

# The CLARITY Ubiquitous Robotic Testbed

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*The CLARITY Centre for Sensor Web Technology in Ireland is currently constructing a ubiquitous robotics testbed by integrating a collective of mobile robots with a wireless sensor network and a number of portable devices. The new, mixed testbed will be hosted at the School of Computer Science and Informatics at University College Dublin, (UCD), and will also avail itself of the laboratory facilities hosted in Dublin City University (DCU) and Tyndall, Cork. The testbed will provide a service for all researchers interested in developing ubiquitous robot applications.*

The number and variety of applications of robots in our daily environment is on the increase. Examples include robotic pets (eg Sony Aibo), household appliances (eg iRobot vacuum cleaner Roomba) and assistive technology (eg the MANUS wheelchair). At the end of 2006, figures for service robots for personal or domestic use stood at nearly 3.5 million, with this projected to more than double before the end of 2010.

At this point, a principal challenge for the robotics community is the integration of robots into today's digital society. Inexpensive Internet access and the diffusion of wireless computing devices have made ubiquitous/pervasive computing a viable reality that augments the normal physical environment and supports the delivery of services anytime, anywhere to human users. Endowing these ubiquitous devices with intelligent behaviour, and thus creating intelligent environments, is termed ambient intelligence.

Robots are a compelling instance of those artefacts that comprise and deliver the ambient space. Modern multi-robot applications have moved away from the historical view of monolithic control systems: they run on specific computational units and are in charge of their own 'hardwired' hardware. They are already perceived to belong to a larger, open distributed network made up of different sensors and effectors. Ubiquitous robotics further extends this view by explicitly addressing the need for interoperability between robots and existing ubiquitous and pervasive infrastructures, such as wireless sensor networks (WSNs).

CLARITY is particularly interested in employing the new testbed in three overlapping areas of research:

## Integration between Robots and WSNs

The new testbed represents an ideal arena in which to develop and test pro-

posed advances in mobile networking, routing, data collection and data analysis within the WSN community. Robots are just another class of user of sensor data, potentially harvested both by their on-board sensors and by the sensors already available in their environment.

and software components are not stable but may change at run-time. In order to adapt to such environments, these applications must exhibit run-time flexibility, such as the ability to reorganize the interaction patterns of their architectural elements during execution. In par-



Figure 1: Robots at the CLARITY Centre for Sensor Web Technology.

Robots can also actively help the sensor network, not only by acting on the environment, but also by helping to deploy, program and maintain sensors; collaborating with sensors' localization; and by acting as mobile gateways in multi-hop networks. They also push the boundaries of WSN research by requiring interoperable and efficient solutions to data collection and online analysis.

## Adaptive and Self-Organising Software Architectures

The need for adaptive and self-organising software architecture for ubiquitous robotics emerges from the very same requirements as for autonomous operations. In traditional networked robot systems, component integration is essentially an offline feature. In contrast, these systems demand a more open and dynamic approach, as the nature and availability of their hardware

particular, Component-Based Software Engineering (CBSE) and Agent-Oriented Software Engineering (AOSE) paradigms are natural candidates to provide modular architectures to integrate and dynamically organize the different system functionalities.

## Ubiquitous Personal and Social Assistant Agents

Not only will these robots have to deal with a variety of complicated tasks, but they will also be expected to behave in a socially intelligent and individualized manner in order to meet the diverse requirements of each user. However, reconciling the personalization/social aspect with pervasiveness and ubiquity remains a largely unexplored area of research. On both fronts, user interface agents, eg acting as a personal agent assistant (PAA) to their user, have already been widely adopted as intelli-

gent, adaptive social interfaces to the digital world, eg in the form of virtual characters interacting with the user via PCs, PDAs and the Internet. As such, the experience accumulated in these applicative domains may be used to inform robotics research. Moreover, as both software agents and robots increasingly inhabit the same human social space, their mutual interaction and combined operation within human societies will also acquire increasing importance.

### The New Testbed

The new testbed integrates and extends some pre-existing facilities, specifically:

- WSN of 70 Berkeley motes measuring humidity, light and temperature
- ten mobile robots, equipped with an array of state-of-the-art sensors, including USB cameras, laser range finders, sonar, infrared, odometers and bumpers. Each robot carries a mote able to measure ambient variables, which is also equipped with triple-axis accelerometers, magnetometer, compass and microphone
- a variable number of Internet gateways
- a variable number of PDAs and mobile phones equipped with Bluetooth.

Ubiquitous robot systems involve many interacting hardware and software components, and malfunctions in both types of component can encumber them. Such characteristics pose a considerable challenge to the application of a strong engineering perspective within robotics, as it is difficult to correctly gauge the accomplishment of specific system objectives and guide improvements and further developments. For these reasons, our research has commenced by defining a number of logging and inspection facilities.

On the robot side, an XML service developed in collaboration with the Interoperable Systems Group at DCU will provide a generic logging service for the instrumentation of both CBSE and AOSE frameworks. In addition to offline analysis, the service will also support hardware-in-the-loop simulations (HILS), thanks to synchronization and replay functionalities that will allow focusing online analyses and simulation over isolated groups of software modules.

The Octopus interactive dashboard, developed at UCD, will be employed to

(i) visualize the topology and behaviour of the WSN through a network map; (ii) log collected parameters for network analysis; (iii) localize nodes on a provided 2D floor plan; and (iv) formulate and inject composite queries into the network.

### Links:

CLARITY Centre for Sensor Web Technologies:

<http://www.clarity-centre.com/>

CLARITY Ubiquitous Robotic

Testbed: <http://ubirobot.ucd.ie>

IFR Statistical Department. 2007 world robotics survey:

<http://www.worldrobotics.org/index.php>

The Interoperable Systems Group at DCU:

<http://www.computing.dcu.ie/~isg/>

Octopus:

<http://www.csi.ucd.ie/content/octopus-dashboard-sensor-networks-visual-control>

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