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Robin Milner, The Computer Journal Lecture, February 2006, BCS

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VISION: Populations of computing entities will be a significant part of our environment, performing tasks that support us, and we shall be largely unaware of them. (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

A UKCRC Grand Challenge for Computing Research. See manifesto at
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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.
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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;*
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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)

Software: The gulf between engineering and science(2)

Example The year-2000 fiasco:

There was no disaster, but enormous sums wasted expecting one!

Appropriate theory to prevent it had been around for *two decades*.

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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:

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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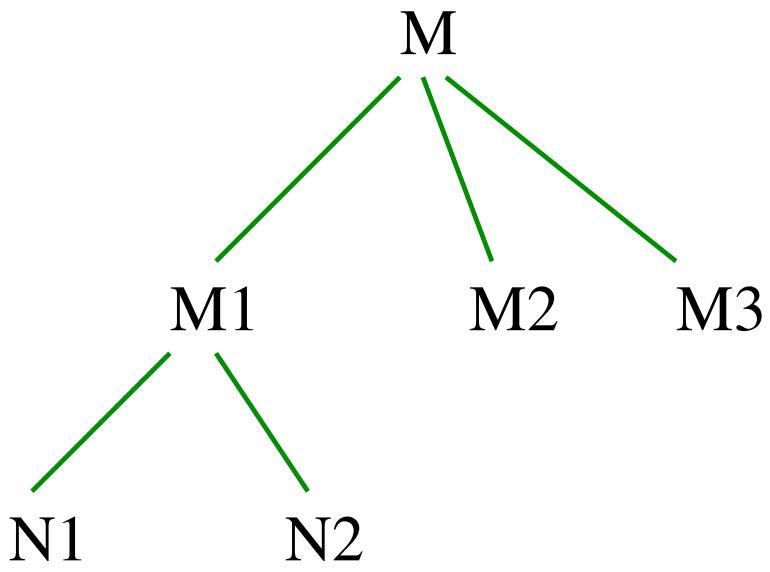
- Thus we can express derivation of a **language** from a model.
- A **tower of models** is built using *combination* and *realisation*.

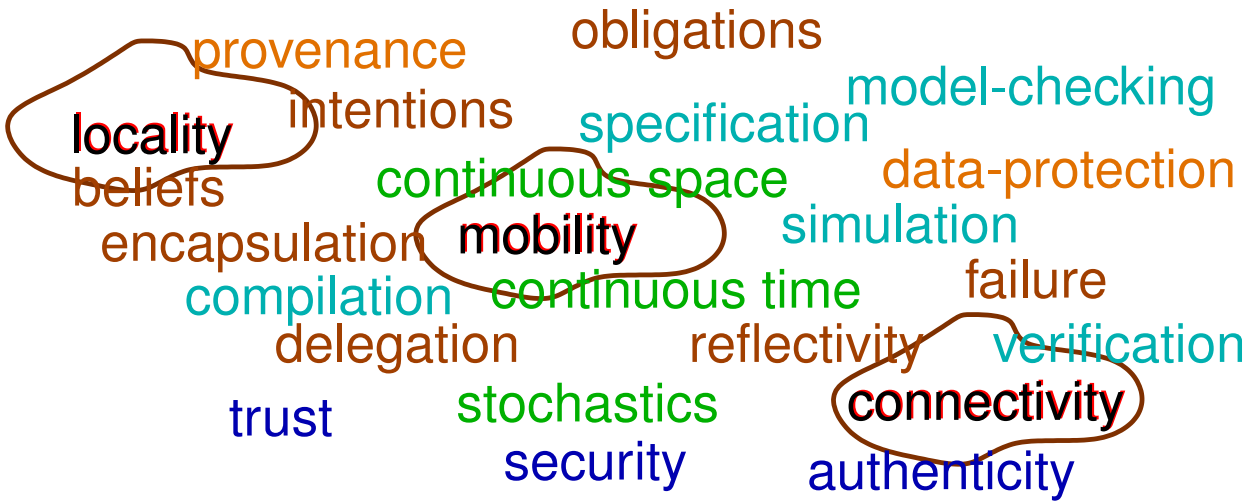
Example: a small tower of models



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

Model M1 is realised by a combination of N1 and N2.

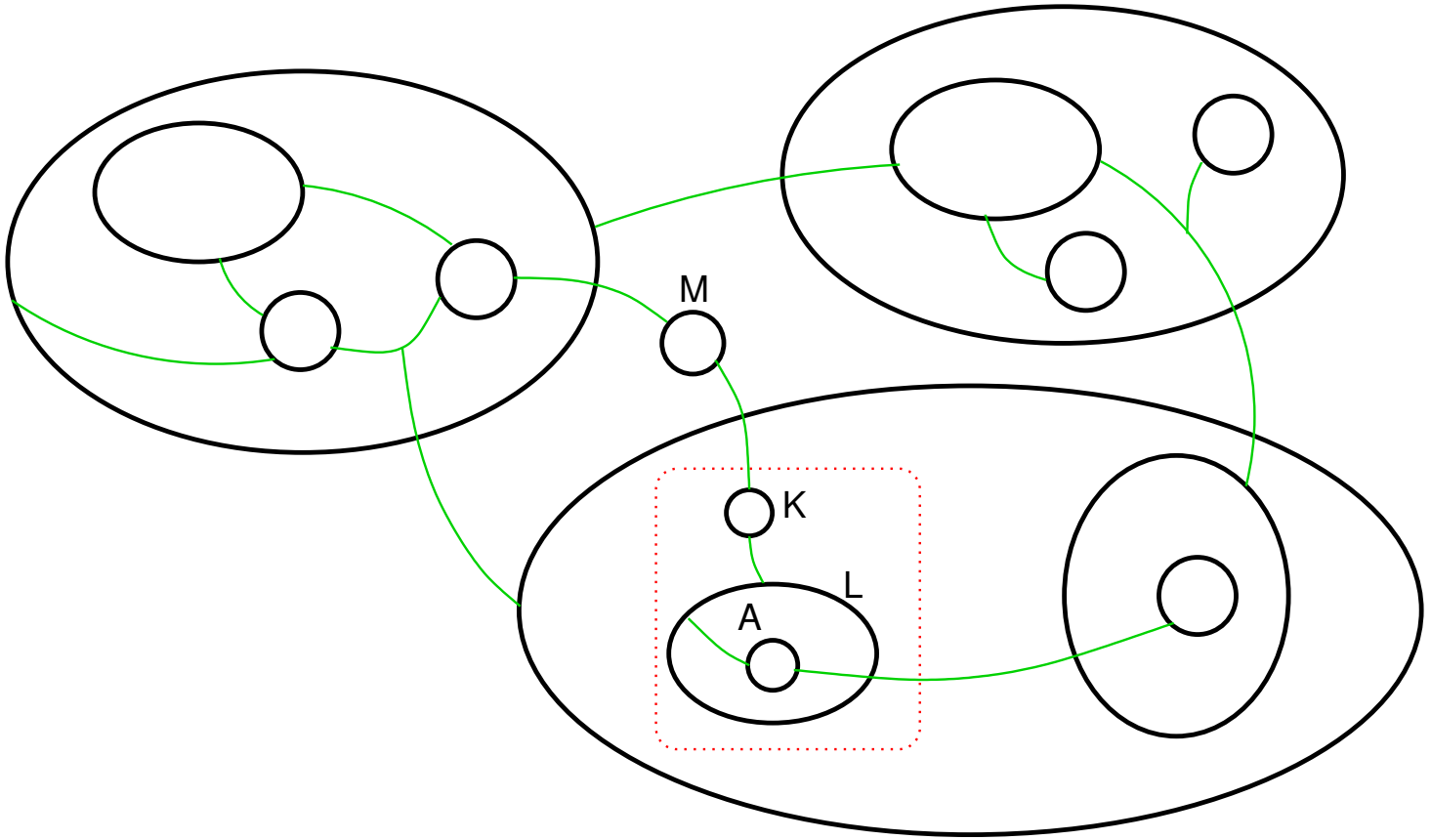
A model: movement in a sentient building



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

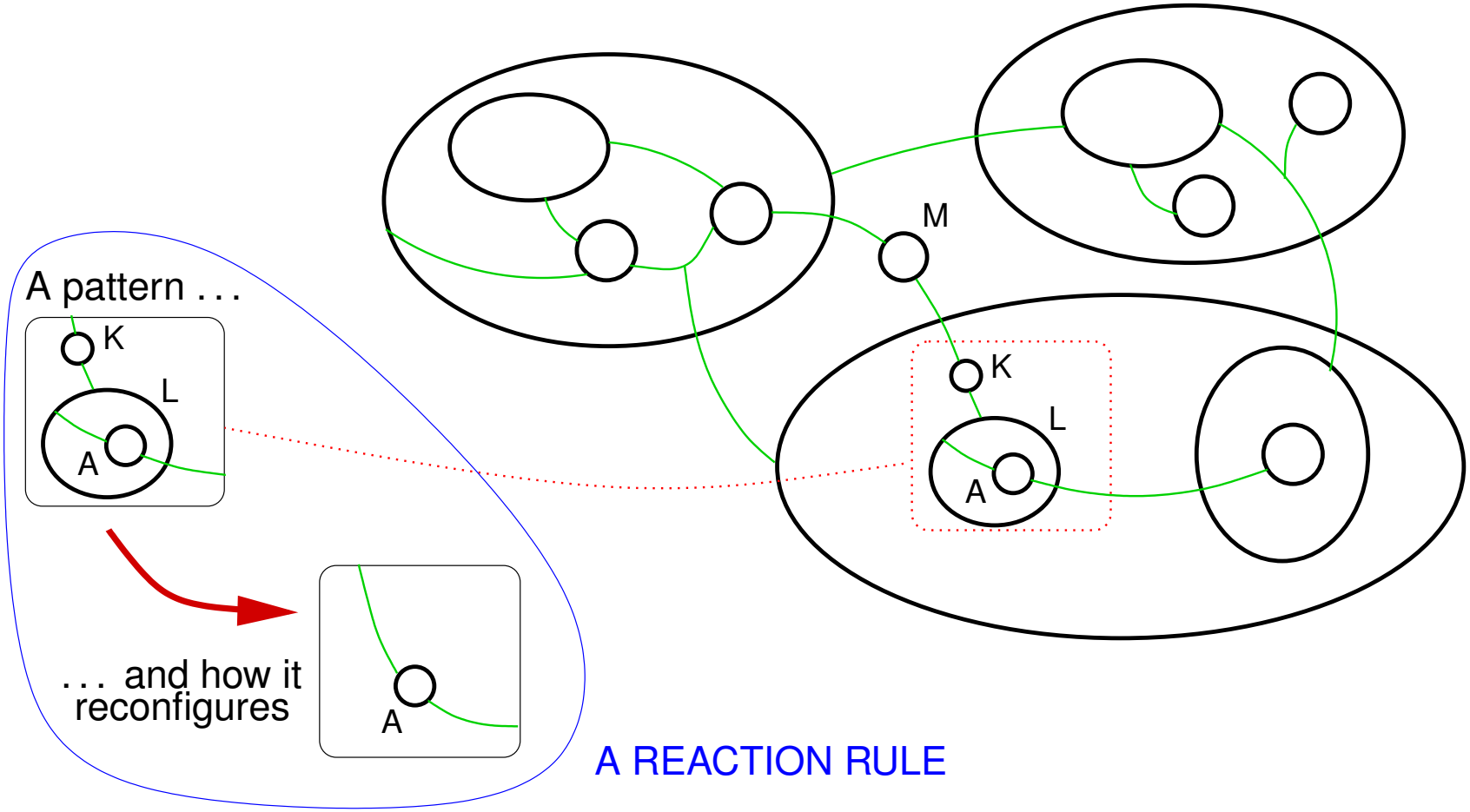
The model is a **bigraphical reactive system**, in a generic process calculus based on **bigraphs**.

A TYPICAL BIGRAPH



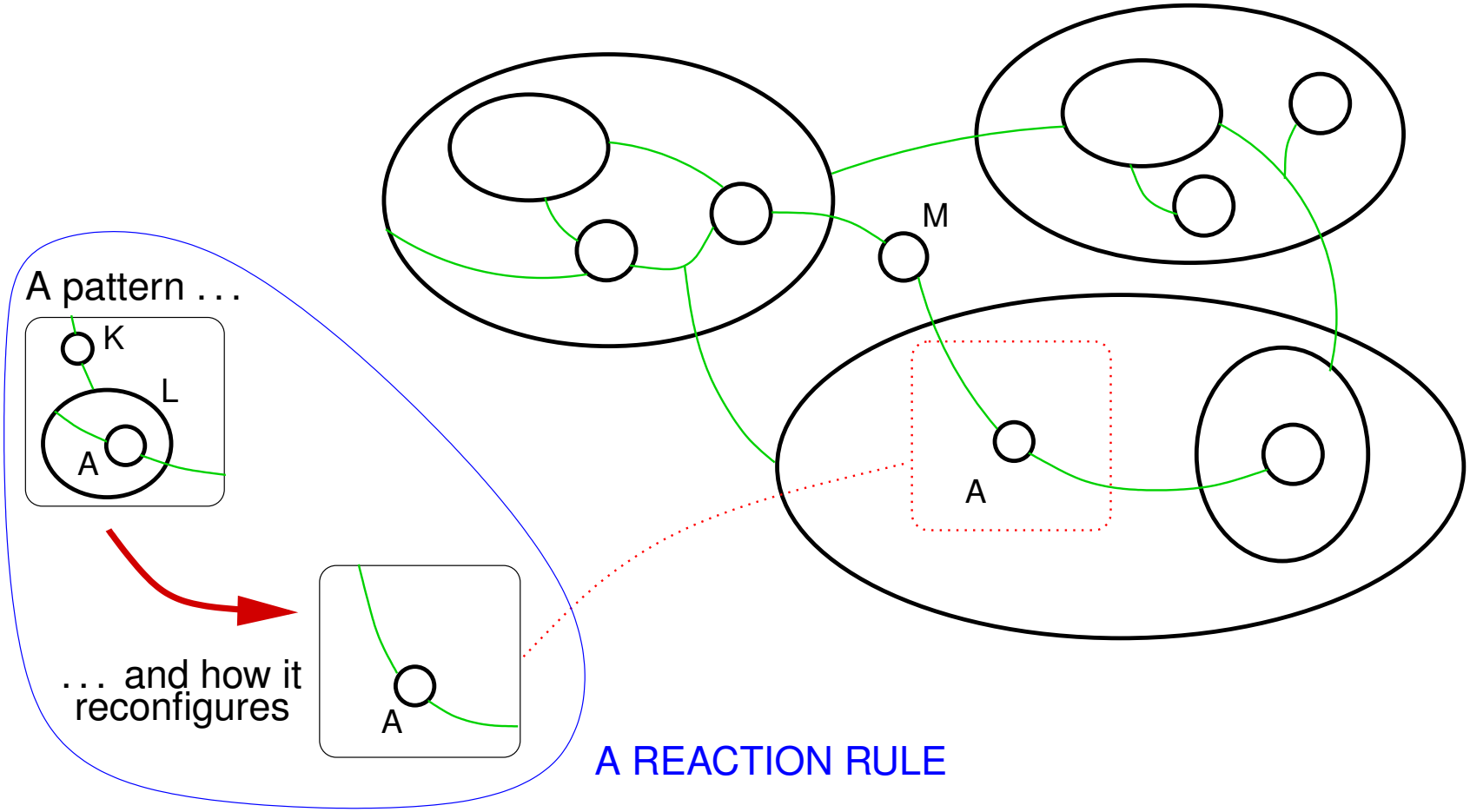
Activity is defined by declaring **reaction rules** (graph-rewriting):

HOW A SYSTEM MAY RECONFIGURE . . . . . .



A REACTION RULE

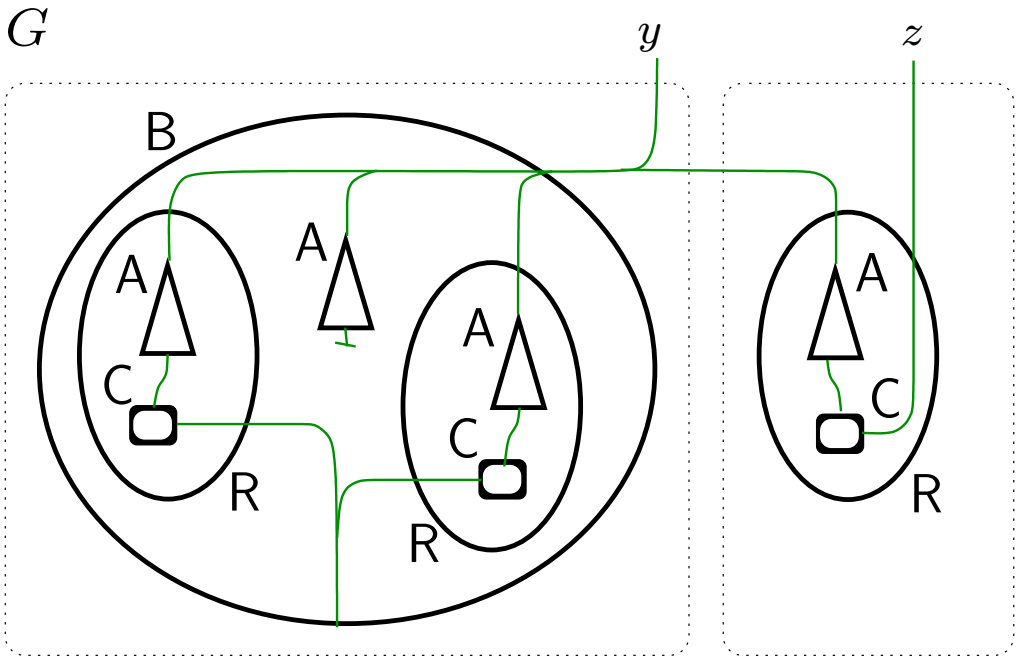
. . . . . AND THE NEW CONFIGURATION



INTERACTIONS IN A BUILT ENVIRONMENT (1)

A bigraph G with two regions, representing a conference call

B	BUILDING
R	ROOM
A	AGENT
C	COMPUTER



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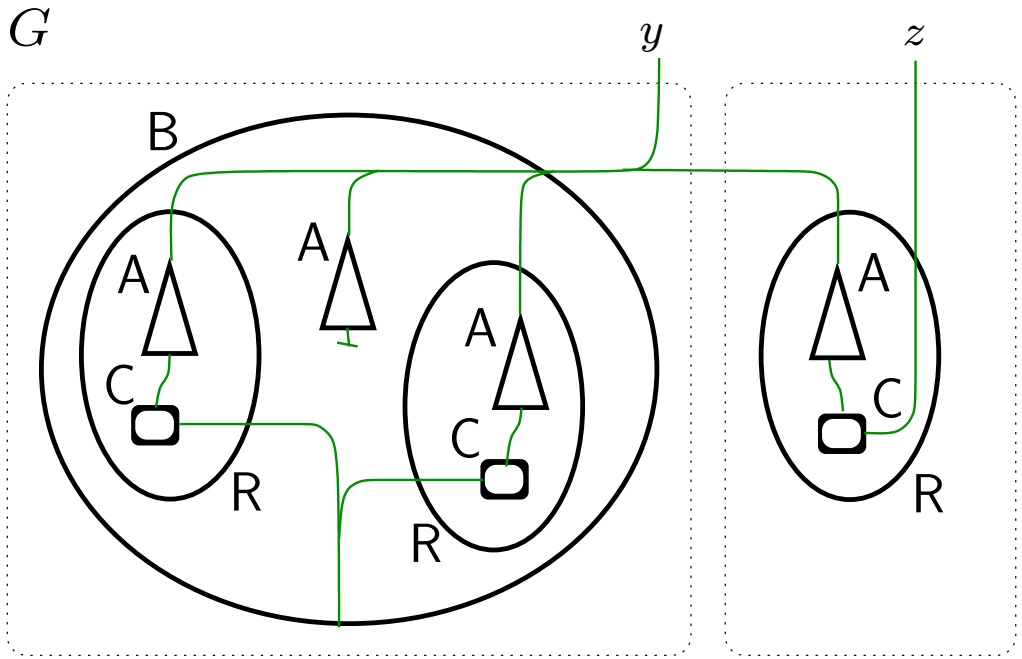
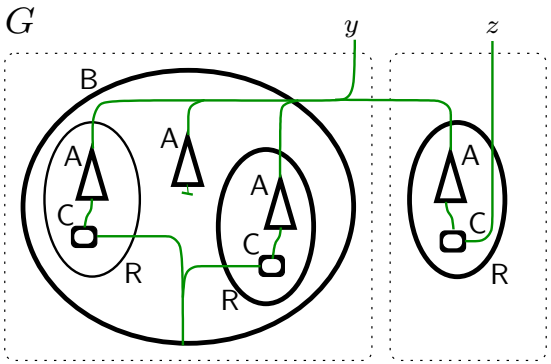


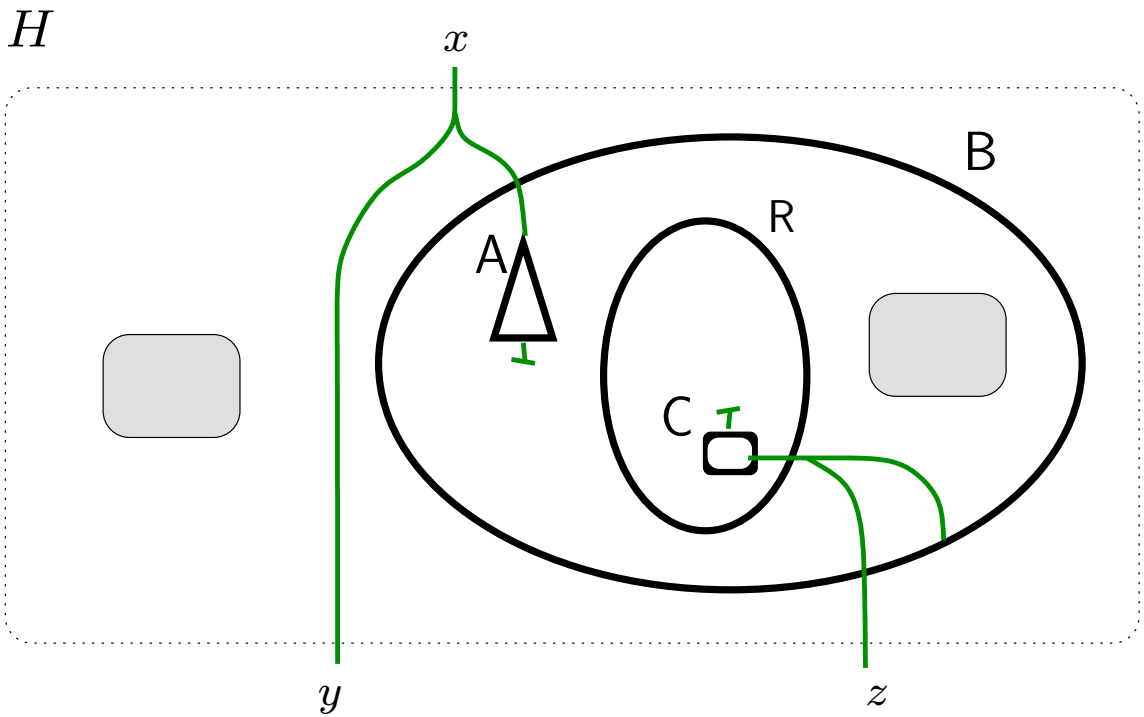
algebraic form:

$$/x\ (\mathsf{B}x(\mathsf{R}(/u\ \mathsf{A}yu \mid \mathsf{C}ux) \mid /u\ \mathsf{A}yu)\mathsf{R}(/u\ \mathsf{A}yu \mid \mathsf{C}ux))$$
$$\| \mathsf{R}(/v\ \mathsf{A}yv \mid \mathsf{C}vz)$$

INTERACTIONS IN A BUILT ENVIRONMENT (2)

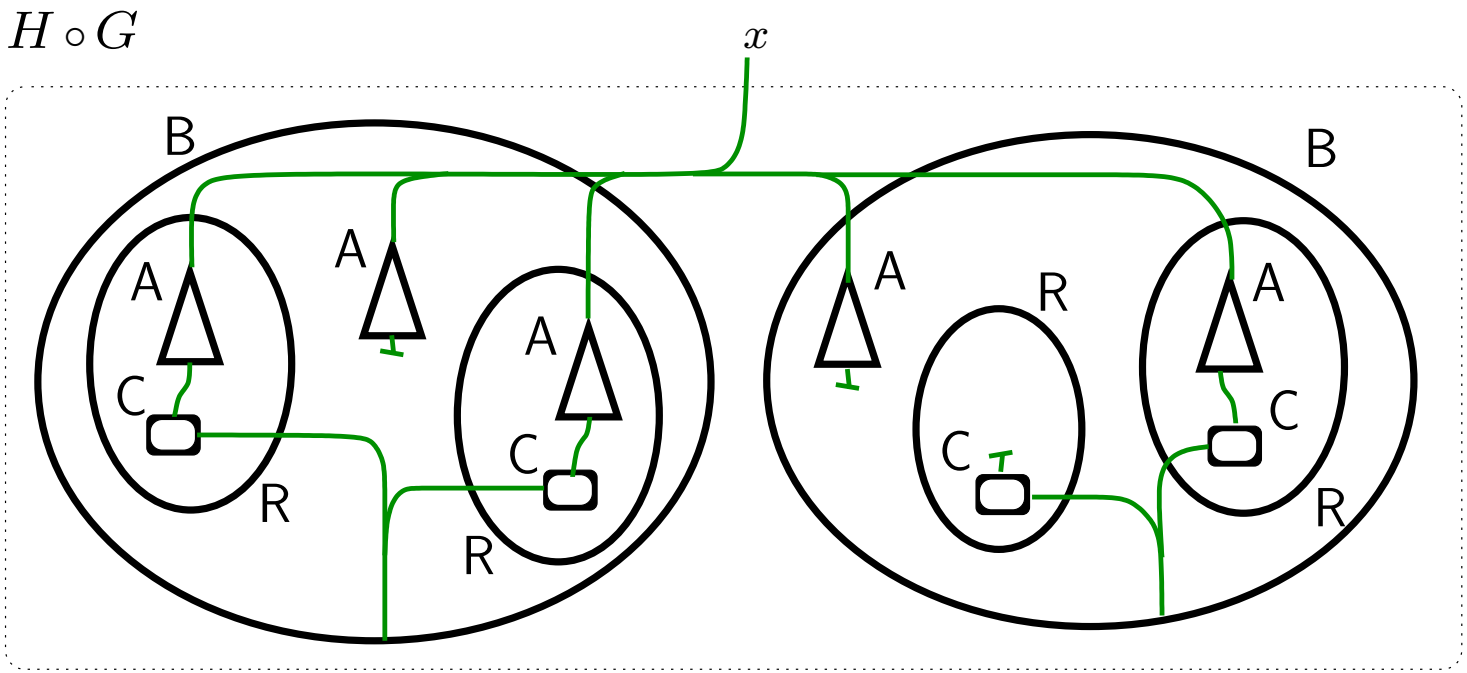
A host environment H, which G may inhabit





INTERACTIONS IN A BUILT ENVIRONMENT (3)

The larger environment, $H \circ G$.



INTERACTIONS IN A BUILT ENVIRONMENT (3)

One agent leaves the call!

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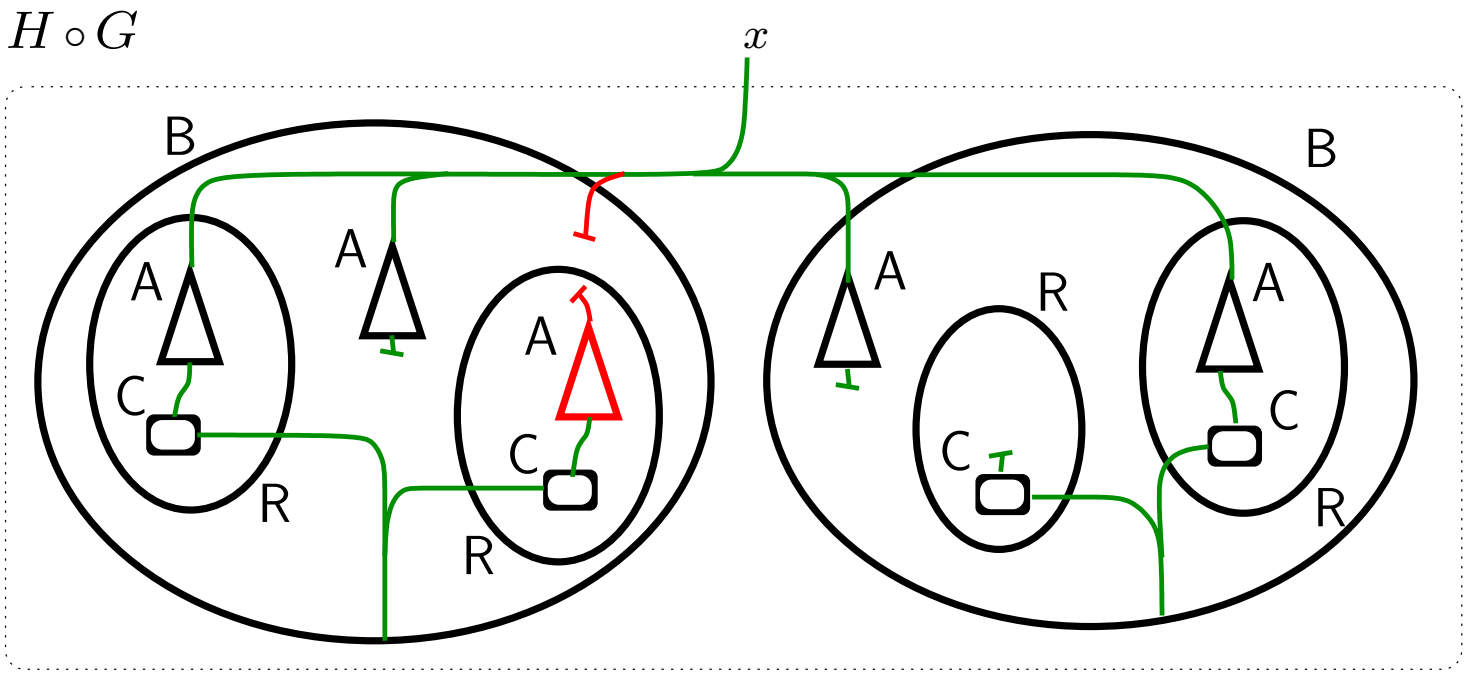

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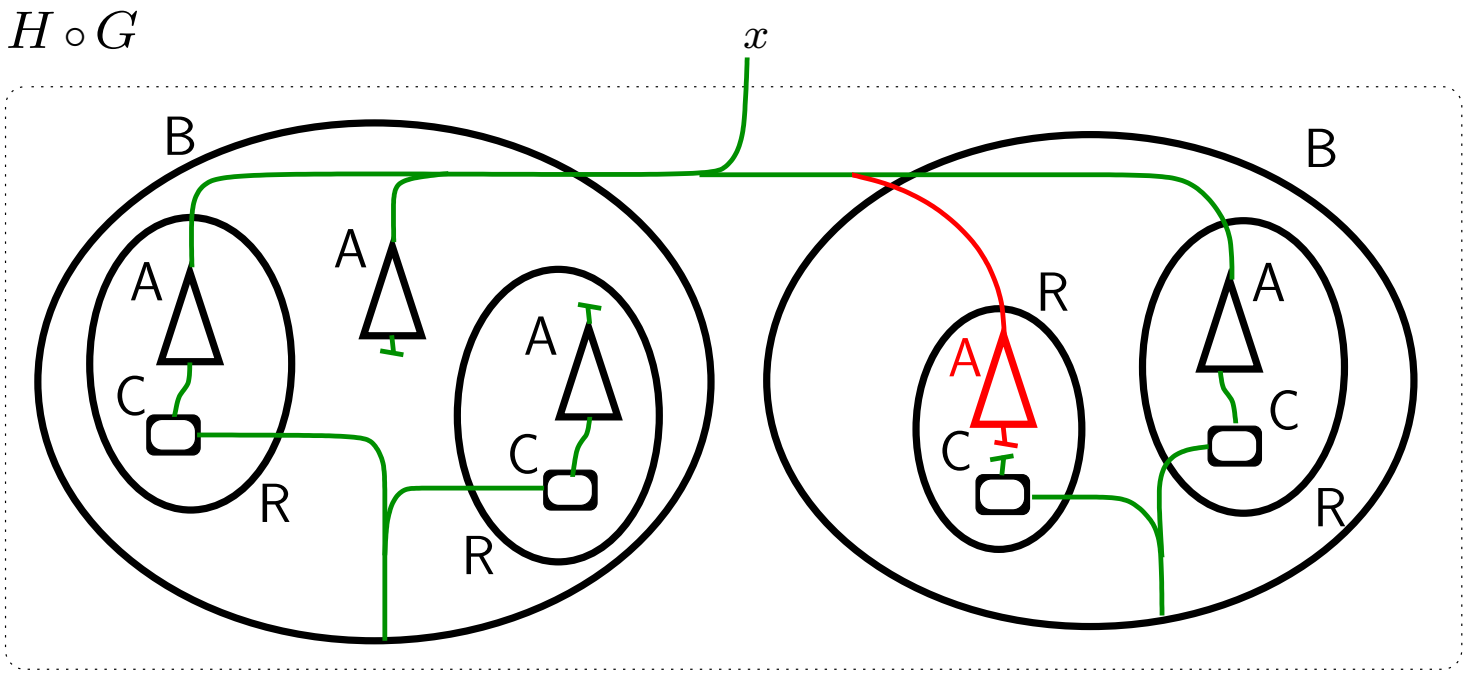

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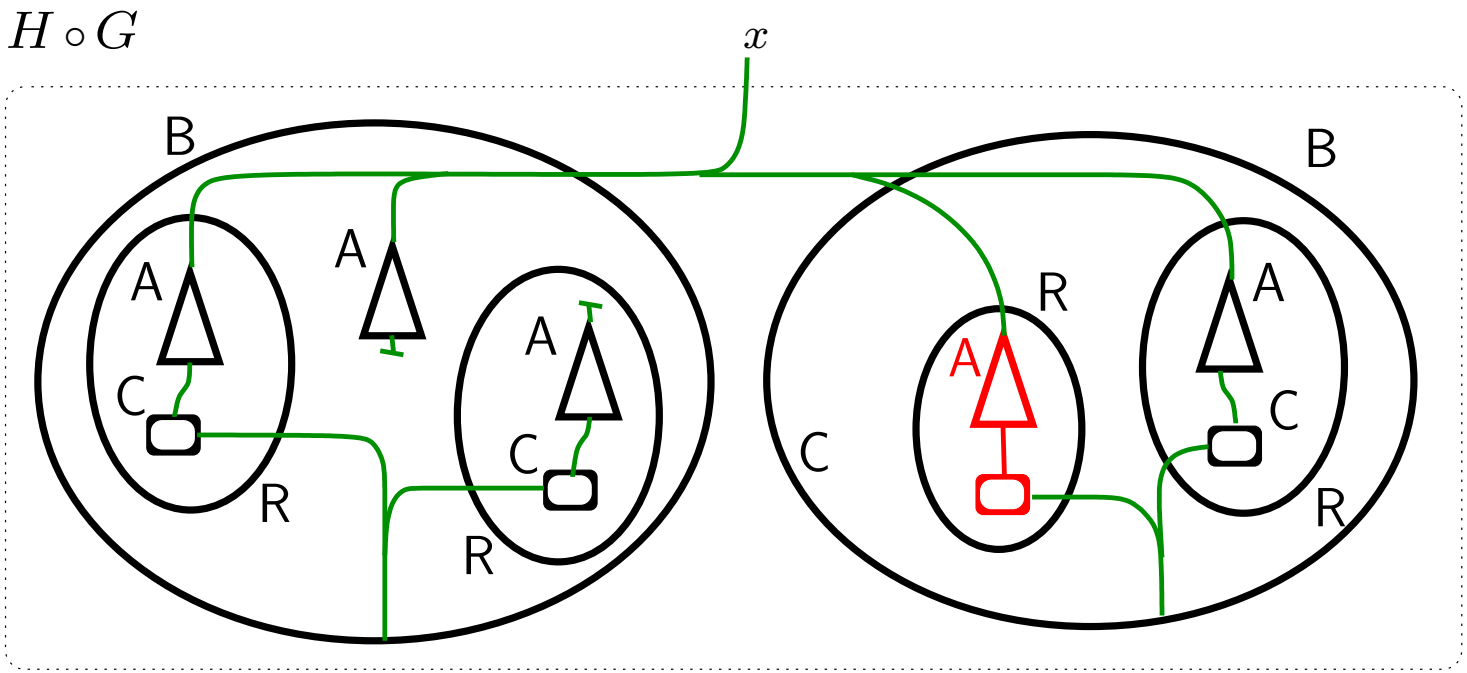
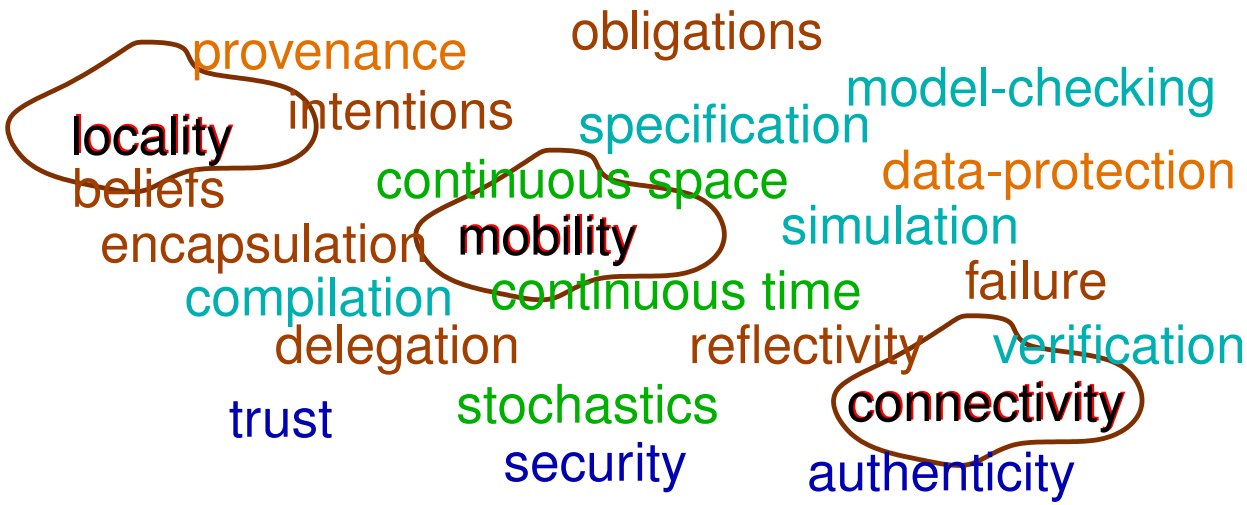


Enriching the model



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Use this model to realise higher models with **intentions**, **beliefs**, **trust**, . . .

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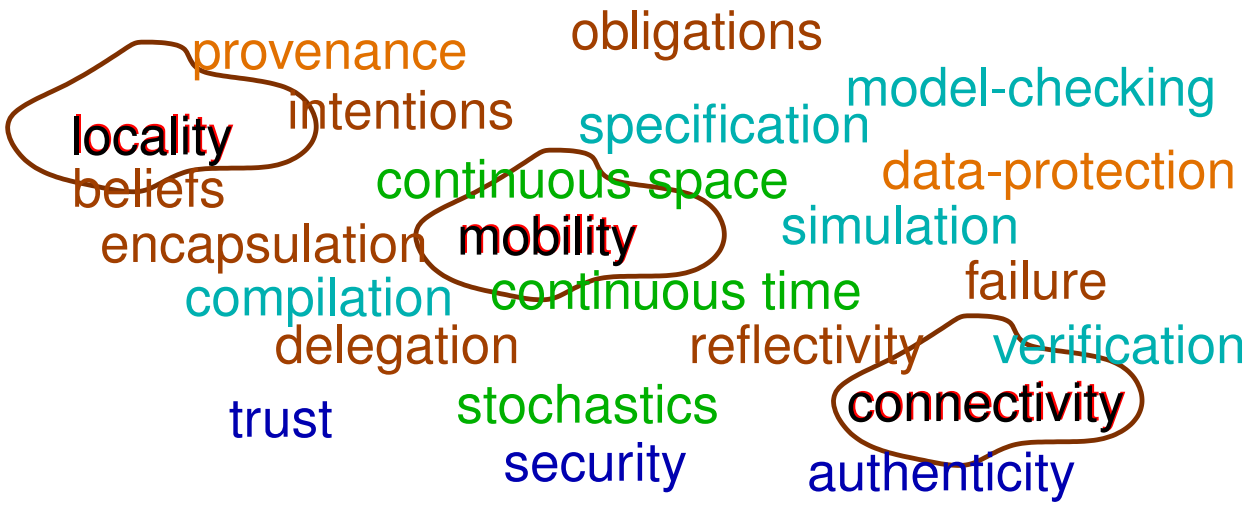

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The dualistic approach: program experiments with this model, to explore the behaviour of humans who use sentient buildings.

PART III: Embarking on the Challenge

Embarking on the Challenge: FOOTHILL PROJECTS

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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

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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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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**

....oooo0000OOOOO0000oooo....

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