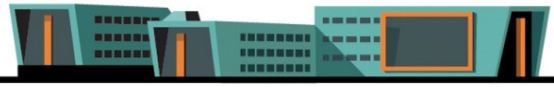
Bio-Inspired Mechanisms for Coordinating Multiple Instances of a Service Feature in Dynamic Software Product Lines

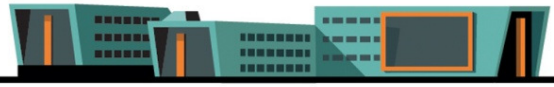
Jaejoon Lee, Jon Whittle, and Oliver Storz

School of Computing and Communications
Lancaster University



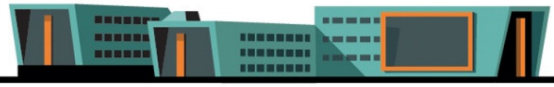
Outline

- Background
- Focus
- A Motivating Example: Next Generation Smart Homes
- Three Techniques
- An Initial Prototype
- Summary



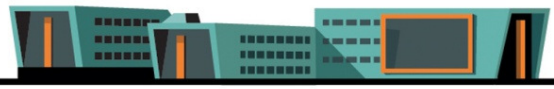
Background

- Bio-SCALE: This project aims to kick-start a major new interdisciplinary effort in bio-inspired software engineering
  - the development of breakthrough paradigms for engineering next generation assisted living environments,
  - inspired by the self-organizing capabilities of organisms.
- Towards developing new software composition mechanisms for significantly improving maintainability, scalability, and dependability of assisted living systems.



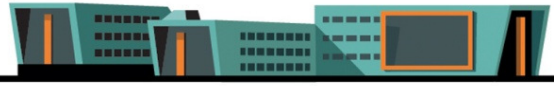
Background

- Assisted living systems (ALSs) are a form of smart home that coordinate a set of software services to provide supervision of or assistance with daily living activities.
- The state-of-the-art in software systems development for ALSs is that, in practice, it is manually-intensive and time-consuming to modify the service configuration (e.g., to add a service with a new interface).
  - Human engineers must get involved in complex integration tasks to integrate new services, as well as challenging retuning tasks to ensure that overall system goals are maintained.
- This heavy requirement on human intervention is a major barrier to the future progress of ALSs because it prevents the ALS vision whereby homeowners purchase their own services on the internet, which are then seamlessly integrated into the existing system.



Background

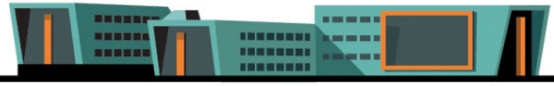
- Complexity and contingency are ubiquitous in biology.
- The self-organizing capabilities of biological organisms, which are not reflected in mainstream thinking in computing, could inspire novel organizational rules and patterns.
- These patterns could represent a step change in software systems engineering and could enable true self-organization in the ALSs of tomorrow.



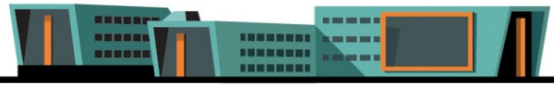
Focus

• We focus on one specific software engineering challenge for next generation smart homes: *coordination of multiple instances of a service feature* in the context of DSPLs.

• In conventional software product lines, whenever multiple instances of a service feature need to be deployed for a product configuration, this information is gathered at the product analysis phase and taken into consideration for the product configuration.



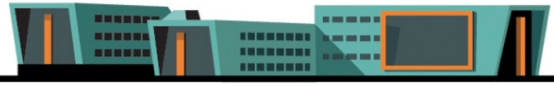
Multiple Instances of the Same Feature



Focus

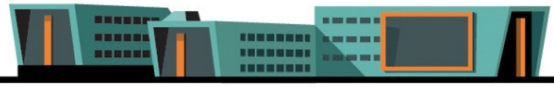
- The critical assumption here is that the number of instances is determined and it will not be changed at runtime.

- For example, in a telephony domain, the maximum number of single line subscribers is determined for a product and their interactions are managed by a central coordinating component.



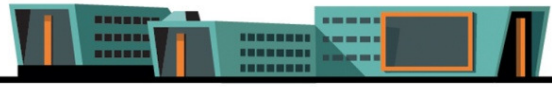
Focus

- In the smart home domain, this approach (i.e., centralized coordination of predetermined number of instances) is not feasible, because:
  - the number of active service features depends on available mobile devices and these devices may join in and leave from a product configuration at runtime;
  - a central coordinator cannot be deployed in a particular device due to the mobility and ad-hoc connectivity of devices; and
  - the physical location of a device (e.g., two devices close to or far from each other) may also matter for deciding behavior changes (e.g., only one instance of a service feature should be active if multiple instances of them are close to each other)
    - no variability management technique adequately supports such a situation.

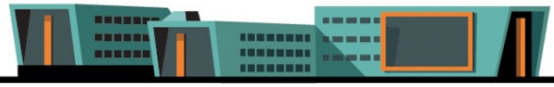


Motivating Scenario

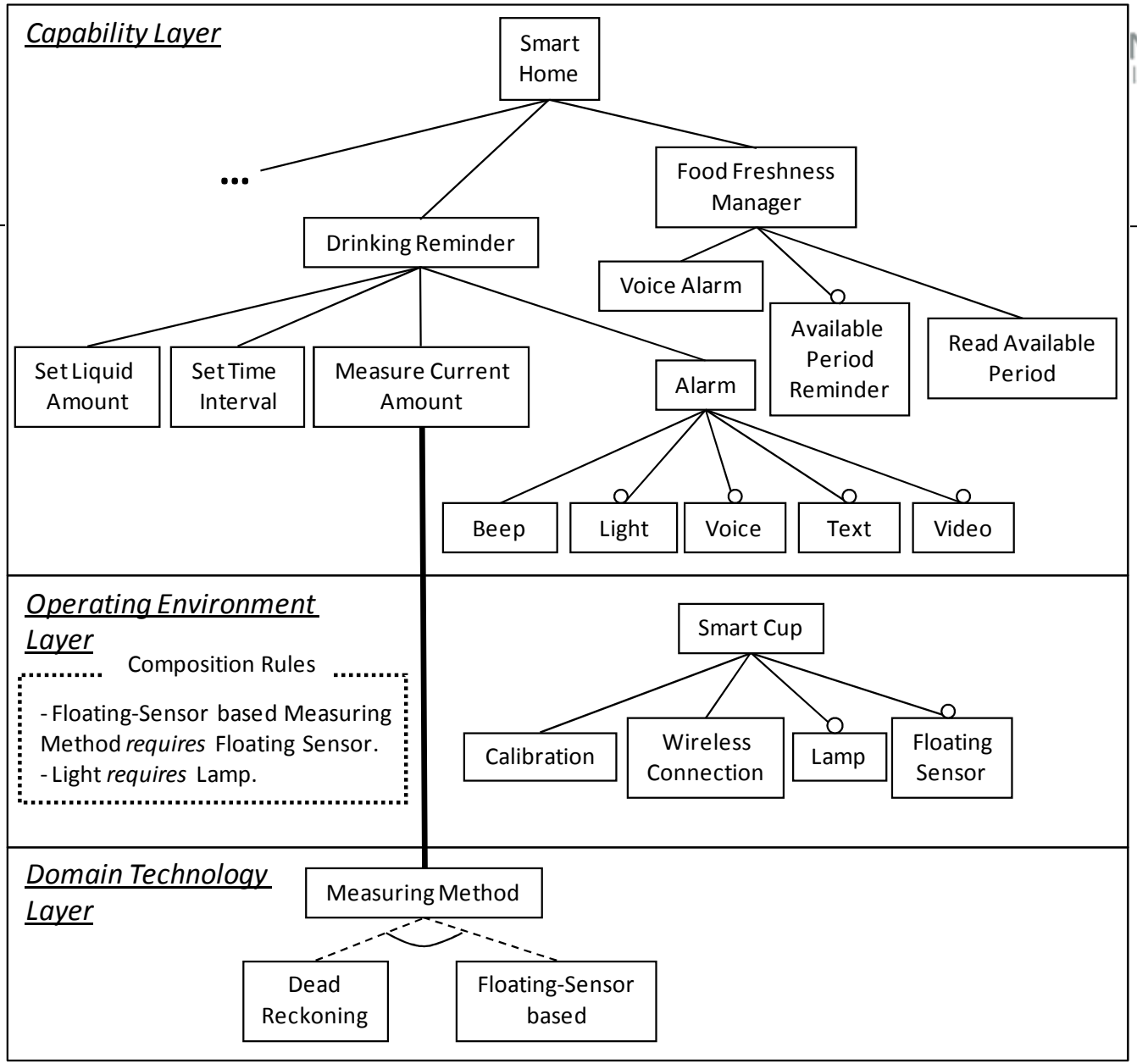
- A motivating scenario that we will use as a case study is a smart cup.
- An in-home networked smart home assists the elderly by monitoring their daily intake of crucial fluids.
- This is implemented by a sensor-enabled cup that
  - beeps when fluid intake is necessary,
  - has a level to monitor the fluid consumed,
  - shares consumption-data with its neighboring smart cups, and
  - also adjusts the required intake level when notified of consumption-data from other smart cups.
- This service feature is called a drinking reminder feature and each cup has an instance of this feature.



Motivating Scenario

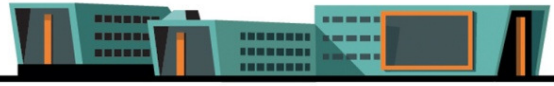


A Feature Model of Smart Home



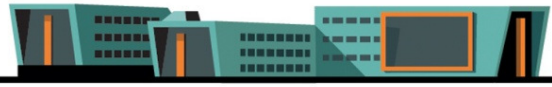
Challenges

- The problems posed by this scenario include:
  - the dissemination of information about the fluid intake,
  - the dissemination of the targeted fluid intake and the evaluation window during which actions of liquid intake should be considered as being relevant for the current evaluation.
  - the synchronisation of the evaluation cycles of the individual devices, with the aim of getting all devices to evaluate (and therefore sound the alarm) in a coordinated fashion, i.e. at the same time.
  - the selection of devices within the home that should be responsible for sounding the audio alarm.



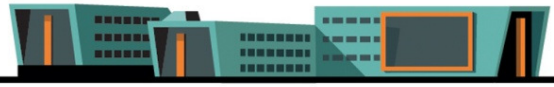
Solutions: A Gossip Protocol

- We propose to use a gossip protocol to propagate information within the smart home.
- Each time fluid is consumed through one of the intelligent devices, the device records information about this event, including:
  - the amount of liquid that was consumed.
  - the time that has elapsed since the event took place, enabling devices to discard events that occurred too long in the past and are therefore irrelevant for determine the overall fluid intake over the current evaluation period.

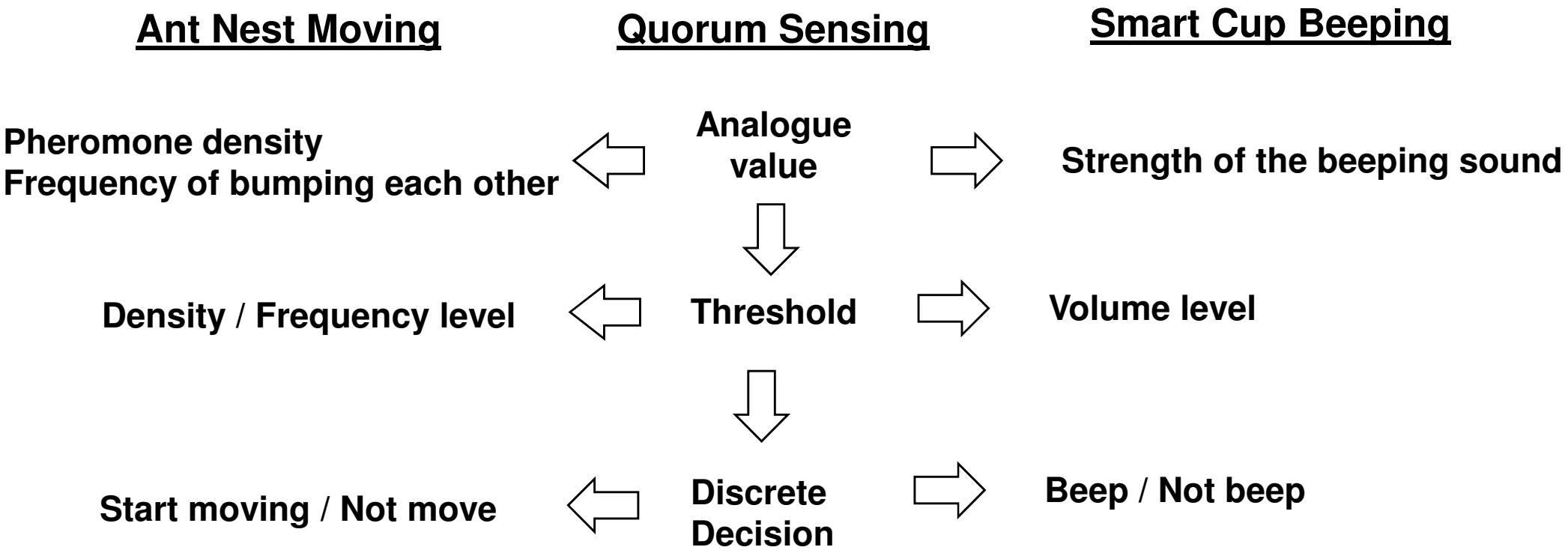


Solutions: Firefly Synchronization

- To synchronise the evaluation times, each device regularly broadcasts timing information to all devices within communication range.
- Each message contains the following information:
  - the amount of time that will pass until the sender will evaluate the fluid intake again.
  - the unique identifiers of devices that the sender considers itself to be in synchrony.
- If the clock cycles differ, the receiving device compares the number of devices that the sender considers itself synchronised with and the number of devices the receiver considers itself synchronised with.

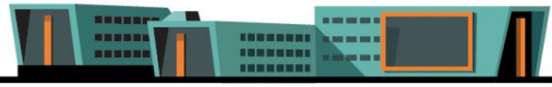


Solution: Quorum Sensing

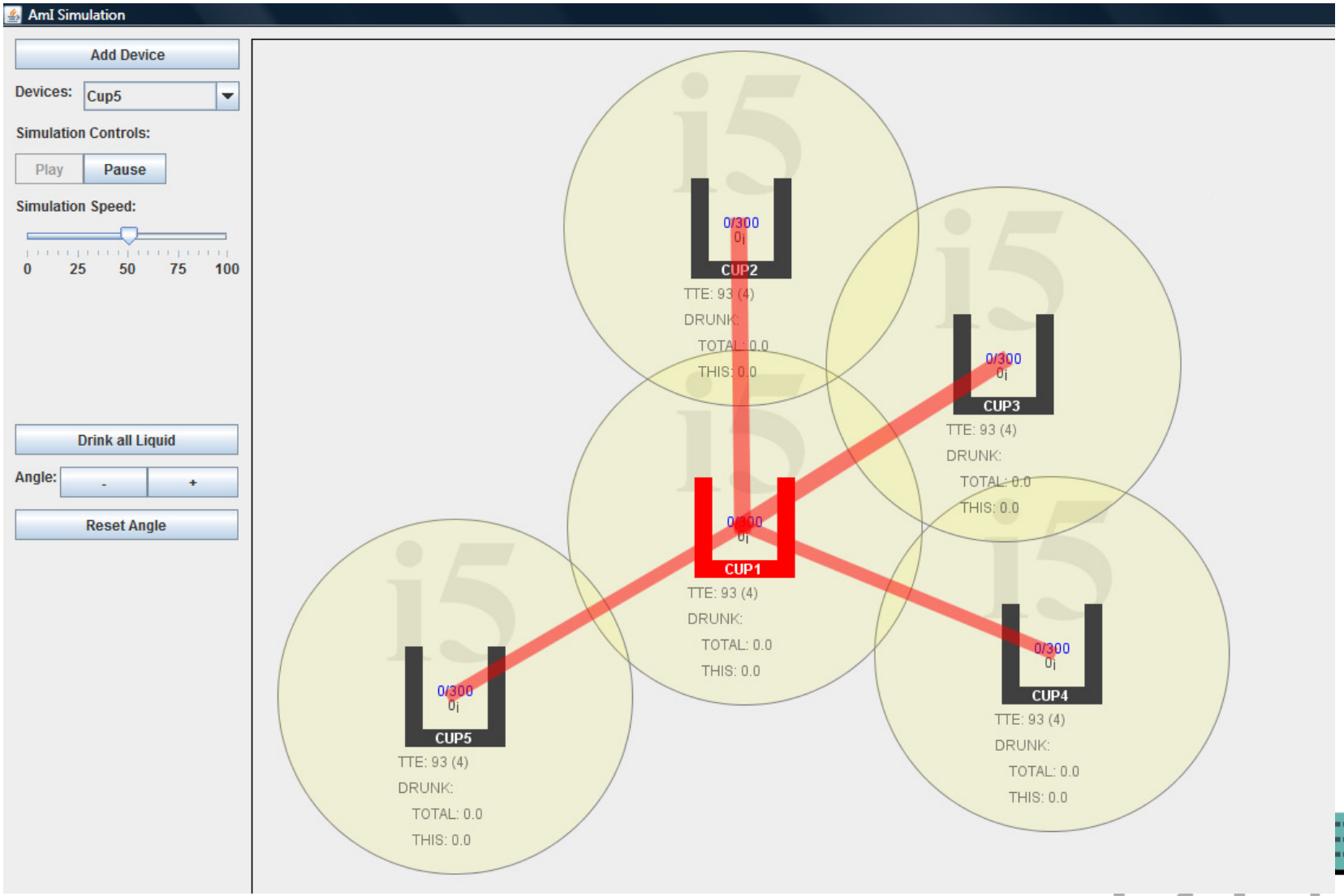


Solution: Quorum Sensing

- Once a device has come to the conclusion that the targeted fluid intake has not been reached, it uses a quorum-sensing-inspired algorithm to decide whether to activate its built-in audible alarm or not.
- To achieve this devices activate their built-in microphones and listen for audible alarm signals emitted by other devices for a randomly selected number of clock ticks.
- If a device receives an audio signal (in the frequency band that is used by the alarm) that is above a certain volume threshold during this period, they assume that a device is close by that has already activated its alarm signal, and that activating another alarm signal in this area is unnecessary. As a result, the device does not activate its own audio alarm.



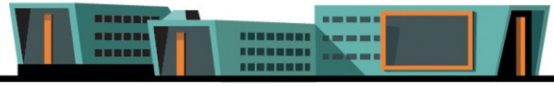
Software Prototype: A Simulator



Summary

- The simulation results show that it is feasible to apply such mechanisms in DSPLs for smart homes.
  - Each device makes its own decision
  - But they look coordinated from a user's perspective

- The current simulator, however, also reveals its limitations:
  - the support for heterogeneous devices
  - the enhancement of service quality
  - the deployment of smart cups in a real environment



Questions, Comments, …

Contact
Dr. Jaejoon Lee: j.lee3@lancaster.ac.uk