The TerraSwarm Research Center

http://terraswarm.org/

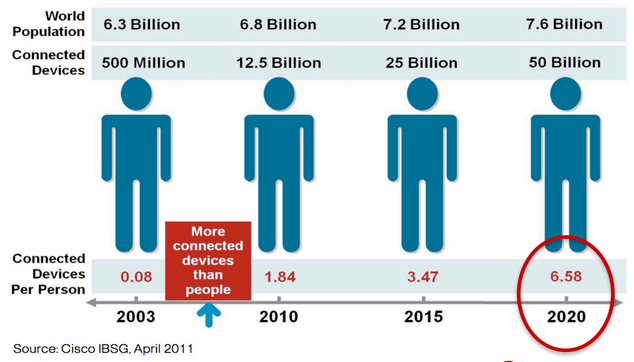
Presented at INC12 by Pat Pannuto, University of Michigan

May 2016, Leuven, Belgium

The Impending Internet of a Trillion Things

The TerraSwarm Research Center, a consortium of 27 faculty across 9 universities in collaboration with MARCO and DARPA, is addressing the huge potential (and associated risks) of pervasive integration of smart, networked sensors and actuators into our connected world.

Current estimates project 50 billion connected devices by the year 2020, roughly 7 devices per person on the planet. Looking 20 or 30 years beyond 2020, there will soon be hundreds of connected devices per person. While today's Internet connects billions of machines, ultimately most Internet-connected computers share a similar set of capabilities. The Internet of Things disrupts this homogeneity. Today, building rich interactive scenarios is a series of siloed solutions, using one company's lock software platform to control a different company's thermostat. The TerraSwarm project aims to break devices out of this closed ecosystem to transform the emerging physical web into a platform that both developers and everyday users can leverage to create applications that improve quality of life, utilization of resources, or any other desire.

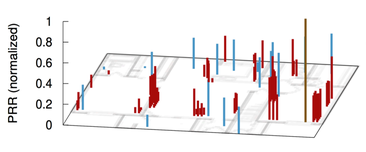


Source: Cisco IBSG, April 2011

Primary Themes of TerraSwarm

Proactive Worlds

Software and architectural techniques for a proactive world, where networked sensors, actuators, and infrastructure enable cooperating computing to provide smarter environments for humans to operate in. A central part of this effort is a hierarchical and compositional system architecture, supported by a distributed, loosely coupled executive that we call the "SwarmOS." This architecture must accommodate heterogeneous and dynamic compositions of sensor and actuator devices, mobile vehicles, handheld devices, networking components, and cloud infrastructure. A key challenge is to dynamically balance the needs of distributed concurrent application resources, quality of service (QoS), and real-time guarantees. Equally important is the need to respect the privacy and integrity of streams of information.



Recent Highlights:

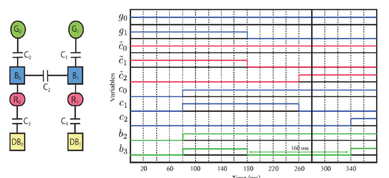
Full Coverage Submetering and Environmental Monitoring

Methodologies, Models and Tools

The complexity of TerraSwarm systems and their safety requirements pose significant challenges for the design of sensing, control, and actuation infrastructures, as well as for application development and deployment. These challenges are compounded by the requirement for on-line adaptation and reconfiguration. Applications need to adapt to the disappearance of resources, recruit useful resources that appear, and adapt services dynamically as part of a utility-driven optimization. There will be less of a distinction between "design time" and "run time," so design techniques, tools, algorithms, and flows must themselves become services that can be recruited online. Design techniques must be formal and rigorous, or they will not be reliable for on-the-fly reconfiguration, in which there is no opportunity for testing prior to deployment.

Recent Highlights:

DIARY: Diagnosis and repair of hybrid controllers



Services and Cloud Interaction

Technologies for scalable, adaptive composition of heterogeneous services. Applications that combine mobile and fixed sensor and actuator resources that interact directly with physical assets and humans; handheld communication, sensing, and computing devices; wireless and wired networking devices; and networked computing services (e.g. cloud-based computing). A key objective is to enable TerraSwarm applications to leverage large data streams through learning and inference, while preserving privacy and security.

Recent highlights:

Empirical Analysis of E-mail Security

Wearable for Automatic Sign-Language Translation

The Urban Heartbeat

The Global Data Plane

Accessors

The SwarmOS

The recent focus of the center culminates all of these efforts in the Urban Heartbeat. A city-scale sensing project that aims to deploy and integrate thousands of sensors and actuators to first measure the utilization of resources (electricity, water, pedestrian and automotive traffic, RF spectrum) and then leverage this information to both inform city management plans and to opportunistically integrate with devices that enter the city space, such as air quality-aware pedestrian navigation for asthmatics.

Ask me about any (or all) of the pieces!

Sponsored by the TerraSwarm Research Center, one of six centers administered by the STARnet phase of the Focus Center Research Program (FCRP) a Semiconductor Research Corporation program sponsored by MARCO and DARPA.

WaitWhat? The RoboCafé

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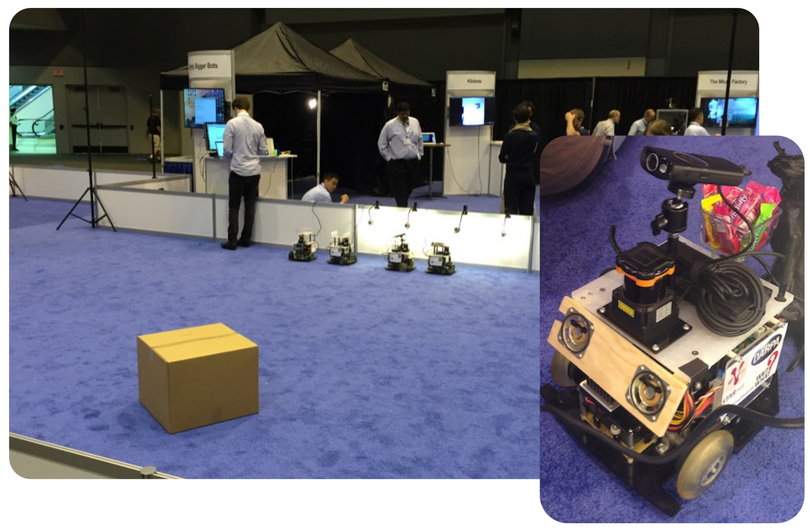
Robot Delivery Service at the Push of a Button

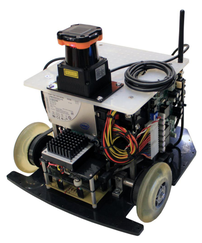
At DARPA's WaitWhat? conference in 2015, the TerraSwarm Research Center debuted the RoboCafé, an interconnected swarm of robots, sensors, cloudlets, and people.

The RoboCafé is the marriage of five best-in-class technologies from four universities across the United States coming together to explore how to build the applications of the future.



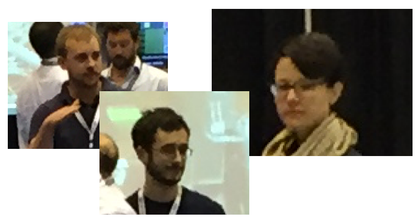
In the RoboCafé, a swarm of mobile robots patrol the café, moving in a sentry pattern to periodically visit the whole space. As the robots move around an online summarization algorithm continuously extracts "interesting" things the robot encounters, clips of each new face the robot see. Users in the RoboCafé can use a smartphone app to order candy or snacks. Upon ordering, the smartphone is automatically localized and a robot is taken off patrol and tasked to deliver the goods to the user. At any point, the detection of applause in the environment will demand robot attention no matter its previous task, simulating critical events such as gunshot detection.

Core Technologies



GMTK

The Graphical Models Toolkit



ALPS Localization

ALPS is an ultrasonic localization system that can find the position of unmodified smartphones to within 30 cm error. ALPS anchors can self-localize by walking a phone around a new space, easing the burden of installing the system.

Accessors/Ptolemy II

Accessors provide a sandboxed JavaScript environment for interacting with physical devices, including robots, smart devices, and other networked devices. They execute inside of the Ptolemy II modeling and simulation tool.

Scarab & Navigation

Scarab robots are relatively low-cost ground robots that run the open-source ROS operating system for robots. They emply "human-friendly" navigation to plot and follow a path while avoiding people in the same space.

Applause Detection

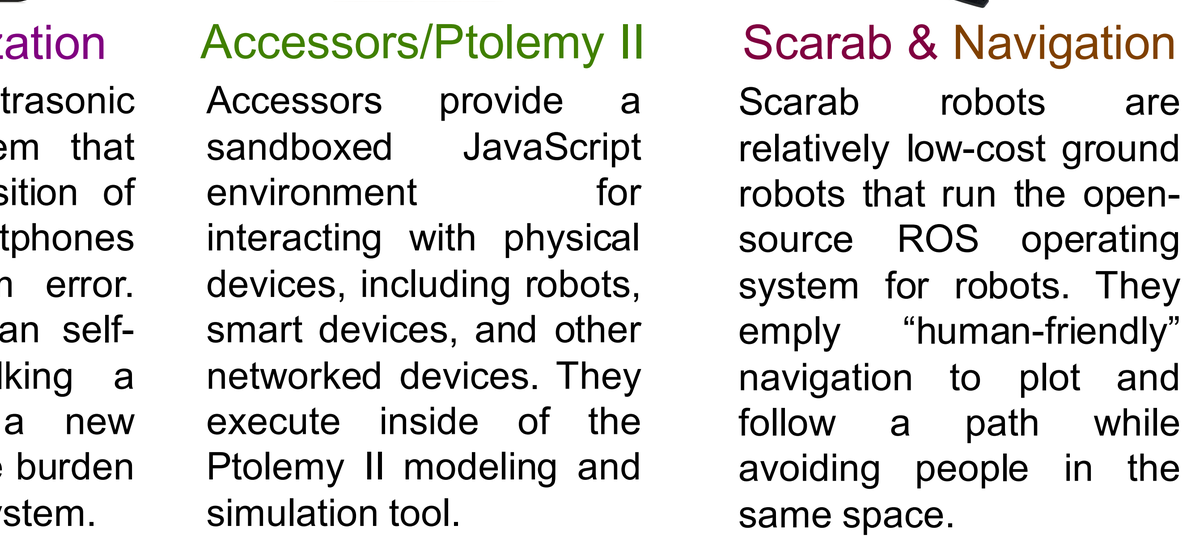
The Graphical Models Toolkit enables rapid prototyping of statistical models using dynamic graphical models (DGMs) and dynamic Bayesian networks (DBNs). GMTK powers the real-time applause detection.

Video Summarization

As a sentry, the robots see many individuals. Summarization extracts "interesting" features (different faces) and presents an overview of all of the persons that the robots have encountered in real time for quick and easy review.

Swarmlets Leverage Accessors to Synthesize Applications

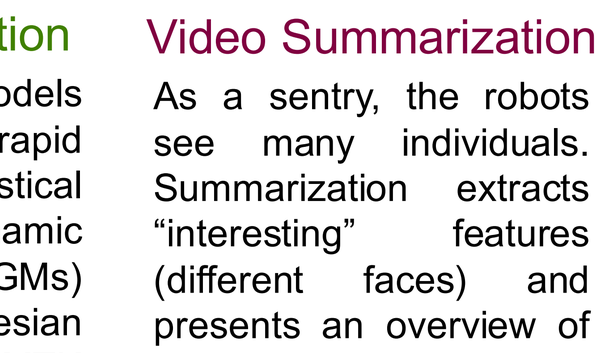
An accessor is an encapsulation mechanism that expresses the capabilities of a device as well as the mechanisms for interacting with devices. By abstracting to a common model of computation, synthesizing applications is as easy as drawing connections.



And Facilitate Easy Reconfigurability

Using Accessors and a Swarmlet provides a GUI based editor for easily reconfiguring how the application runs. For example, tapping state to add outputs that drive smart light bulbs or integrating a different location service is simply a matter of dropping in new Accessors, connecting the ports, and re-running the Swarmlet.

Models are strongly typed and connections are verified before the app is deployed, giving authors confidence that changes will have the expected and desired behavior.



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