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(after Mark Weiser, 1994)

In the next five to ten years the computer will be erased from our consciousness. We will simply not talk about it any longer, we will not read about it, apart from experts of course.

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It will empower us, if we understand it.
PART I: The Challenge of Ubiquitous Computing
PART II: Software and Models
PART III: Embarking on the Challenge
PART I: The Challenge of Ubiquitous Computing
Qualities of a ubiquitous computing system (UCS)

What is new about a UCS?

- It will continually make decisions hitherto made by us
- It will be vast – orders of magnitude larger than today’s systems
- It must continually adapt, on-line, to new requirements
- Individual UCSs will interact with one another
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Can the industry cope, using traditional software engineering?
Ubiquitous Computing: Experience, Design and Science

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STRATEGY: Build many types of model; integrate them; base software engineering principles on these models.
Ubiquitous Computing: Experience, Design and Science


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- Humans are embedded in ubicomp. Model them too?
- How do existing theoretical models measure up to the task?
Two views of modelling Ubicomp

- **Holistic view:** Model humans along with modelling the artefact.
  e.g., to design a good health-monitoring system we need a model of how humans will interact with it.

- **Dualistic view:** Make rigorous models of possible ubicomp artefacts before evaluating particular designs against human needs.
  e.g., analyse features of a mobile communications system (latency, error recovery, ...) without a complex model of the humans who will use it.
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**Strategy for the Grand Challenge:** Reach a *synthesis*!  
This means close-coupling of approaches.
First goal: aiming for experience

To develop ubiquitous computing methods and techniques that are sensitive both to the needs of individuals and society and to the impact upon them. This will include new forms of interaction and new interaction paradigms for the realisation of human experiences that will make ubiquitous computing usable by all.
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- **Adopt holistic viewpoint.** Cannot predict the systems needed until we can predict likely human behaviour, on basis of experimental projects (play!). *cf* EQUATOR project, Rodden *et al*.

- **Experiments will help to identify important generic properties;** e.g. modes of interaction, new networking methods, failure-handling, reflectivity. *This leads to the design goal:*


Second goal: aiming for design

To define engineering design principles that:

- pertain to all aspects of ubiquitous computing;
- are agreed among both academic and professional engineers;
- are taught regularly in Master’s Degree courses;
- are instantiated in the design and rigorous documentation of several ubiquitous systems with a successful operational history.
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Liaise with experiments (experience goal) to identify principles of how humans wish to interact with/through ubicomp artefacts.

Liaise with theories (science goal) from dualistic viewpoint, to evolve models that can analyse and validate the design principles.
Third goal: aiming for science

- To develop a coherent informatic science whose concepts, calculi, models, theories and tools allow descriptive and predictive analysis of ubiquitous computing at many levels of abstraction;
- to employ these theories to derive all its systems and software, including languages;
- to analyse and justify all its constructions by these theories and tools.
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What kinds of theoretical model will underlie the huge variety of UCSs?
There are likely to be many, but forming a coherent whole.
PART II: Software and Models
Software: The gulf between engineering and science(1)

Software science has an established base in concepts, such as

universal machines, automata theory, formal language theory, automation of logics, program semantics, specification and verification disciplines, type theories, process calculi, temporal and modal logics, calculi for mobile systems, intelligent agents, semi-structured data, game-theoretic models.
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The impact of these on practice is low and haphazard. Why?

The pace of technological change and the ferociously competitive nature of the industry ...... lead to the triumph of speed over thoughtfulness, of the maverick shortcut over discipline, and the focus on the short term.

G Robinson, quoted in RAEng/BCS report:
The Challenge of Complex IT Projects (2005)
Example The year-2000 fiasco:
There was no disaster, but enormous sums wasted expecting one!
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Symptoms of the gulf:

- The theories themselves are neither complete nor unified
- Software houses have designed what the market required, rather than what has been subjected to available theoretical analysis
- The software industry is over-concerned with managing software production, at the expense of an intimate understanding of software itself.
Concepts for Ubicomp

Each ubicomp domain, hence each model will involve several concepts. Here are a few:

- provenance
- intentions
- locality
- beliefs
- encapsulation
- compilation
- delegation
- trust
- security
- stochastic
- stochastics
- specification
- model-checking
- data-protection
- simulation
- failure
- verification
- connectivity
- authenticity
Tower of models

A model consists of some concepts, and a description of permissible activity in terms of these concepts. For example, a model may be a specification, or a language, or a program in that language.
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- Two models $M_1$ and $M_2$ can be **combined** by taking the union of their *concepts* and their permitted *activities*. 
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- Model M2 **realises** model M1 if
  - Each concept of M1 is defined in terms of M2’s concepts;
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- Model M2 realises model M1 if
  - Each concept of M1 is defined in terms of M2’s concepts;
  - The activity allowed in M2 consistent with what M1 allows.
- Thus we can express derivation of a language from a model.
- A tower of models is built using combination and realisation.
Example: a small tower of models

Model \( M \) is realised by a combination of \( M1, M2 \) and \( M3 \).

Model \( M1 \) is realised by a combination of \( N1 \) and \( N2 \).
A model: movement in a sentient building

Main concepts for the example: locality, connectivity, mobility.

The model is a bigraphical reactive system, in a generic process calculus based on bigraphs.
Activity is defined by declaring **reaction rules** (graph-rewriting):
HOW A SYSTEM MAY RECONFIGURE …..

A pattern …

… and how it reconfigures

A REACTION RULE
•••••• AND THE NEW CONFIGURATION

A pattern …

... and how it reconfigures

A REACTION RULE
A bigraph $G$ with two regions, representing a conference call

B BUILDING
R ROOM
A AGENT
C COMPUTER
INTERACTIONS IN A BUILT ENVIRONMENT (1)

A bigraph $G$ with two regions, representing a conference call

B BUILDING
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algebraic form:

$$/x (Bx(R(/u Ayu | Cux) | /u Ayu)R(/u Ayu | Cux)) \parallel R(/v Ayv | Cvz)$$
A host environment $H$, which $G$ may inhabit
The larger environment, $H \circ G$. 

INTERACTIONS IN A BUILT ENVIRONMENT (3)
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One agent leaves the call!

The larger environment, $H \circ G$.
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The larger environment, $H \circ G$.

One agent leaves the call

Another moves into a room!
INTERACTIONS IN A BUILT ENVIRONMENT (3)

The larger environment, $H \circ G$. One agent leaves the call
Another moves into a room
...and is logged in!
Enriching the model

Add extra concepts: continuity, stochastics, reflectivity, ... 
Use this model to realise higher models with intentions, beliefs, trust, ...
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Use this model to realise higher models with intentions, beliefs, trust, ...

The dualistic approach: program experiments with this model, to explore the behaviour of humans who use sentient buildings.
PART III: Embarking on the Challenge
Embarking on the Challenge: FOOTHILL PROJECTS

Approach the goals for experience, design and science bottom up, in close harmony. What is a foothill project?
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- Modest aims, achievable in three years;
- Involve new collaborations;
- Explore at least two of experience, design and science;
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After five years, the goals of the Challenge become refined and articulated, yielding a road-map. Foothill projects are the only way to get there!
Topics for foothill projects

The community has identified six topics for foothill projects:

- Ubiquitous computing and the urban environment
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For outlines, see the GC website.

Many projects may address the same topic. And we need more topics!
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What’s the point of Grand Challenges?

To make applications that startle the world?

(e.g. beating a grandmaster at chess)
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OR

To develop organising principles for a science?
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OR

To develop organising principles for a science?

For ubicomp:

- The first without the second spells danger
- The two together will embed computing in our scientific culture

....0000000000000000000....
Thankyou!

This Grand Challenge:
www-dse.doc.ic.ac.uk/Projects/UbiNet/GC/index.html

The Grand Challenges for Computing Research:
www.ukcrc.org.uk/grand_challenges/

The Grand Challenges Conference
Perceptions in Computing, Glasgow March 22-24 – register now! – :
www.ukcrc.org.uk/grand_challenges/news/challenge06.cfm