Intelligent Environments

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Drawing by Paul Rumsey
(www.paulrumsey.co.uk/)

Structure of Presentation

- About Me
- What are intelligent Environments
- Examples of Intelligent Environments
- A motivational scenario
- Research Issues
- Videos
- Final Remarks

http://www.billychasen.com/

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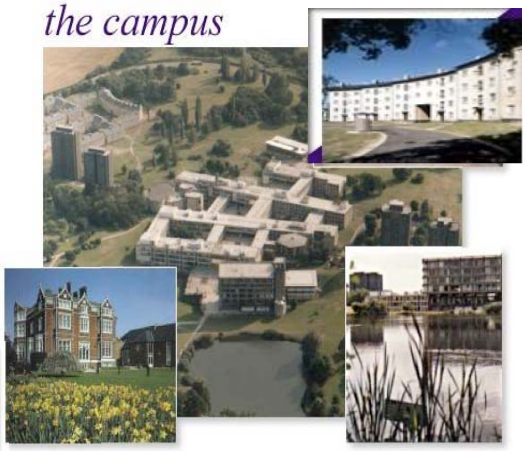
About Me

- Professor of Computer Science at Essex University
- Head of Intelligent Environments group and director of Digital Lifestyles centre
- Worked in avionics (aircraft) before joining university system
- Expert in robotics and artificial intelligence (founded Robotics at Essex)

- Current research focused on Intelligent Environments, Pervasive Computing, Digital Homes, End-User Programming and Embedded Intelligent Agents
- Part of organizational team for numerous conferences, workshops, journals

the campus



- *parkland of 200 acres*
- *Royal Charter in 1965*
- *9,162 students*
- *30% post graduates*
- *38% overseas (130 countries)*
- *Ranked 9th in UK for research*

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Conferences I Organise

IE'10

Co-sponsored by the **IEEE** Systems, Man & Cybernetics Society Technical Committee on Computational Intelligence and the **Association for the Advancement of AI**

6th International Conference on Intelligent Environments

IEEE **July 19-21, 2010 (workshops: July 18-19)**

Monash University (Sunway campus), Kuala Lumpur, Malaysia

Web: http://intelligentenvironments.org/conferences/ie10

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Workshops I Organise

1st International Workshop on Creative Science - Science Fiction Prototyping for Research Innovation

CS'10

Sponsored by the intel

Monash University (Sunway campus), Kuala Lumpur, Malaysia

www.creative-science.org

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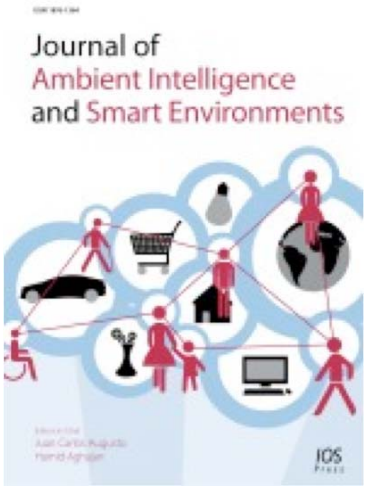
Journals I'm Editing

- Themed Issue on **Smart Homes**
- Journal of Ambient Intelligence and Smart Environments
- *IOS Press Nieuwe Hemweg 6B, 1013 BG Amsterdam, The Netherlands*
- *Journal of Ambient Intelligence and Smart Environments serves as a forum to discuss the latest developments on Ambient Intelligence (AmI) and Smart Environments (SmE)*



http://www.iospress.nl/loadtop/load.php?isbn=18761364

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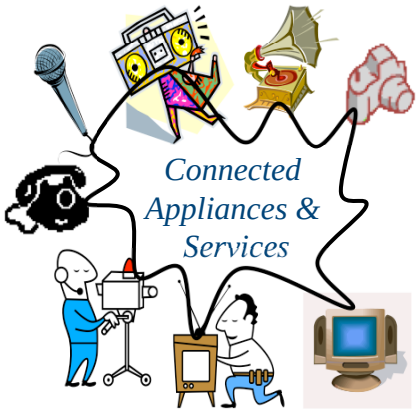
What Are Intelligent Environments?

- They are: *environments "where (**networked**) devices, services and applications work together seamlessly supporting even richer, more engaging and deeply connected (user) experiences"* (Bill Gates, 2006)
- The take the form of: high-tech homes, offices, classrooms, campuses, hotels, restaurants, shops, hospitals, teaching-rooms, stage/studios, manufacturing environments, cars, trains, aircraft, boats, cities, public spaces and electronic clothing/ fashion.
- Applications aim to design living environments that are more comfortable, usable, productive, secure, caring (**medical**), social, entertaining or energy efficient



What Are Intelligent Environments

- In more specific terms "*An Intelligent Environment" is one in where the functionality of the environment is derived from the coordinated actions of networked computer based computer based entities (physical and information based) which sense the environment (eg appliances, people) and "purposefully" coordinates their actions (based on rules) to effect higher level meta functionality required by the users (Callaghan 2003)*

2 approaches to making intelligent environments (creating the associations and rules)

People Control | **Agent Control**

"A building is a machine we live inside" !
Le Corbusier (1887 – 1965)

People & Technology

- Intelligent Environments go by numerous names (each with a subtly differing focus) such as:

  Ubiquitous Computing, Pervasive Computing, Intelligent Buildings, Connected Home, Digital Home, Smart Homes, Smart-Cities, Internet of Things etc (intelligent environments has a bias towards embedding intelligent processes into the systems as to simply use and operation)

- is people based and, to some extent, about **choice** (either unconscious or conscious) and **personalisation**.
  - the mix of **people** and technology makes it **multi-disciplinary** in nature.

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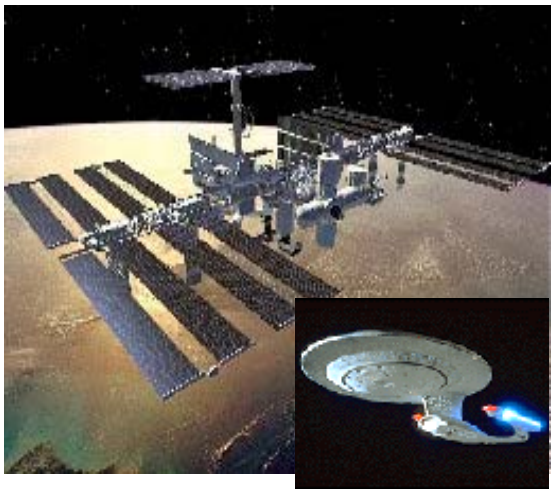
Examples of Intelligent Environments – Space the longer term vision!

Space Exploration space vehicles , planetary habitats are effectively intelligent environments …



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Examples of Intelligent Environments

- Ken Sakamura's (University of Tokyo) TRON Homes (The Realtime Operating system Nucleus);
  - 1st TRON House built in Tokyo,1989, 2nd in Aichi, Japan 2004, 3rd one in Taipei, in 2009 – mostly mix of network control and automation (some context aware but no learning)

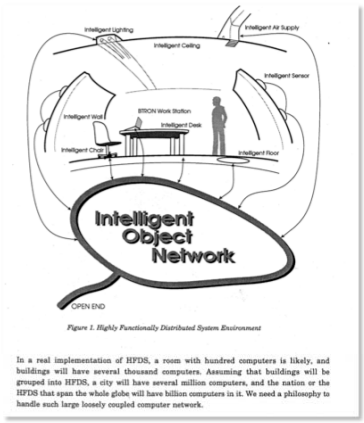

Figure 1. Highly Functionally Distributed System Environment

In a real implementation of HFDS, a room with hundred computers is likely, and buildings will have several thousand computers. Assuming that buildings will be grouped into HFDS, a city will have several million computers, and the nation or the HFDS that span the whole globe will have billion computers in it. We need a philosophy to handle such large loosely coupled computer network.

Examples of Intelligent Environments – BRE's Integer House

Uses Echelon's LONWORKS® as its control backbone. Access to the functions and status of the house is provided through Echelon's i.LON 1000 Internet Server. The house is connected to the Internet via a dial on demand ISDN line devices are devices are available "off the shelf", today.

- The INTEGER program was created to develop an affordable, sustainable, intelligent and green future for housing in the UK (**www.integer.echelon.co.uk/**)

Examples of Intelligent Environments

– Cisco Internet Home

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Examples of Intelligent Environments

– Echelon Demo Room

http://demo.echelon.com/

Interact with a *live LONWORKS network* at Echelon's headquarters in Sunnyvale, California.

Some Other Interesting Examples:
- **MavHome – University of Texas**
- **Gator Tech Smart Home – University of Florida**
- **Aware Home - Georgia Institute of Technology**
- **Adaptive House – Colorado University**

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Examples of Intelligent Environments

– Essex iSpace

Dorm@iSpace (development environment)

Home@iSpace (evaluation environment)

- Test-bed for ambient intelligent and pervasive computing in a domestic setting (Full sized 2 bedroom apartment)
- Sensor, actuator, computer and network rich environment to enable open-ended R&D
- Capable of supporting evaluations with long-term occupants

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Examples of Intelligent Environments

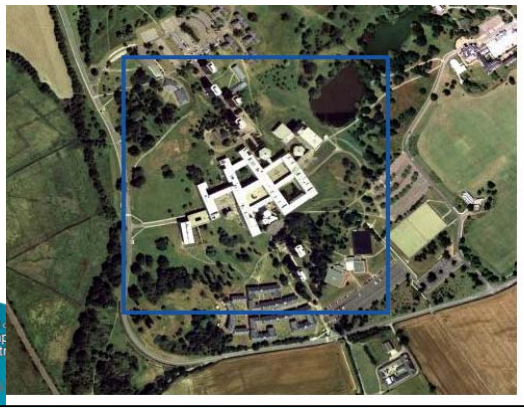
Essex Campus@iSpace

Also; as part of "Digital Britain" progarmme rolling out technology into a real town – Southend (to the east of London)

(via WiMax Testbed)

HIPNet Project "*Validation and Modelling of Next Generation Networks*"

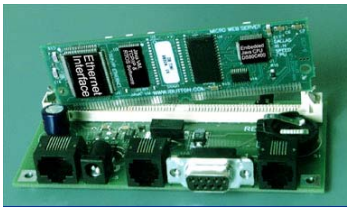
Campus Coverage



Suburb Coverage (5km radius)

Technology Examples – TINI

TINI: Tiny InterNet Interface from Maxim's (was Dallas Semiconductors)



potential to use the internet to interconnect all computer based products (eg washing machines, security systems)

For dedicated Java chips, see http://ftp.tu-chemnitz.de/home/mailing-list/sunflash95/0213.html

- embedded Java programming environment
- ~20 MHz clock ,8/32-bit CPU/ALU (24-bit addressing)
- 512 kB NV SRAM, expandable to 1 MB NV SRAM
- +5V power supply
- TINI's I/O includes: Ethernet 10Base-T interface, Dual 1-Wire® net interface, CAN interface,Dual serial port (one RS-232 level and one +5V level), I^2C port, Expansion bus

See http://www.maxim-ic.com/products/microcontrollers/tini/

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Technology Examples – Sun SPOT

- **Sun SPOT** (Small Programmable Object Technology) – Java programmable embedded computer (similar to the Berkeley Motes ubiquitous Computing sensor boards)
  - **Processor Board** (35x25mm) – 32 bit ARM-7 CPU – up to 80Mhz, on-chip 2MB flash ROM FLASH and 32MB SRAM , 11 channel 2.4GHz radio (802.15.4 see www.ieee802.org/15/pub/TG4.html),
  - **General I/O Board** – 3D accelerometer, temp sensor, light sensor, 2x 3-colour LEDs, 2x momentary switches, 9 line general purpose I/0
  - **Prototyping Boards** – wire your own hardware.
  - **Software** – *Squawk VM* that replaces OS; *Isolates* that can run multiple Java applications in the one VM (& support migration across different machines e.g., from X86 Squawk VM to Mac Squawk VM). *Integrated Development Environments* (IDEs) eg Net-Beans™

Useful Links:
Epsilon Project
http://research.sun.com/projects/dashboard.php?id=62
Squawk
http://sunlabs.eng/projects/squawk/squawk-rjvm.html
SPOT
http://research.sun.com/sunlabsday/talks.php?id=21
Capability Descriptions
http://research.sun.com/techrep/2005/smli_tr-2005-131.pdf

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A Futuristic Scenario

'a future where appliance don't exist (disruptive technology)"

"the 'radio-sphere' is awash with services available for use –some local, some remote"

"monolithic appliances given way to deconstructed systems"

"interacts with the environment via a personal 'wireless assistant' (WA)"

- **Background** - *Liping is a visiting researcher at the University of Essex. She arrived at the University and moved into her new temporarily accommodation, an intelligent apartment (home@iSpace). Like all environments in the future the 'radio-sphere' is awash with services that are available for her use. Many of these services are local such as lighting, heating whilst others are remote such as video, music, news, email. Monolithic appliances and computer applications have given way to more atomic networked functions (deconstruction) such as switches, video displays, codecs, editors, mp3 files etc. Liping interacts with the environment via her personal 'wireless assistant' (WA) which also holds descriptions of her preferred world*

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A Futuristic Scenario – 2

- **Virtual Appliances & Applications** – *The concept of appliances and applications has lingered on as people still need to utilise functions akin to TVs, telephones, word processors etc. Consequently all environments had their networked devices / applications pre-formed into familiar default configurations. (called Virtual Appliances). Each Virtual Appliance has description that describes it's aggregated services and behaviour; a MAp (meta-application or meta-appliance). Thus, both physical and information spaces function as normal. It is possible for users to purchase new MAps and, for more creative individuals, to devise their own.*

"deconstruct then reconstruct"

"Virtual Appliance describes a familiar everyday appliance or application" (plus new ones a user might create)

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A Futuristic Scenario – 3

"if people move, WA discovers what is available creating as near matches as possible"

"if devices move or fail, the system tries to find suitable replacements"

"sell missing devices"

- **Mobility** - *On entering her apartment, Liping's WA started to flash in an unobtrusive manner indicating she was within a 'smart space'. Her WA contained her ontology based descriptions of her preferred MAps, discovered what was available in the environment, and then requested as near matches as possible to be constructed. If devices moved or failed, the system would similarly try to find suitable replacements. Of course this was not always possible but her WA would indicate what was missing, so she had the option to borrow, buy or replace any missing devices. One such MAp was her 'communication centre' (CC). On moving to other rooms and environments the WA attempted to maintain Liping's preferred configuration for her CC MAp.*

A Futuristic Scenario – 4

- **Programming** – *The original CC MAp consisted of a telephone service, audio transducer and dialler. Liping had modified the MAp to add in a light, video entertainment media stream and associated rules using an end-user programming tool that was resident in her WA. For example, she had re-programmed the CC MAp configuration and rules to, "if she wanted to take an incoming call, to pause any incoming media streams, divert the call to the audio/video-transducer in use at the time, and raise the light if it was dark".*
- *While Liping generally only modified existing MAps there were numerous hobby clubs and small industries that generated novel and sometimes highly complex MAps which they then traded.*

"Implicit autonomous agents versus explicit user control?"

"Trade in MAps"

A Futuristic Scenario – 5

- **Interaction -** *Liping selects the 'News' menu on her WA, which causes the smart space to invoke an 'interactive display MAp', connecting it to her preferred RSS News feeds. Whilst reading her news feed, a video-conference request arrived, and the CC acted like a sophisticated 'virtual-appliance', activating previously programmed rules that caused the news feed to be suspended, lights to be raised and the video conference to be patched through to the current audio and video system. Like any appliance, Liping could manually override any of the settings on this "soft- appliance".*

"Users Rule, OK!"

"Interaction via wearable devices (phone?) or speech? etc"

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Reaching the Vision– Some Research Issues

- Devices are resource constrained (ie relatively low processing speed & memory)
- What network architecture, communication standards, middleware etc is appropriate (so far, no perfect solution)?
- How do people manage the intelligent environments (eg via autonomous embedded–agents or by end user programming)?
- How do people interact with Intelligent Environments –implicit interfaces, explicit interfaces (speech, gesture, GUI etc)
- How are intelligent–environments developed & debugged?
- How is privacy and security protected?
- How do you know what people want (or don't want) from this type of technology?

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Some Project Examples

Drawing by Paul Rumsey
(www.paulrumsey.co.uk/)

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Mixed Reality Intelligent Environments

- Virtual and Real worlds connected by common middleware

- Advantages of Virtual Intelligent Environments
  - Can provide a convenient mechanism for interfacing with physical devices.
  - Can augment a physical intelligent environment (reveal the invisible, communication, agent learning etc)
  - Can run faster than real time (reduce experiments to hours rather than days)
  - Don't need to follow the same rules as a physical environment.
  - Can have multiple cheap instances

Technical Components
- **Physical Component: The University of Essex iSpace.**
- **Virtual Component: A RealXtend based replica of the physical iSpace.**
- **UPnP: Middleware that joins the real and virtual**

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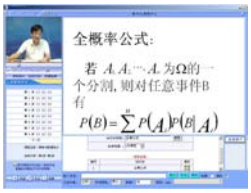
Mixed Reality Demo

Connected Realities – iSpace & iWorld

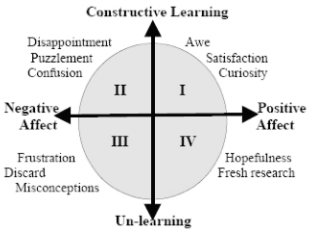
Live Network Education



Shanghai Smart Classrooms

Essex Collaboration –
Affective Computing + Virtual reality

Russell's Circumplex Model of Affect



Kort's Learning Style

- Online system issues:
- No insight into student attention
- Remote student isolation

- Solution -> Emotion sensing

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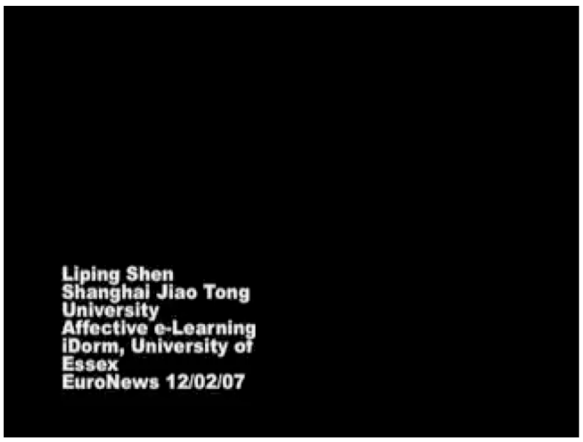
Affective Learning Demo



Affective Learning (Essex-SJTU)

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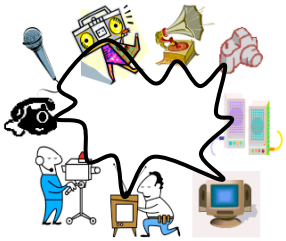
Mixed reality Learning

Simple Prototype for Mixed Reality Learning

How to Program Intelligent Environments?



Agents Versus People

Autonomous Agent Programming

Advantages

- Minimal cognitive load on user

Disadvantages

- Lose of control
- Worry about privacy
- Poor predictive performance (cf Microsoft Intellisense)

End-User Programming

Advantages

- User in control
- Promotes more trust (seems transparent)
- Empowers creativity (allows users to use imagination)

Disadvantages

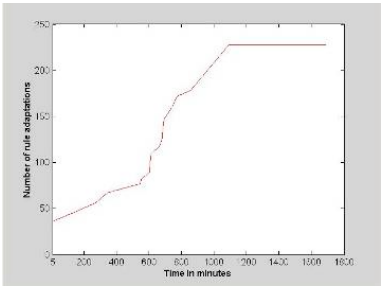
- If done poorly, places cognitive load on user (simple ways include use of programming metaphors such as jigsaw puzzles, programming by example (ie teaching babies or children)

Best of Both Worlds?

- Adjustable Autonomy

Intelligent Embedded Agents -1

- Aimed at Automatic Configuration of Environment:
- Goal directed autonomous agents that sense environment, appliances and people to automatically configure services, associations and meta-service functionality
- Based on metaphor "the user is king" (ie non-dictatorial; user can override system)
- Based on type-1 & type-2 fuzzy logic autonomous agents. Advantages include:
- Has won 3 best paper awards at top IEEE conf's in field; been applied to difficult problems such as controlling ship/train engines (ie proven technology)



A useful analogy of an embedded-agent might be "*a knowledgeable and helpful friend embedded into a product which, by observation of your behaviour learns how to help you*"

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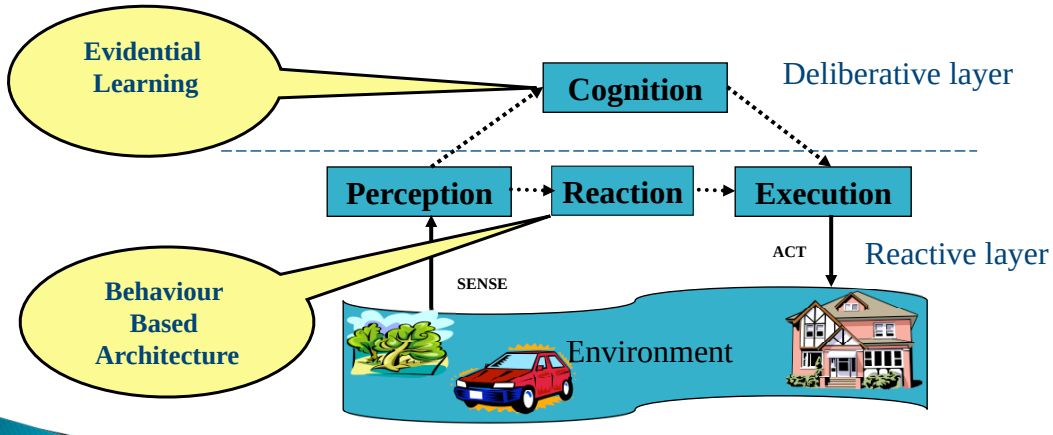
Intelligent Embedded Agents - 2

Our agent model looks something like:



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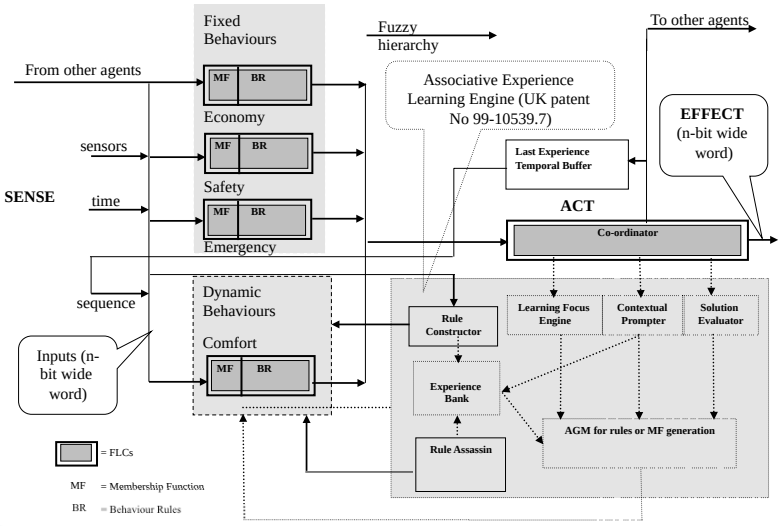
Example of BBA Based Fuzy Logic Implementation



Embedded-Agents Demo 1(early approach)

Early Embedded-Agent Work in iDorm

Embedded-Agents Demo 2 (later approach)

ATRACO
Adaptive and Trusted Ambient Ecologies

More Recent European Project on Developing Agents

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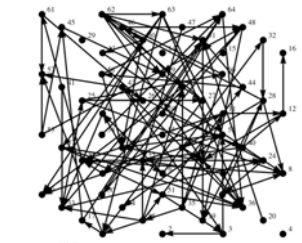
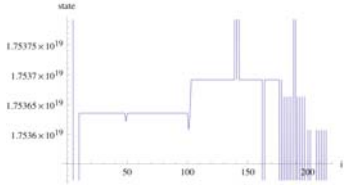
Other Issues – Service Interaction





Grid with 64 node and random connections. The system had 81 cycles.

- Can get oscillating conditions on rule based coordinating network systems!
- Doesn't occur in centralized systems – **only distributed systems** (relatively newly discovered phenomenon in ambient intelligence).
- Complex system theory shows it is not possible to predict theoretically whether an arbitrary set of rules will suffer from instability.
- Variables include:
  - number of agents,
  - Topology
  - Perturbations
  - initial states
  - Coordination rules

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Other Issues – Autonomy and Privacy

- Buildings, and especially our homes, are some of the most private spaces in our lives, do we want
  - Autonomous networked agents recording our behaviours
  - Communicating our behaviors elsewhere
- Who regulates the usage of such systems:
  - Companies,
  - Governments
  - Users
- Need to educate the general public, government officials, politicians, to introduce social and legal framework to make sure systems are not abused.

Final Remarks

- Intelligent Environments can be seen as the application layers of distributed frameworks.
- Still a lot of basic science and technology research needed to turn the vision for Intelligent Environments into a reality
- Technology research alone is not enough, as the vision affects people, business and legislation.

- Problems = Opportunities for researchers

Any Questions?

University of Essex

More information can be found on:

http://ieg.essex.ac.uk

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Some References

- Zamudio V, Callaghan V, "Facilitating the Ambient Intelligent Vision: A Theorem, Representation and Solution for Instability in Rule-Based Multi-Agent Systems, Special Issue Section" International Transactions on Systems Science and Applications (special issue on "Agent based System Challenges for Ubiquitous and Pervasive Computing"), Vol 4, No. 1, 2008
- Callaghan V et-al "*A Soft-Computing DAI Architecture for Intelligent Buildings*", Journal of Studies in Fuzziness and Soft Computing on Soft Computing Agents, Physica-Verlag-Springer, July, 2001
- Clarke G, Callaghan V, "*Ubiquitous Computing, Informatization, Urban Structures and Density*", Built Environment Journal, Vol. 33, No 2 2007
- Callaghan V, Chin J, Shahi A, Zamudio V, Clarke G, Gardner M, "*Domestic Pervasive Information Systems: End-user programming of digital homes*" Journal of Management Information Systems Spring 2007-8, Vol. 24 No. 01, April 2007
- Chin J, Callaghan V, Clarke G, "A Programming-by-example Approach To Customising Digital Homes", Intelligent Environments, July 21-22nd 2008, Seattle, USA [Have a PDF File you can have]
- Callaghan V et-al "*Pervasive Information Systems: Issues for the Individual & Society*", Chap 10, ME Sharp Inc book "Pervasive Information Systems" New York, August 05
- Callaghan V, Clark G, Colley M, Hagras H Chin JSY, Doctor F "*Intelligent Inhabited Environments*", BT Technology Journal , Vol.22, No.3 . Klywer Academic Publishers, Dordrecht, Netherlands, July 2004
- H. Hagras, V. Callaghan, M. Colley, G. Clarke, A. Pounds-Cornish, H. Duman, "Creating an Ambient-Intelligence Environment Using Embedded Agents", *IEEE Intelligent Systems, Vol. 19, Issue 6, pp. 12-20, November/December 2004*

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