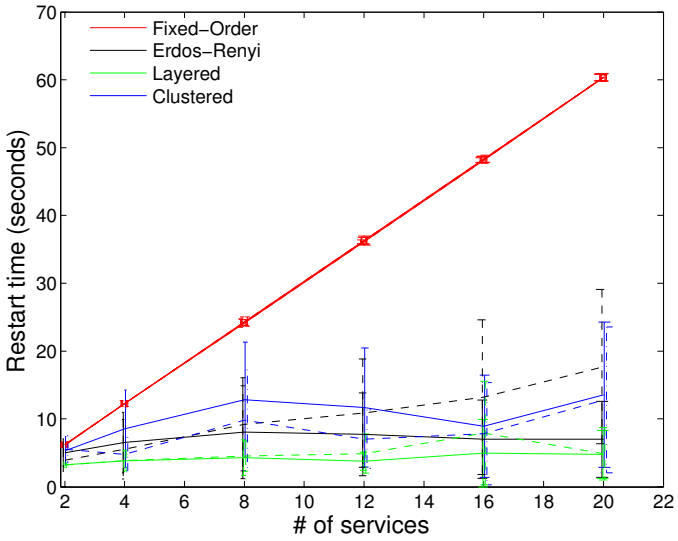
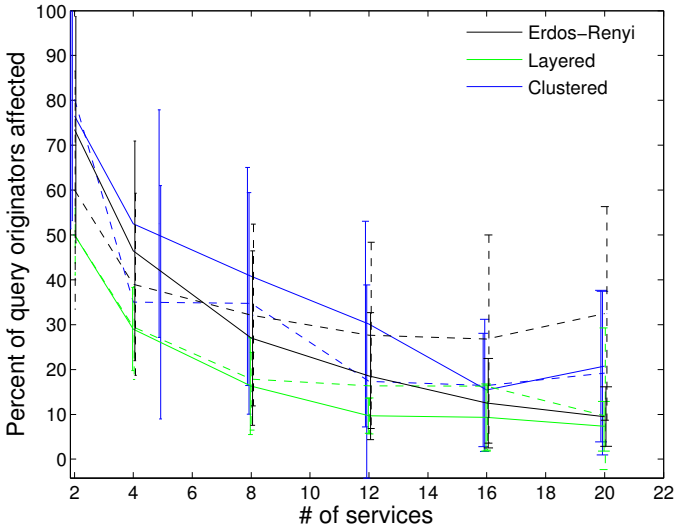


Dramatically better recovery time



Fewer services disrupted



[Clark, Beal, & Pal, SASO '15]

DDR Algorithm

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```
// Collect state of monitored service from service manager daemon
let status = self.getEnvironmentVariable("serviceStatus");
let serviceID = self.getEnvironmentVariable("serviceID");
let depends = self.getEnvironmentVariable("dependencies");
let serviceDown = status=="hung" || status=="stop";

// Compute whether service can safely be run (i.e. dependencies are satisfied)
let liveSet = if(serviceDown) { [] } else { [serviceID] };
let nbrsLive = unionHood(nbr(liveSet));
let liveDependencies = nbrsLive.intersection(depends);
let safeToRun = liveDependencies.equals(depends);

// Act based on service state and whether it is safe to run
if(!safeToRun) {
  if(!serviceDown) {
    self.stopService() // Take service down to avoid misbehavior
  } else { false } // Wait for dependencies to recover before restarting
} else {
  if(serviceDown) {
    self.restartService() // Safe to restart
  } else { false } // Everything fine; no action needed
}
```

Opportunistic Airborne Sensor Sharing

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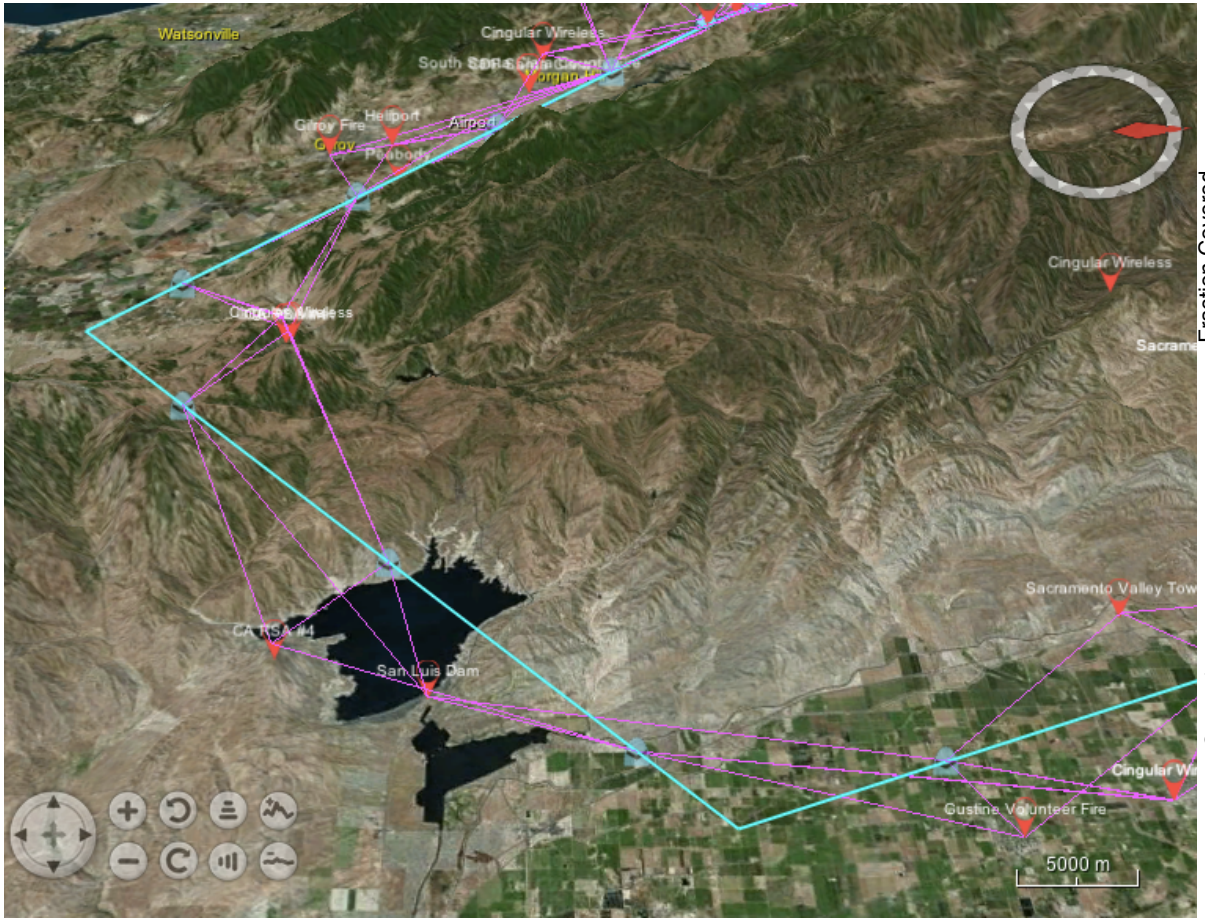
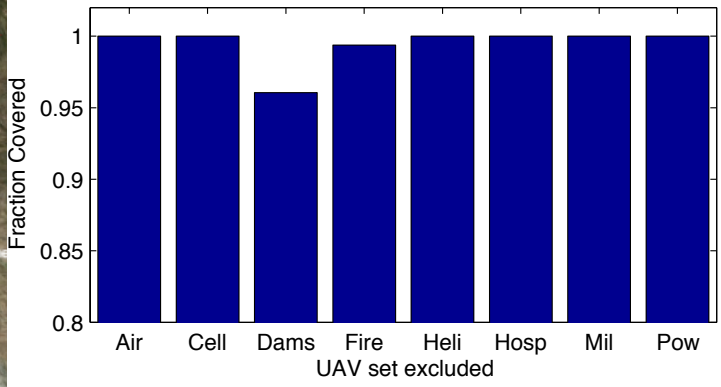
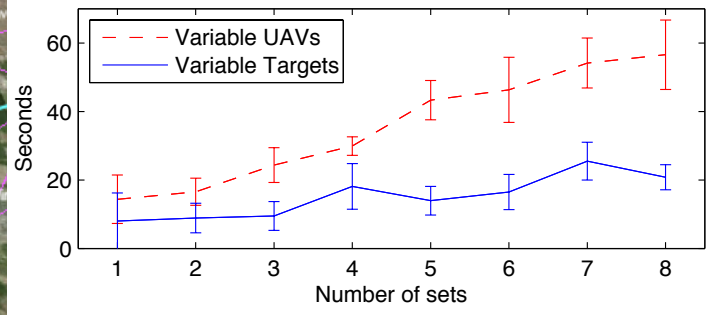
GIS-integrated adaptive mission planning



Highly effective sharing



Low computational cost



[Beal, Usbeck, Loyall & Metzler, *in prep*]

Distributed Rewind and Replay

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Tactical Cloud Services

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Swarm Command & Control

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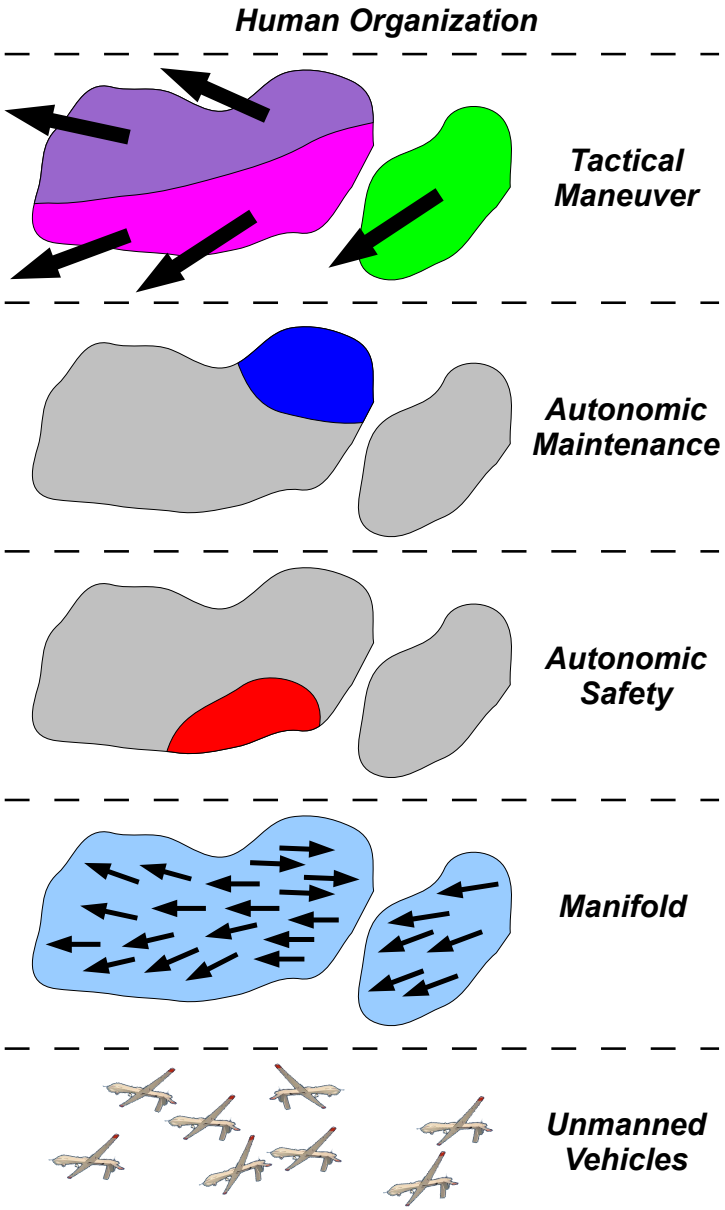
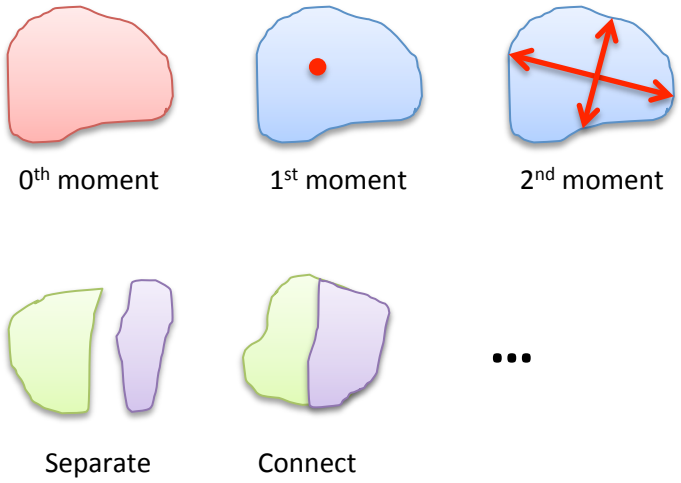


- Build on top of continuous space model with:
  - Modulation by autonomic management layers
  - Basis set of "maneuvers"



[Beal, 2012]

Agent-Based Simulations

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[Beal et al., 2012]

Engineering Biological Systems

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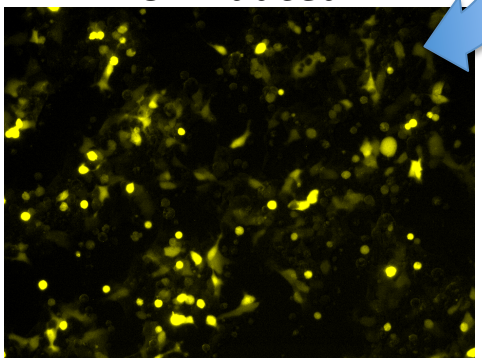
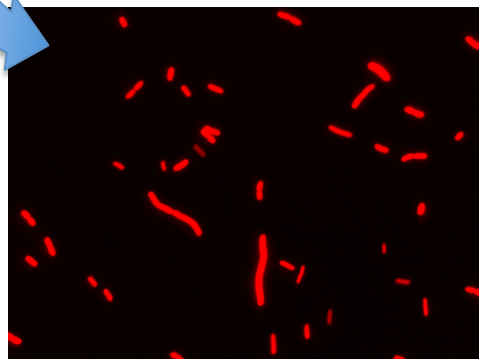
```
(def simple-sensor-actuator ()
  (let ((x (test-sensor)))
    (debug-1 x)
    (debug-2 (not x))))
```

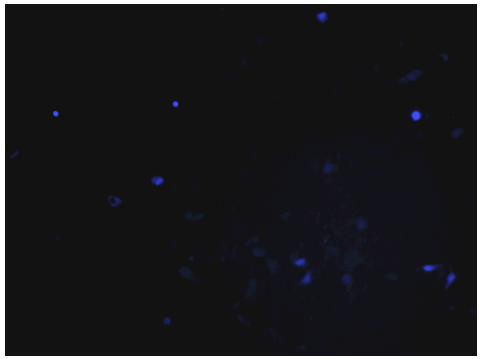
Uninduced



Uninduced



Induced



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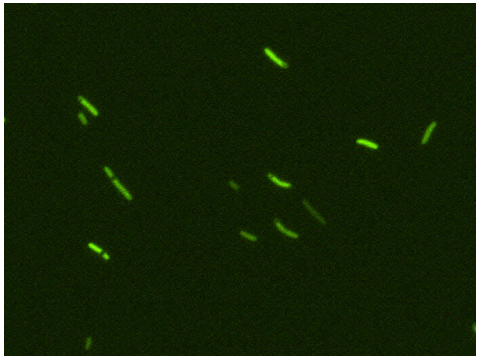
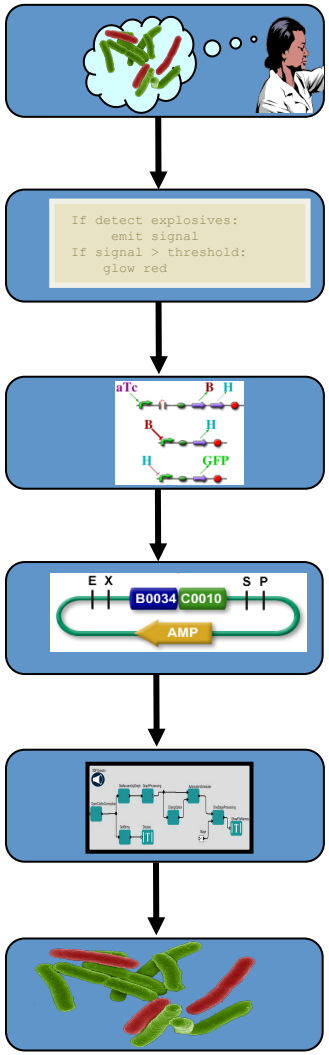


Mammalian Target

E. coli Target



[Beal et al., 2012]

Summary: Aggregate Methodology

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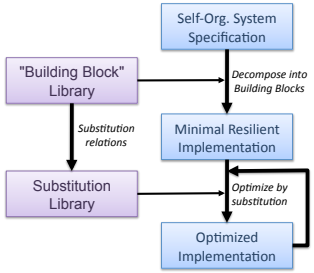

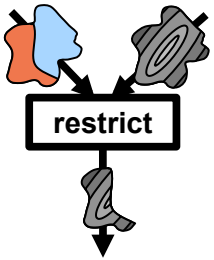

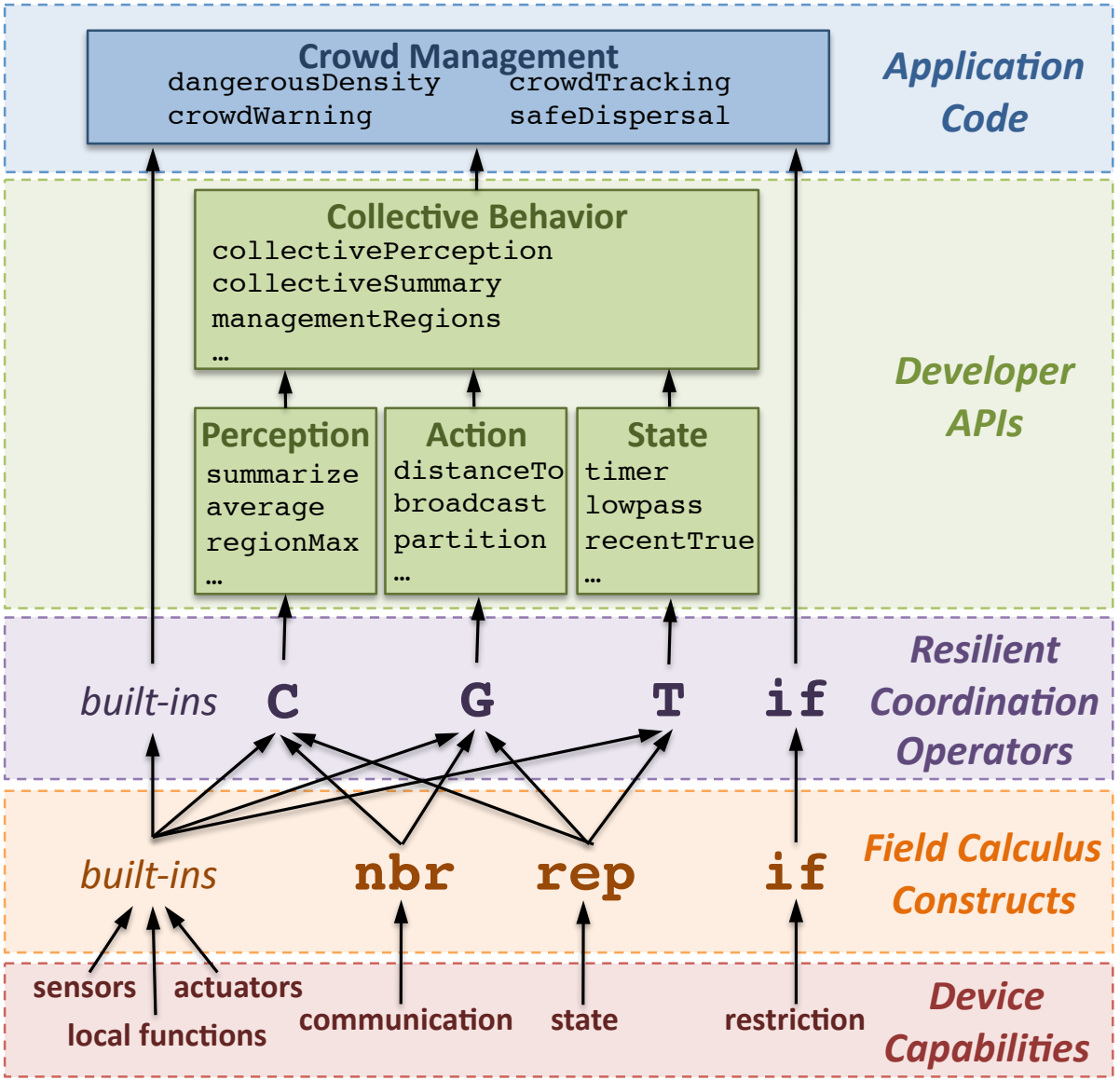

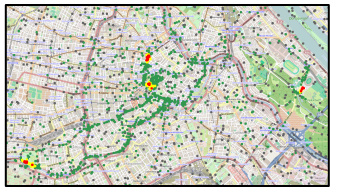

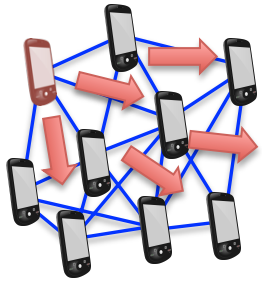

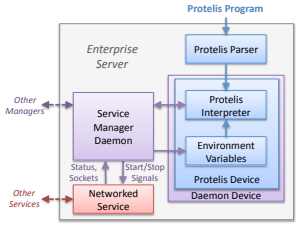

Summary

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- Major technological trends are all driving towards a world filled with distributed systems
- Aggregate programming aims at rapid and reliable engineering of complex distributed systems
- Field calculus provides a universal theoretical foundation for aggregate programming
- Resilient systems design can be simplified by an emerging self-organization toolbox
- Functional composition allows modulation, predictable convergence

Lots of open problems…

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- Many field calculus results may be more generally applicable to all distributed systems
- Extent of basis set needed for various domains
- What implicit propeties are needed/possible for building block algebras and libraries?
- Extension to mobile devices, ongoing changes
- Prediction of approximation quality – “Nyquist”
- Open environments and security

But we’ve already enough for many applications...

Bibliography

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