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eNTERFACE
The SIMILAR NoE Summer Workshop on Multimodal Interfaces
2005

Human-Computer Interaction (HCI)
Interaction modality and Multimodality

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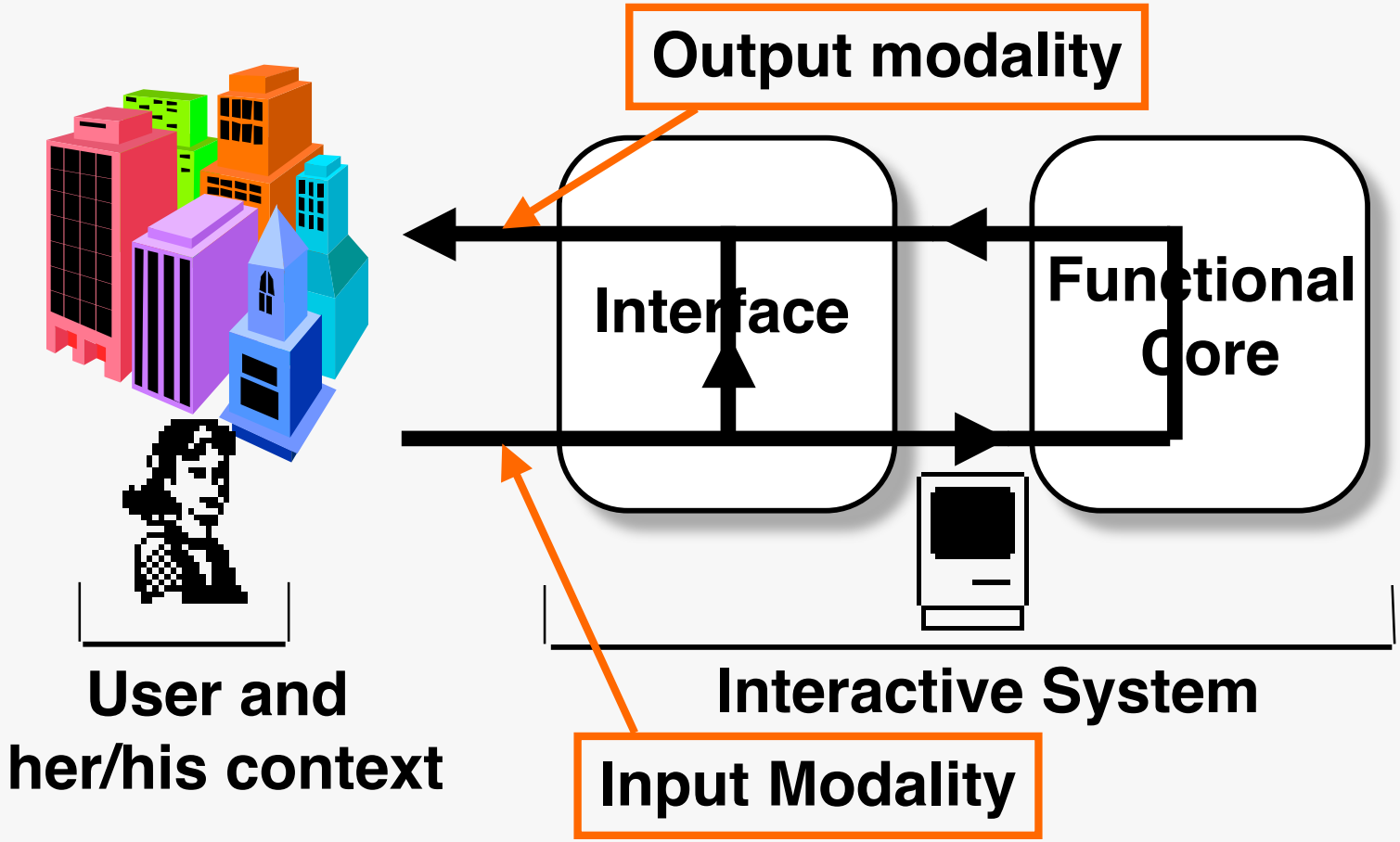
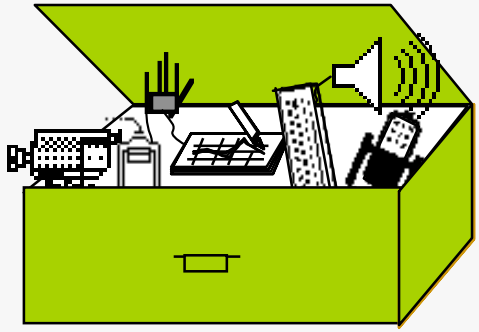
Introduction: the Domain

Human-Computer Interaction



Introduction: the Domain

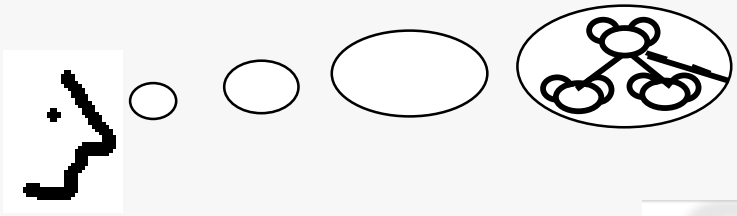
- Human-Computer Interaction
  - Design of usable multimodal interaction



A modality

A multimodal system

  - Software architecture model for multimodal systems

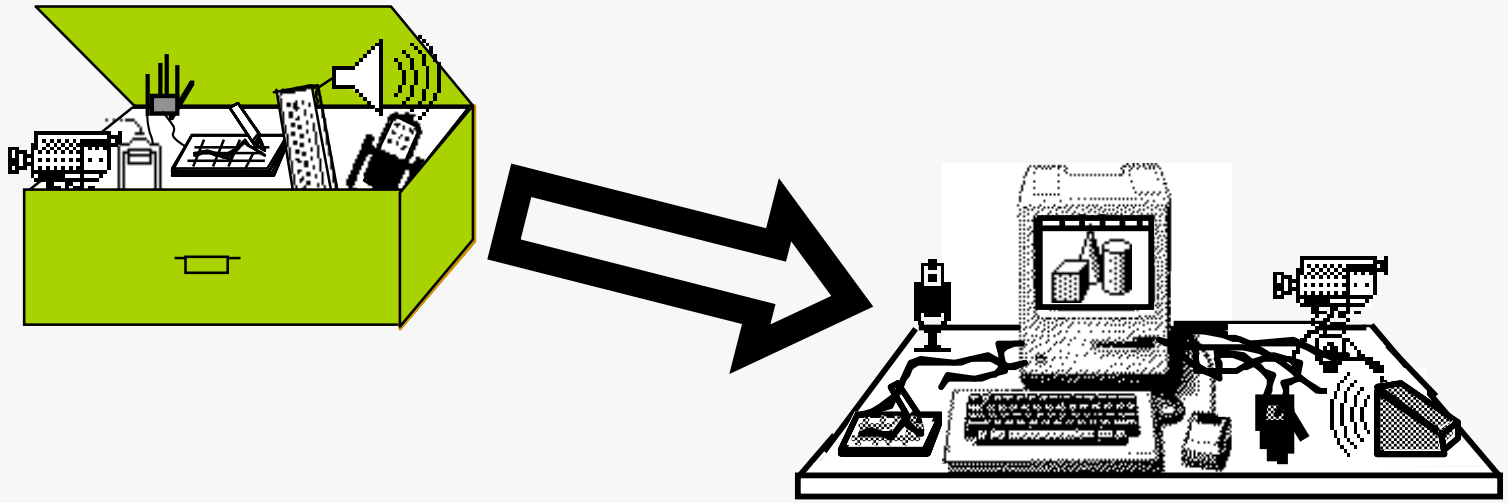


Fusion of different objects from various modelling techniques:

How?

At which level of abstraction?

Introduction: the Domain

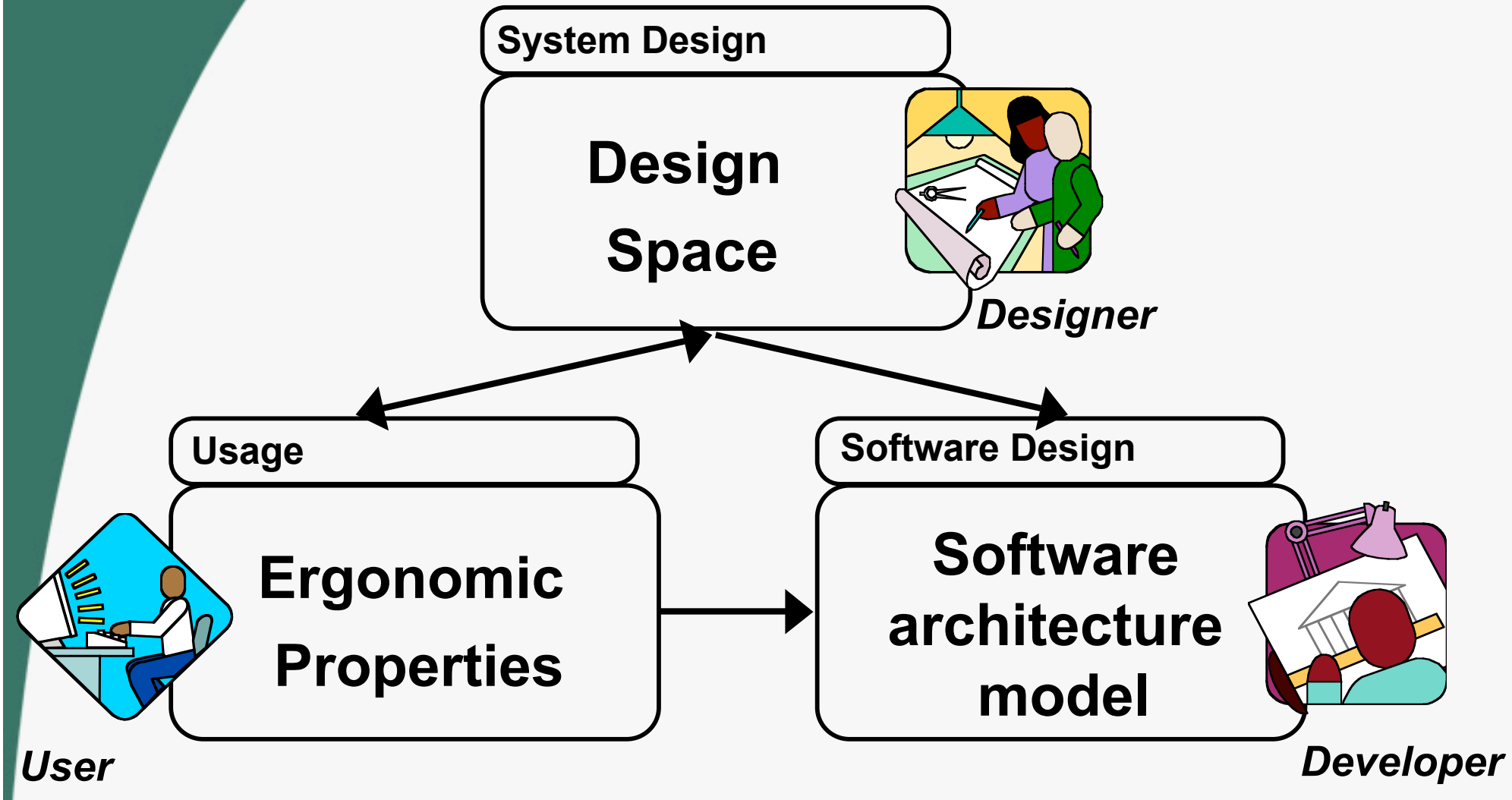


Multimodal Interfaces extend the sensori-motor capabilities of computer systems

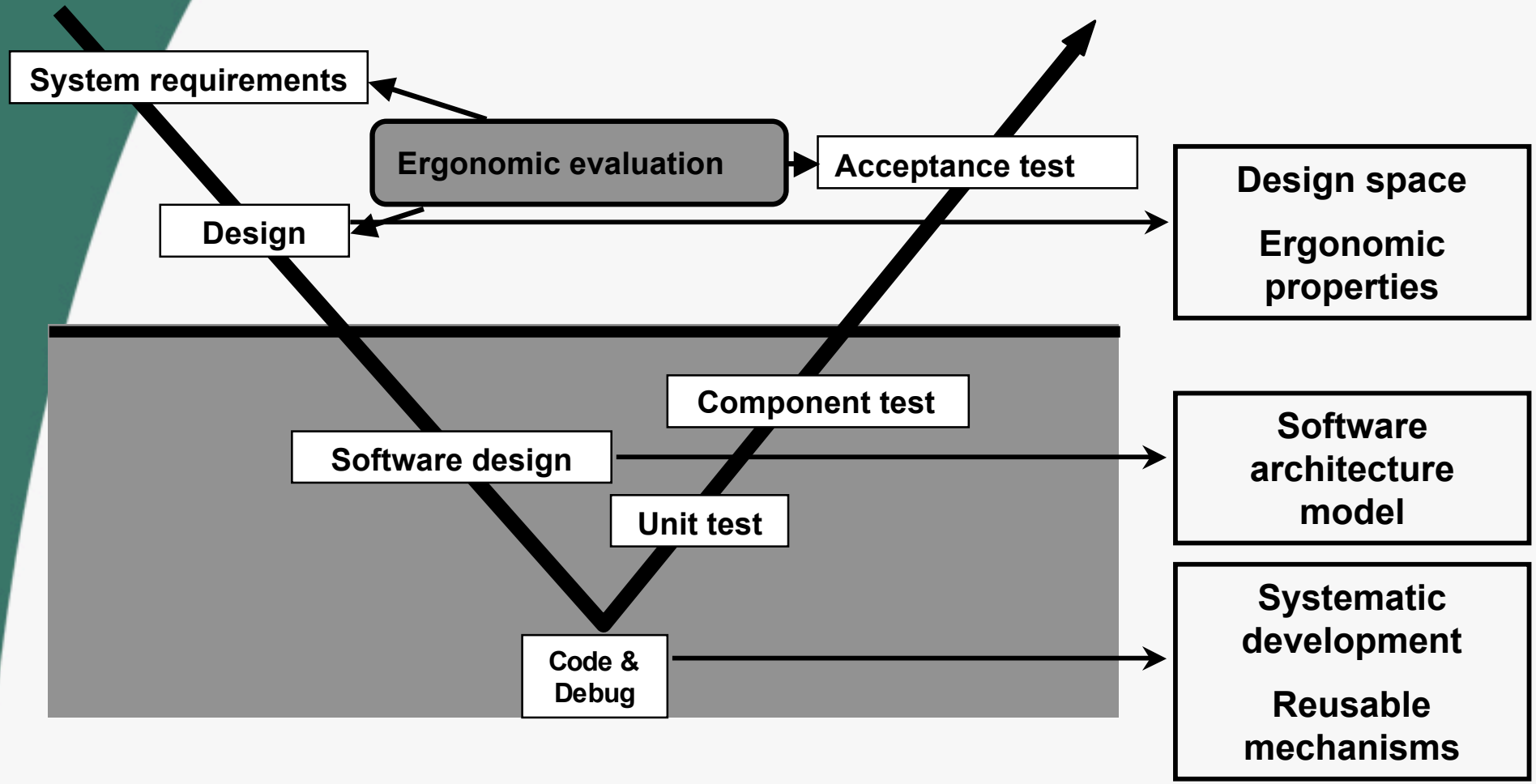
Multimedia ≠ Multimodal

New interaction capabilities will probably appear

Research approach



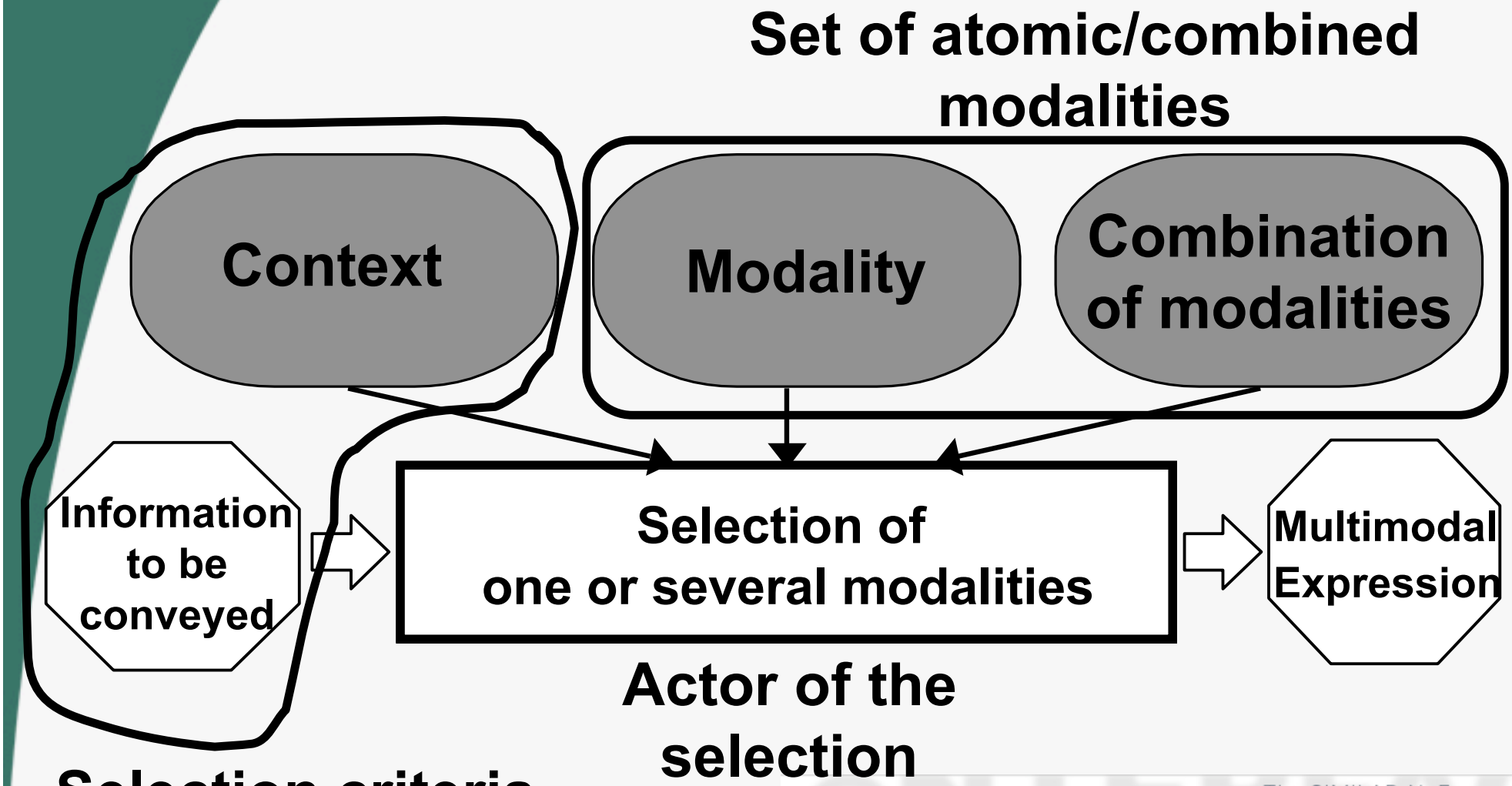
Research approach and the V software lifecycle



Outline

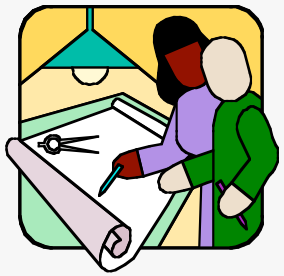
- Terminology
  - Design space
  - Interaction modality
  - Multimodality: combination of modalities
- Fusion/Fission mechanisms
- ICARE platform for input/output multimodal interaction
- Grand Challenges

Multimodality: Design space



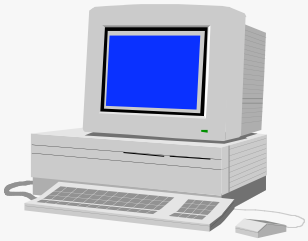
Multimodality
Actor of the selection

- Who is performing the selection



Designer

User



System

Information to be conveyed

Selection of one or several modalities

Multimodal Expression

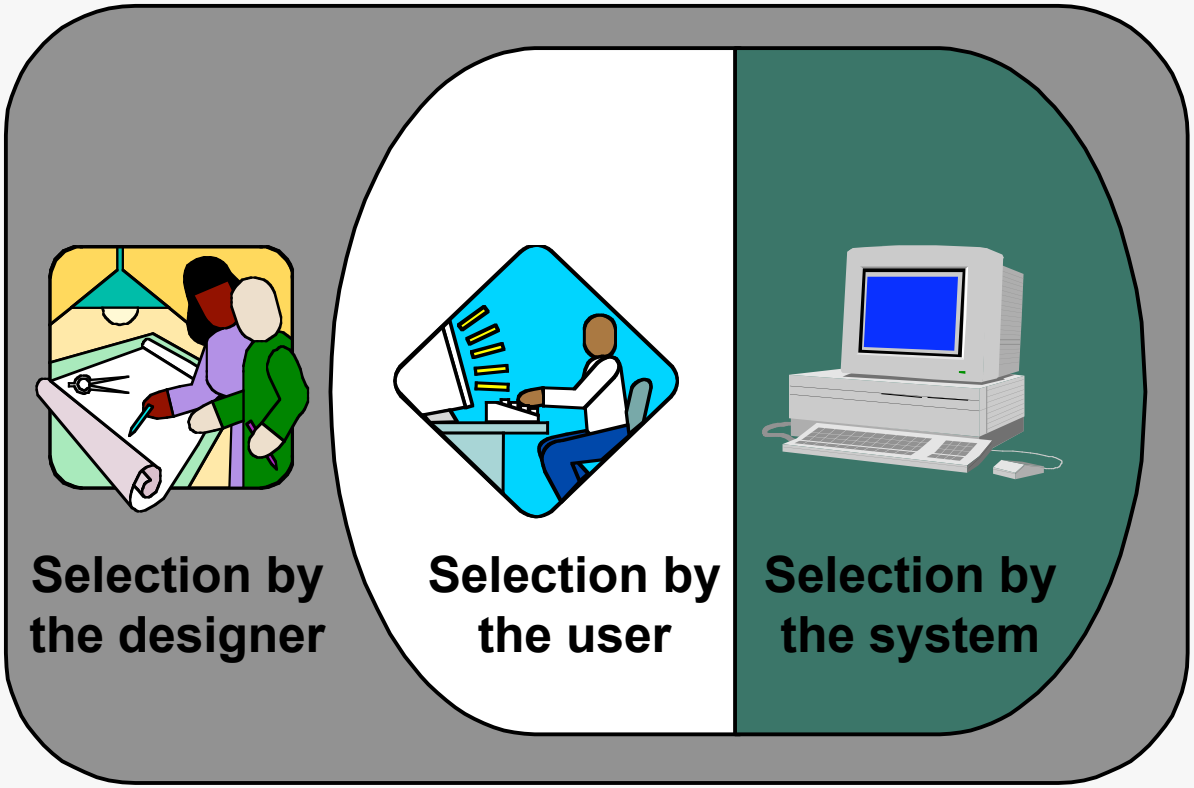
Actor of the selection

Multimodality
Actor of the selection

No adaptation

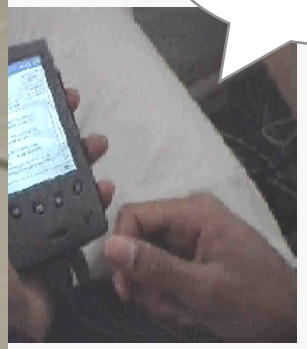
Adaptability

Adaptivity

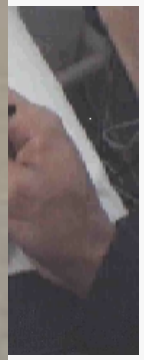


Multimodality Adaptability

Go to the middle of the message



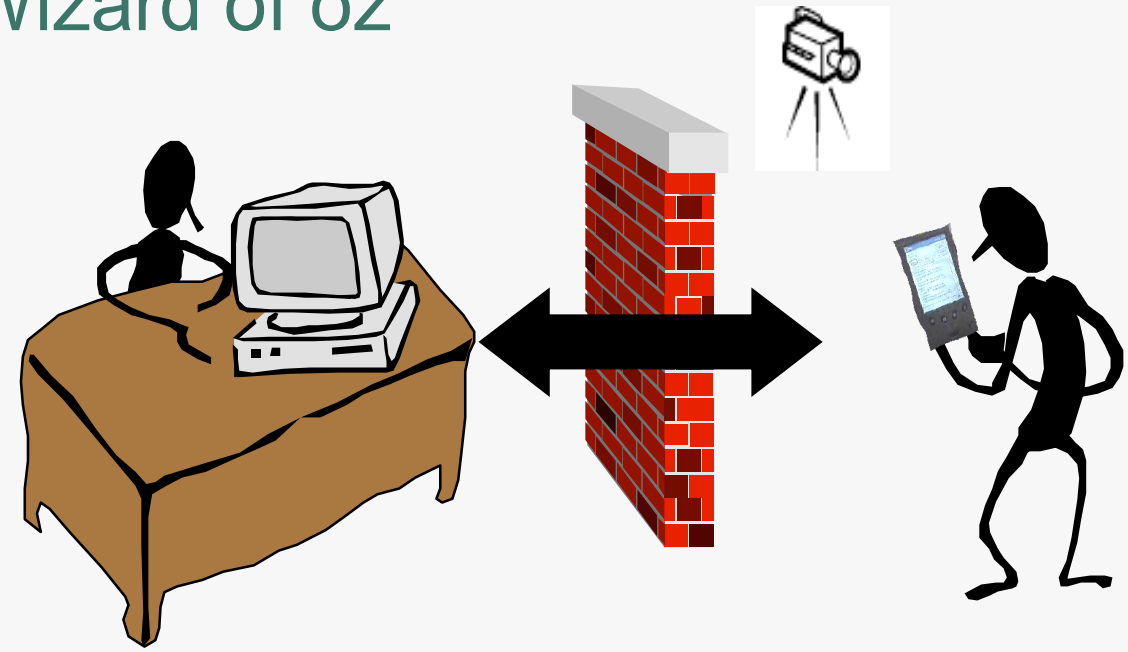
peech



ulation

Multimodality Adaptability

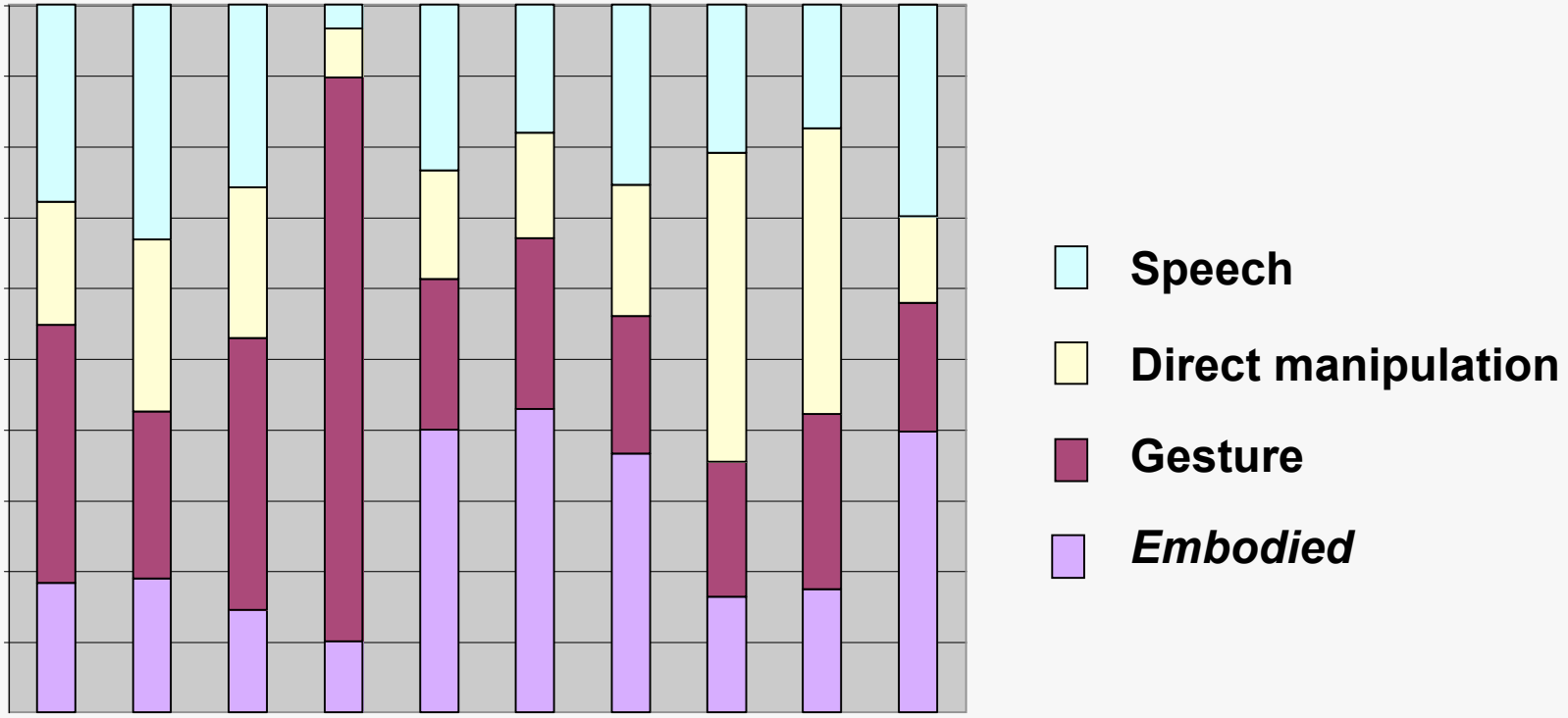
- Wizard of oz



Accomplice **Subject**

Multimodality Adaptability

- Usage of the modalities
- All sessions / All subjects



Multimodality Adaptability

- The subjects used all of the modalities
- Individual preferences leading in some cases to specialization
- Few redundancy and complementarity cases

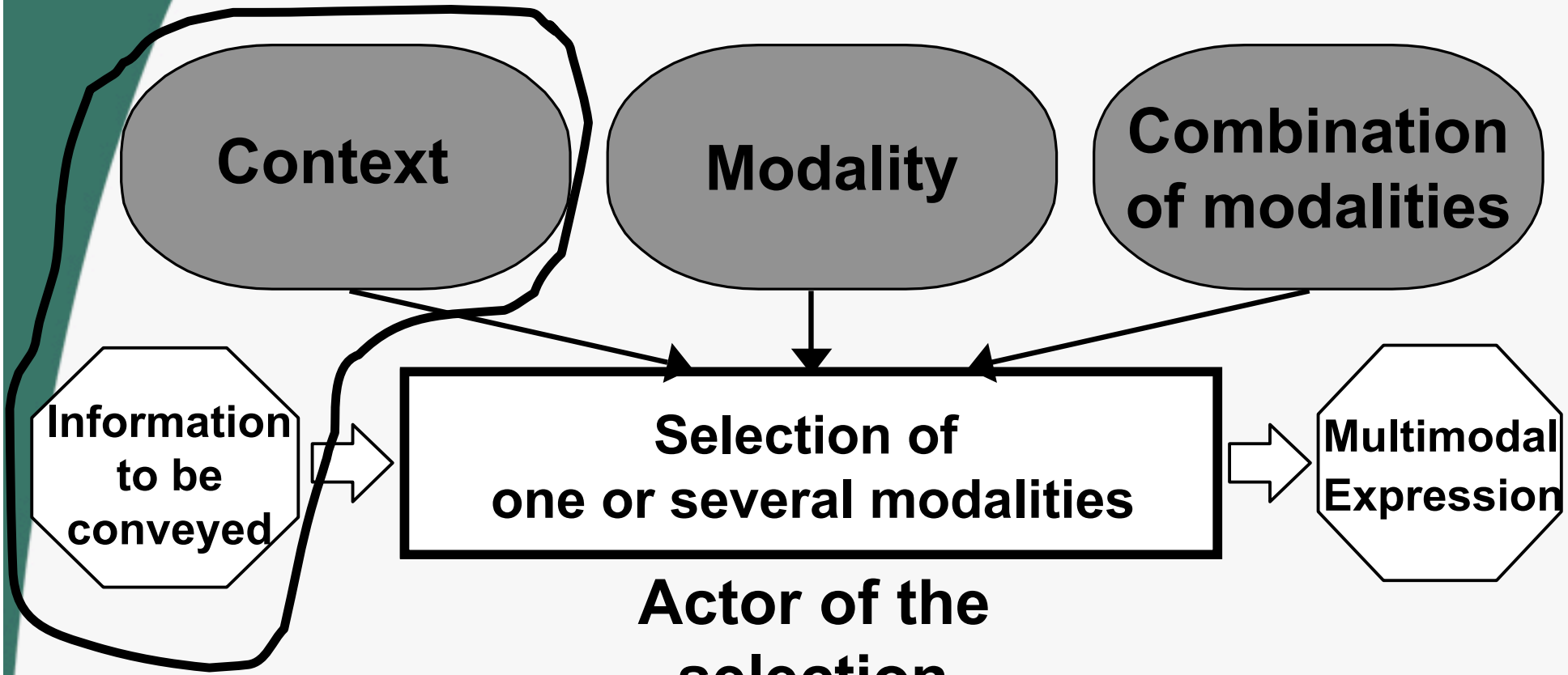
Multimodality Adaptativity

- Selection of the modalities by the system
- Context-aware systems

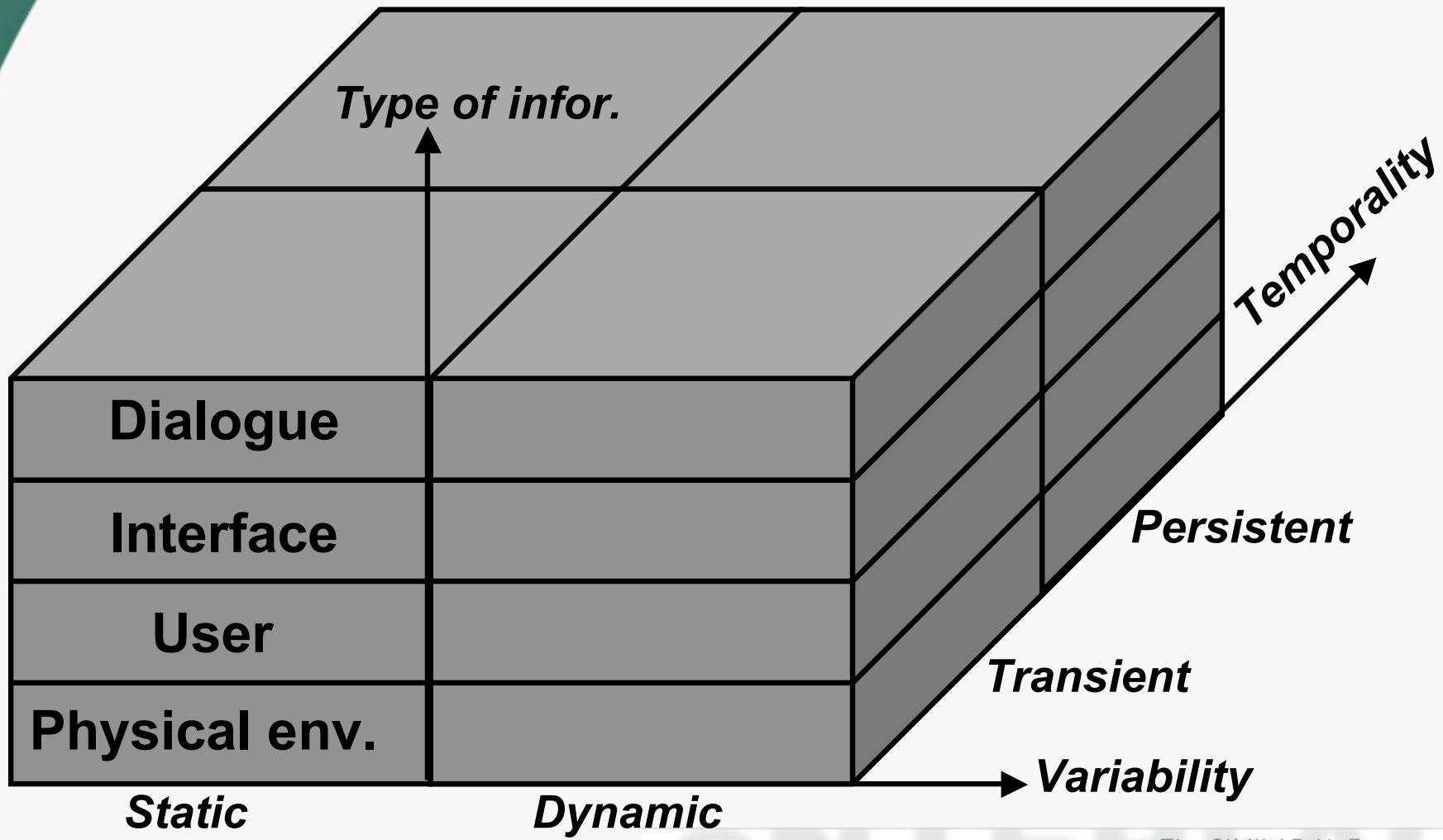
Ring

Vibration

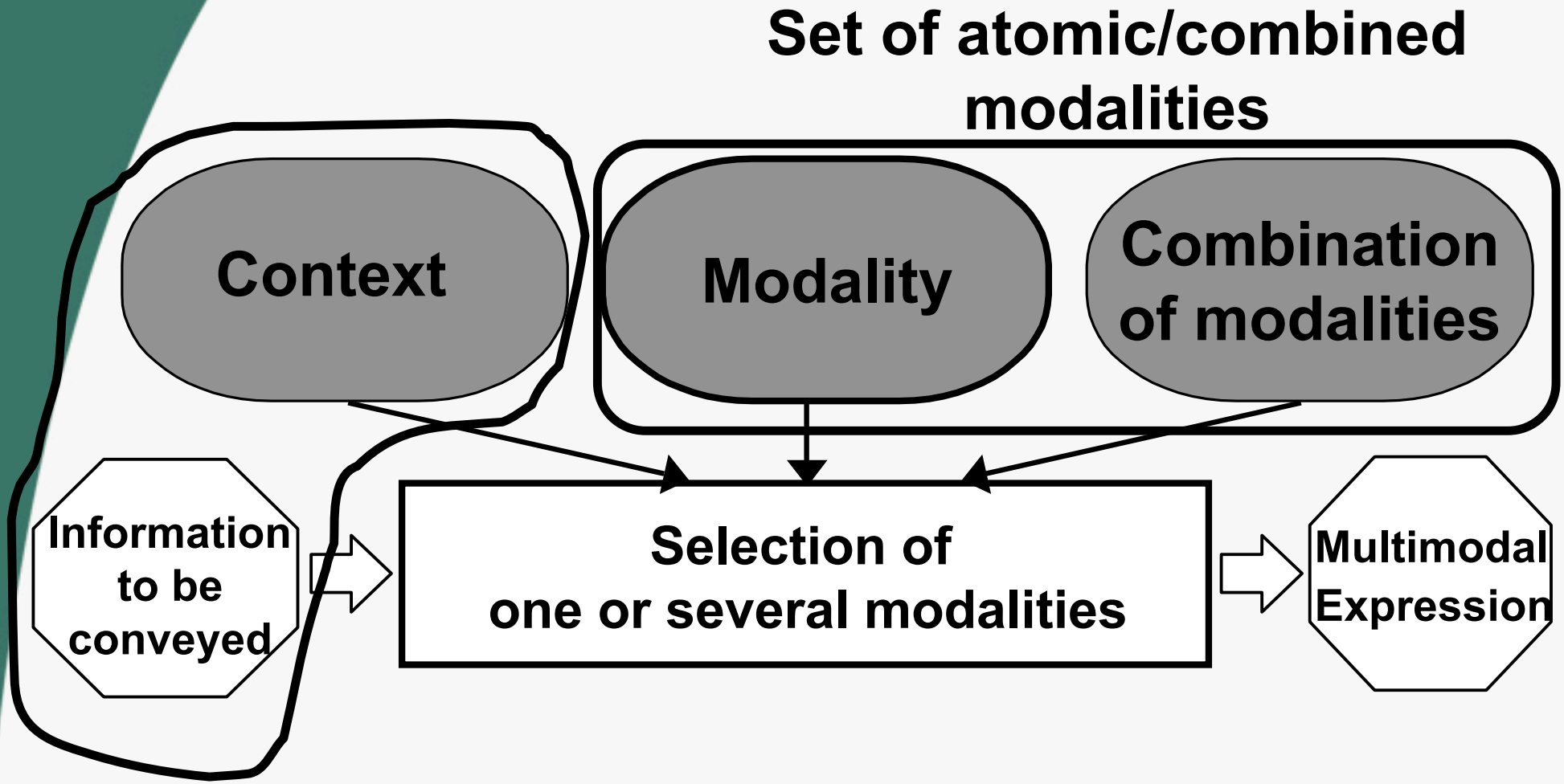
Multimodality: Design space



Multimodality
Selection criteria: Context



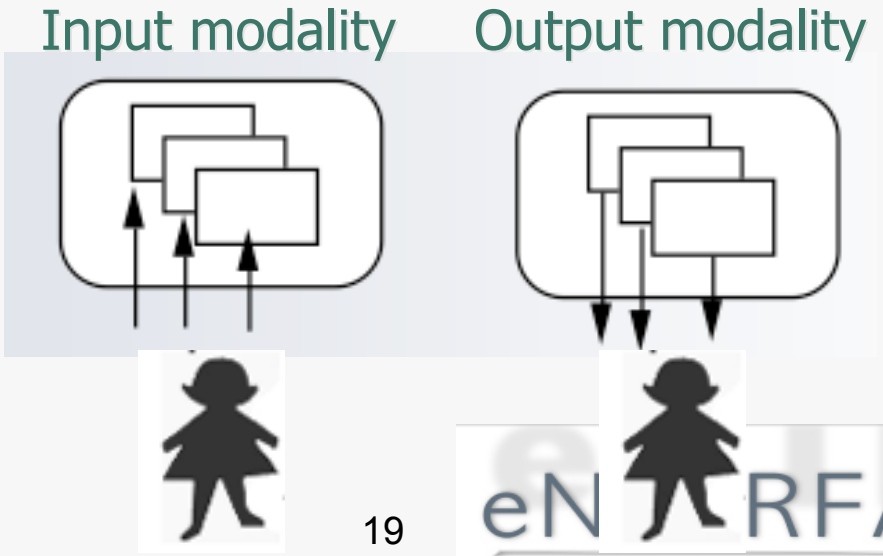
Multimodality: Design space



Multimodality
Characterisation of a modality

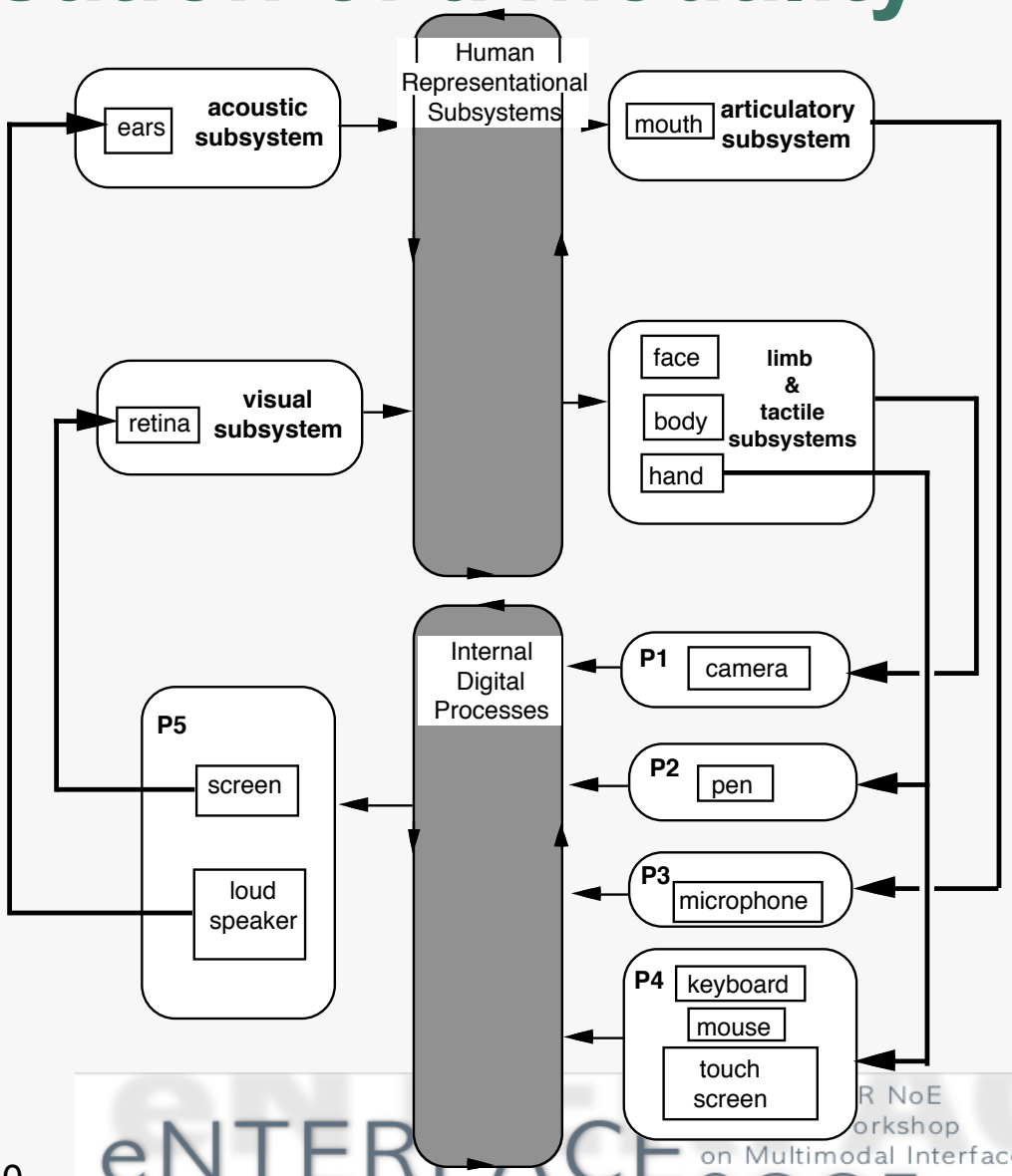
Definition of a modality

- Modality = (device, interaction language)
  - A set of sensors (input devices) or effectors (output devices) ← **Perception/Action**
  - A processing facility based on a language ← **Cognition**



Multimodality
Characterisation of a modality

- Theory ICS
  - APU Cambridge
- ICS as predicting cognitive resources involved in using and choosing modalities



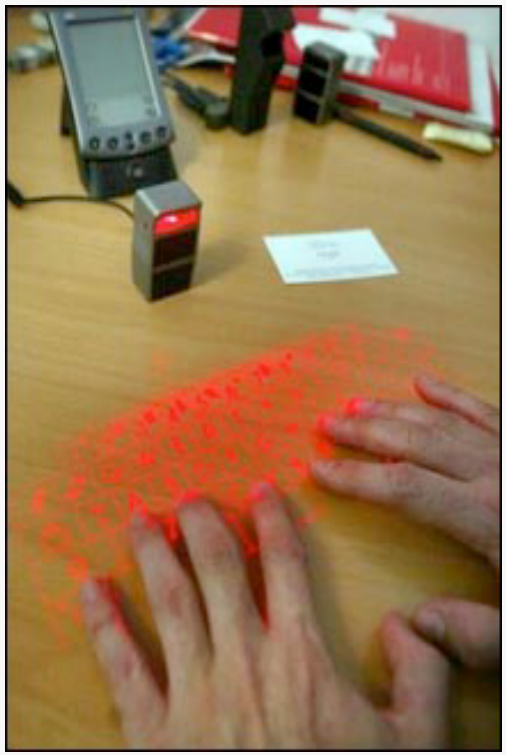
Multimodality
Characterisation of a modality

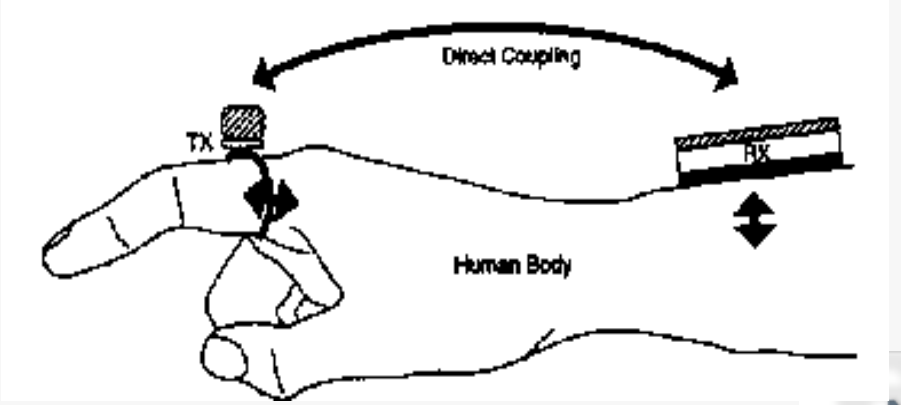
- Modality = (device, interaction language)
- Recent interaction paradigms such as perceptual User UI tangible UI and embodied UI open **a vast world of possibilities**

  - M1 = (microphone, natural language)
  - M2 = (keyboard, command language)
  - M3 = (mouse, direct manipulation)
  - M4 = (PDA, 3D gesture) ***embodied UI***
  - M5 = (HMD, 3D graphics) ***AR***
  - M6 = (bottle-sensor, 3D gesture) ***tangible UI***
  - M7 = (GPS, localization) ***perceptual UI***
  - *M8 = (Tongue display, 2D shape)*

Multimodality
Characterisation of a modality

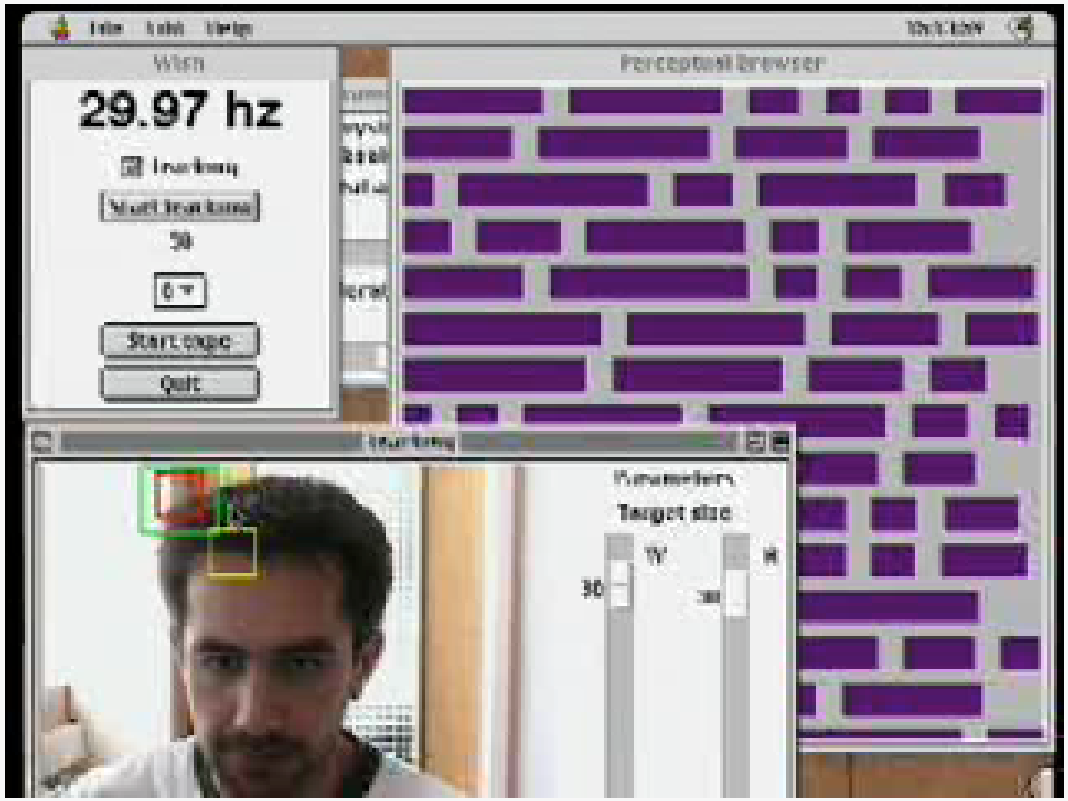
- M = <device, text>





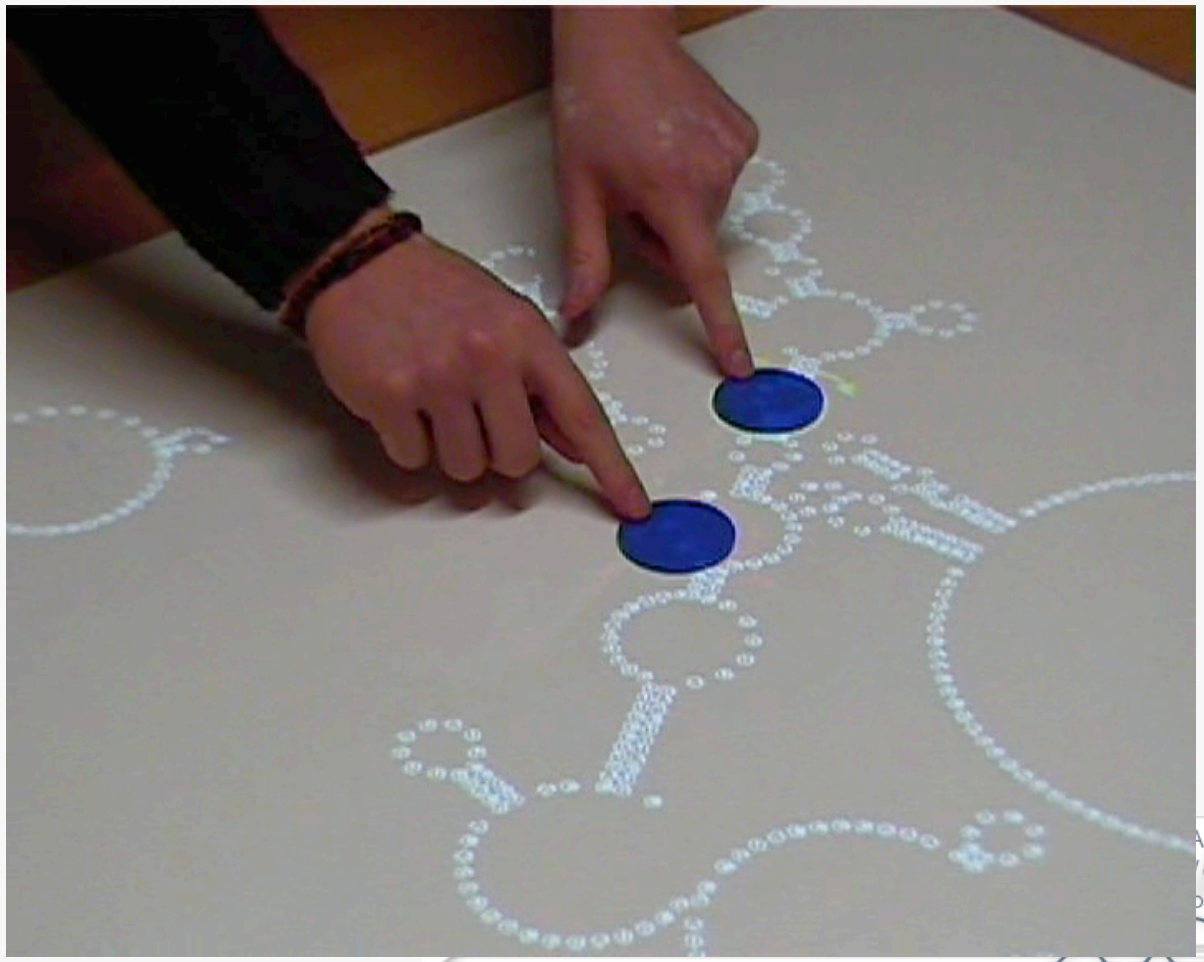
Multimodality
Characterisation of a modality

- M = <camera-head, gesture>



Multimodality
Characterisation of a modality

- M = <camera-token, gesture>
  - Two-handed interaction => two modalities => multimodality

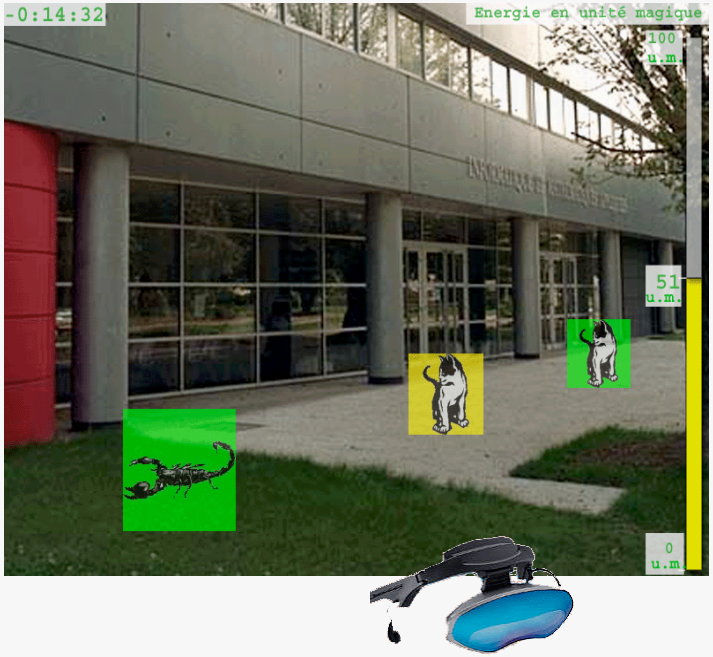


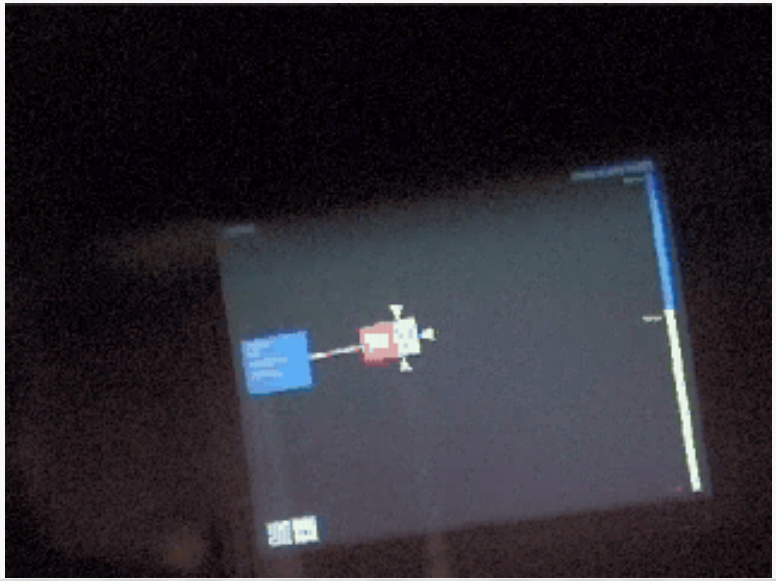
Multimodality
Characterisation of a modality

- M = <bottle-sensor, gesture>

Multimodality
Characterisation of a modality

- TROC: a game based on the technique of barter
- M1 = <GPS, localization>
- M2= <magnetometer, orientation>





Multimodality
Characterisation of a modality

- **ACTIVE** MODALITIES
  - For inputs, active modalities are used by the user to issue a command to the computer such as a pedal to move a laparoscope in a CAS system.

- **PASSIVE - IMPLICIT** MODALITIES
  - Passive modalities are used to capture relevant information for enhancing the realization of the task, information that is not explicitly expressed by the user to the computer (PUI). For example tracking position.

Multimodality
Characterisation of a modality

- Human sense
- Spatial
  - Location
- Temporal
  - Transient/Persistent

- Dimension*: 1D 2D ...*
- *O. Bernsen 93*
  - Linguistic
  - Analogue
  - Arbitrary

Modality

Physical level

Modality = <device,

Logical level

interaction language >

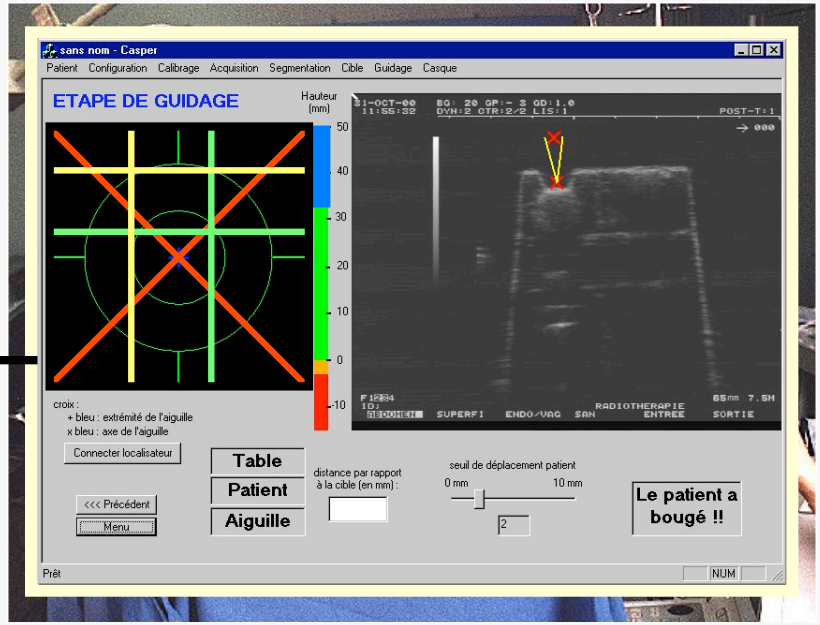
Multimodality
Characterisation of a modality

Multimodality
Characterisation of a modality

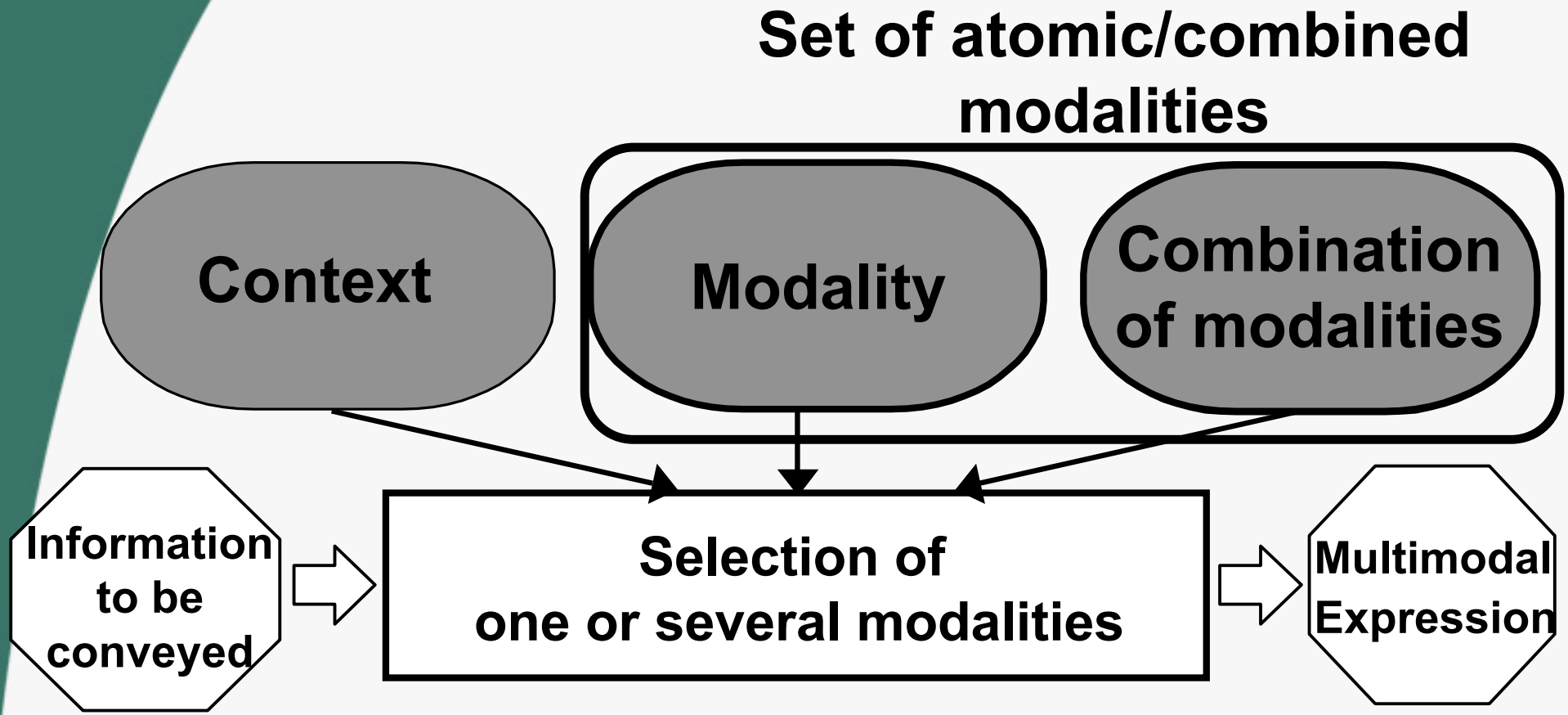
- Physical level
  - Human sense: Sight
  - Spatial:
    Location = operating field
  - Temporal: Persistent
- Logical level
  - 3D
  - Analogue
  - Non arbitrary

Multimodality
Characterisation of a modality

- Physical level
  - Human sense: Sight
  - Spatial: Location = screen
  - Temporal: Persistent
- Logical level
  - 2D
  - Non Analogue
  - Arbitrary



Multimodality: Design space



Multimodality
Combination of modalities

- Several studies
  - UOM 94 / TYCOON 95 / CARE 95 / MSM 96
- CARE properties
  - Relationships between Devices, Interaction languages and Tasks
    - **C : Complementarity**
    - **A : Assignment**
    - **R : Redundancy**
    - **E : Equivalence**

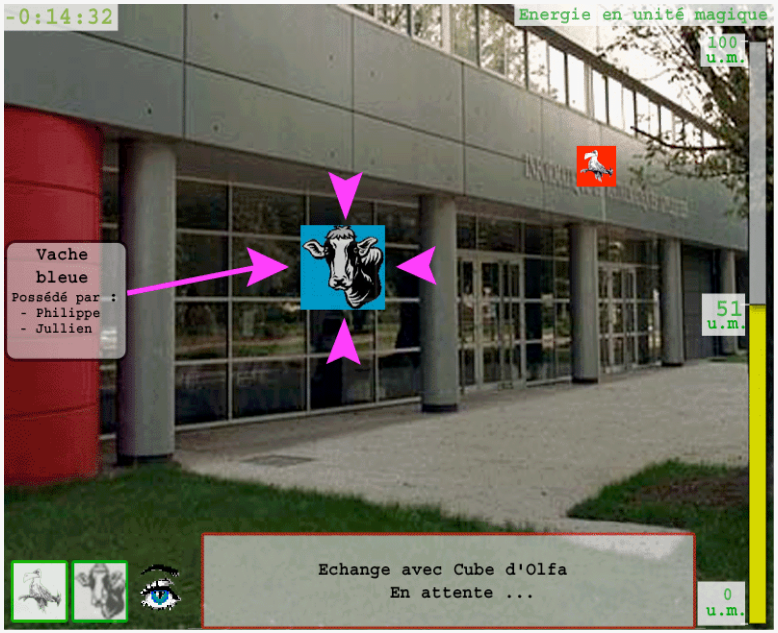
Multimodality
Combination of modalities

TROC: a game based on the technique of barter

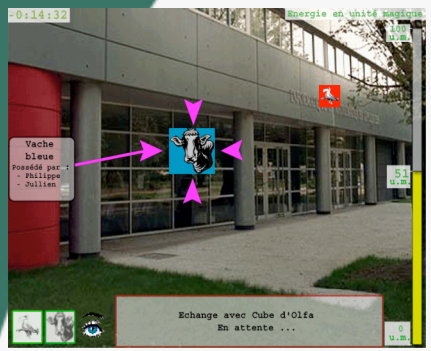
M1 = (Magnetometer, orientation)

M2 = (GPS, location)

Complementarity of M1 and M2 for selecting an object



Multimodality
Combination of modalities



Task:
Update position & orientation of User

Tasks:
Manipulation of Note (create, pick, and remove)

CARE combination

Complementarity 2

Complementarity 1

Redundancy / Equivalence

Languages

3D orientation (radians)

3d location

Mouse Notes commands

Speech Notes commands

Devices

Magnetometer

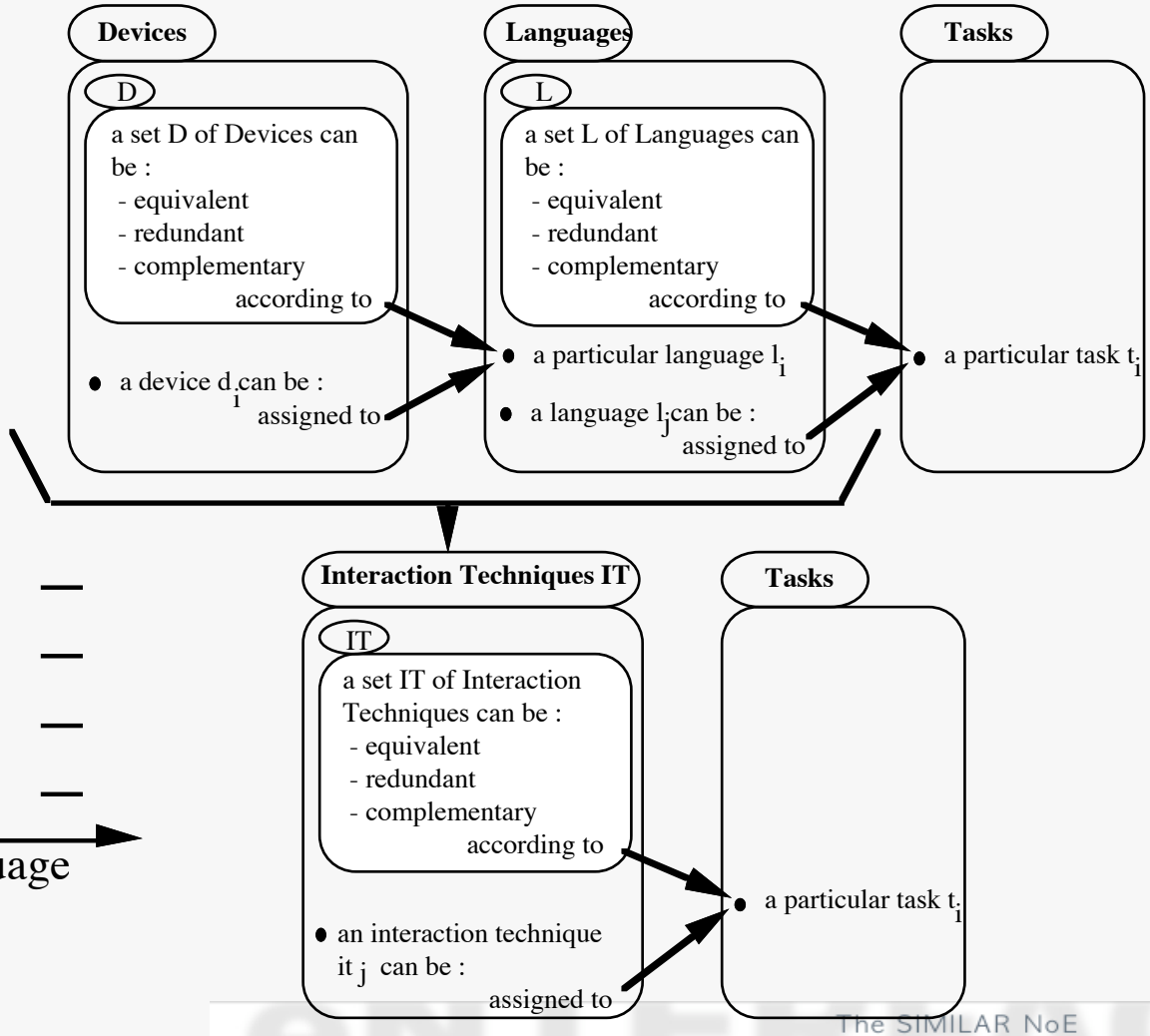
Localization sensor

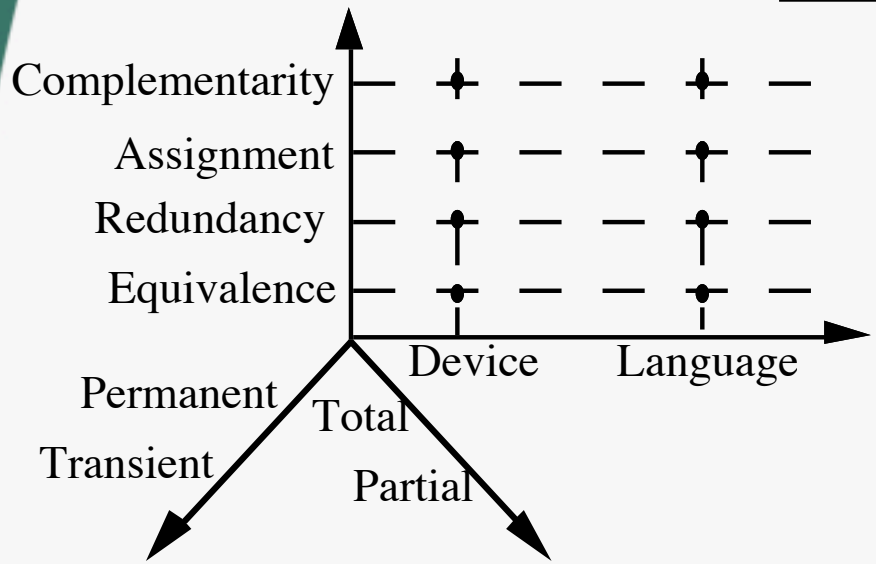
Mouse

Microphone

Multimodality
Combination of modalities

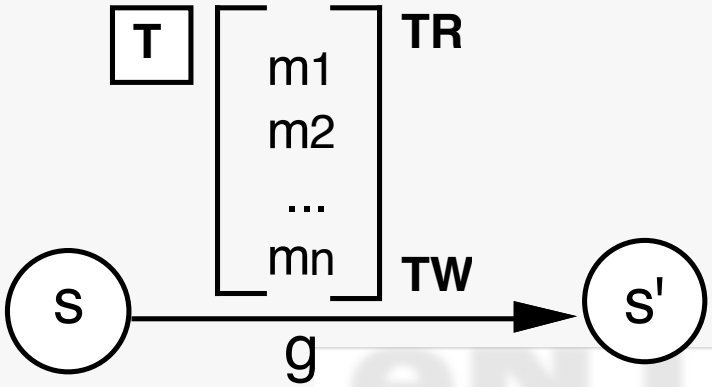
- CARE properties





Multimodality
Combination of modalities

- CARE properties
- The formal expression of the CARE properties relies on the notions of state, goal, modality, and temporal relationships.
- A modality is an interaction method that an agent can use to reach a goal.



Multimodality
Combination of modalities

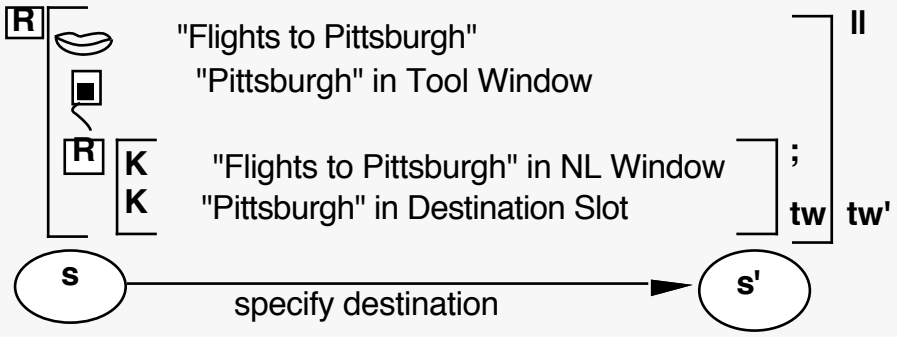
Redundancy : Modalities of a set M are used redundantly to reach state s' from state s, if they have the same expressive power (they are equivalent) and if all of them are used within the same temporal window, tw.

- *Redundancy (s, M, s', tw) ⇔ Equivalence (s, M, s') ∧ (Sequential (M, tw) ∨ Parallel (M, tw))*
- *Parallel (M, tw) ⇔ (Card (M) > 1) ∧ (Duration(tw) ≠ ∞) ∧ (∃t∈tw · ∀m∈M · Active (m, t)*
- *Sequential (M, tw) ⇔ (Card (M) >1) ∧ (Duration (tw)≠∞) ∧ (∀t∈tw · (∀m, m'∈M · Active(m, t) ⇒ ¬Active(m', t)) ∧ (∀m∈M · ∃t∈tw · Active(m, t))*

Multimodality
Combination of modalities

- Redundancy : Modalities of a set M are used redundantly to reach state s' from state s, if they have the same expressive power (they are equivalent) and if all of them are used within the same temporal window, tw.

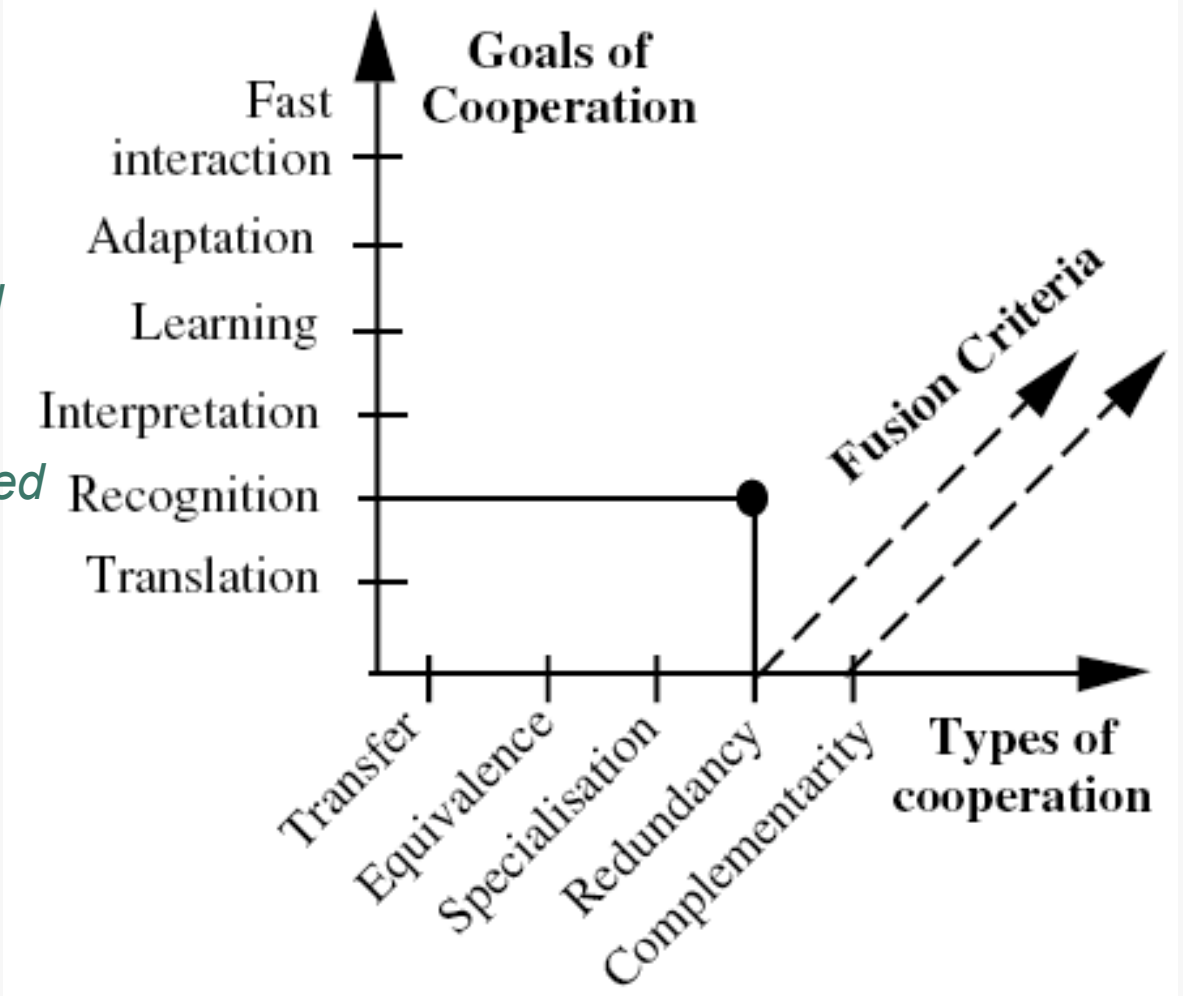
- Example: Multimodal form (airline information)



Multimodality
Combination of modalities

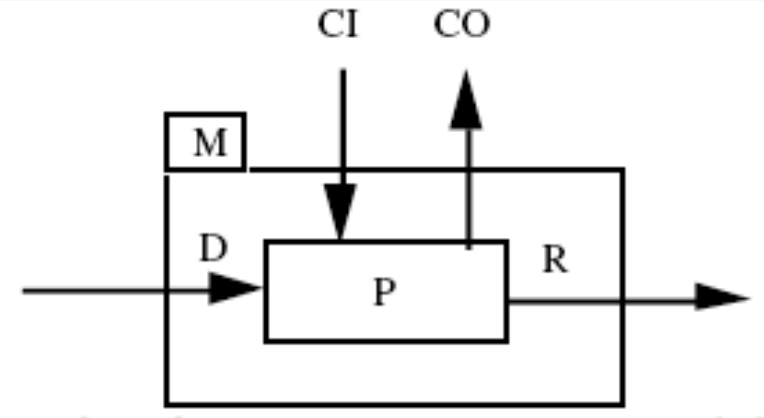
- TYCOON

Each type of cooperation may be involved in several goals. For instance, redundancy between messages uttered and typed on the keyboard by the user may improve recognition. Only redundancy and complementarity need ***fusion*** *which may use combination of several criteria (dotted arrows).*



Multimodality
Combination of modalities

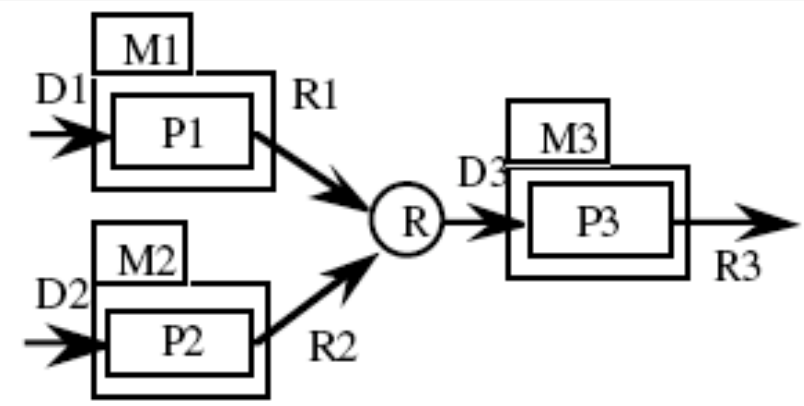
- TYCOON
- Logical formalism to describe the combination
- M = { P, D, R, C }
  - A process P
    - controlled by a set of parameters C (CI Input parameters CO Ouptut parameters)
    - analyzing a set of data D
    - to give a set of results R



Multimodality
Combination of modalities

- TYCOON M = { P, D, R, C }
- Redundancy

  for each possible result r3 of modality M3, the results r1 obtained by modality M1 and r2 obtained by modality M2 have been merged by an intermediate process R and have the same value for an attribute att. The criterion used by R is a parameter of the redundancy definition and may be a combination of temporal coincidence, spatial coincidence...



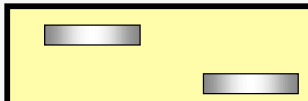
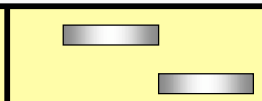
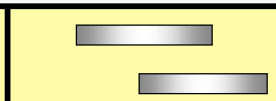
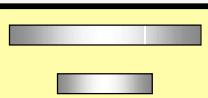
Multimodality
Combination of modalities

- Several studies
  - UOM 94 / TYCOON 95 / CARE 95 / MSM 96

- New combination space
  - Different schemas and aspects of combinations
  - 5 aspects: temporal, spatial, articulatory, syntactic and semantic
  - 5 schemas: [Allen 83]

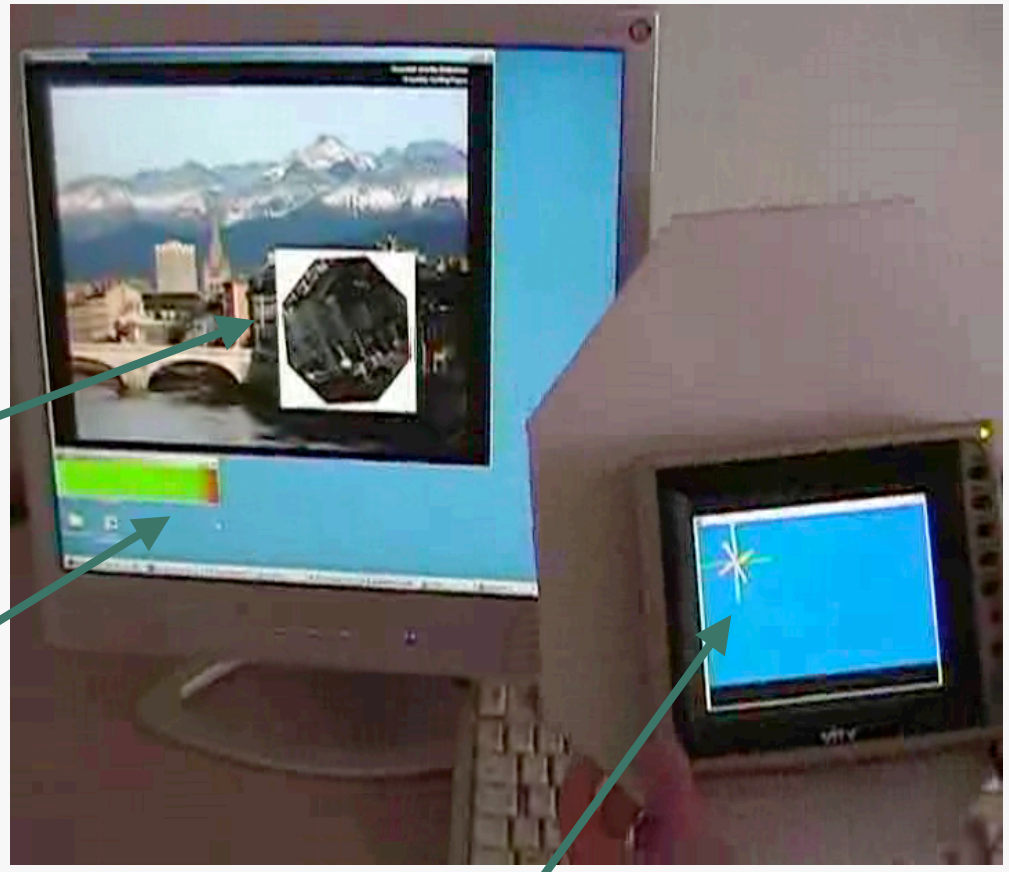
Multimodality: Combination of modalities

Combination schemas

Combination aspects					
Temporal	Anachronism	Sequence	Concomitance	Coincidence	Parallelism
Spatial	Separation	Adjacency	Intersection	Overlaid	Collocation
Articulatory	Independence	Fission	Fission Duplication	Partial Duplication	Total Duplication
Syntactic	Difference	Completion	Divergence	Extension	Twin
Semantic	Concurrency	Complementarity	Complementarity & Redundancy	Partial Redundancy	Total Redundancy

Multimodality: Combination of modalities

- Puzzle



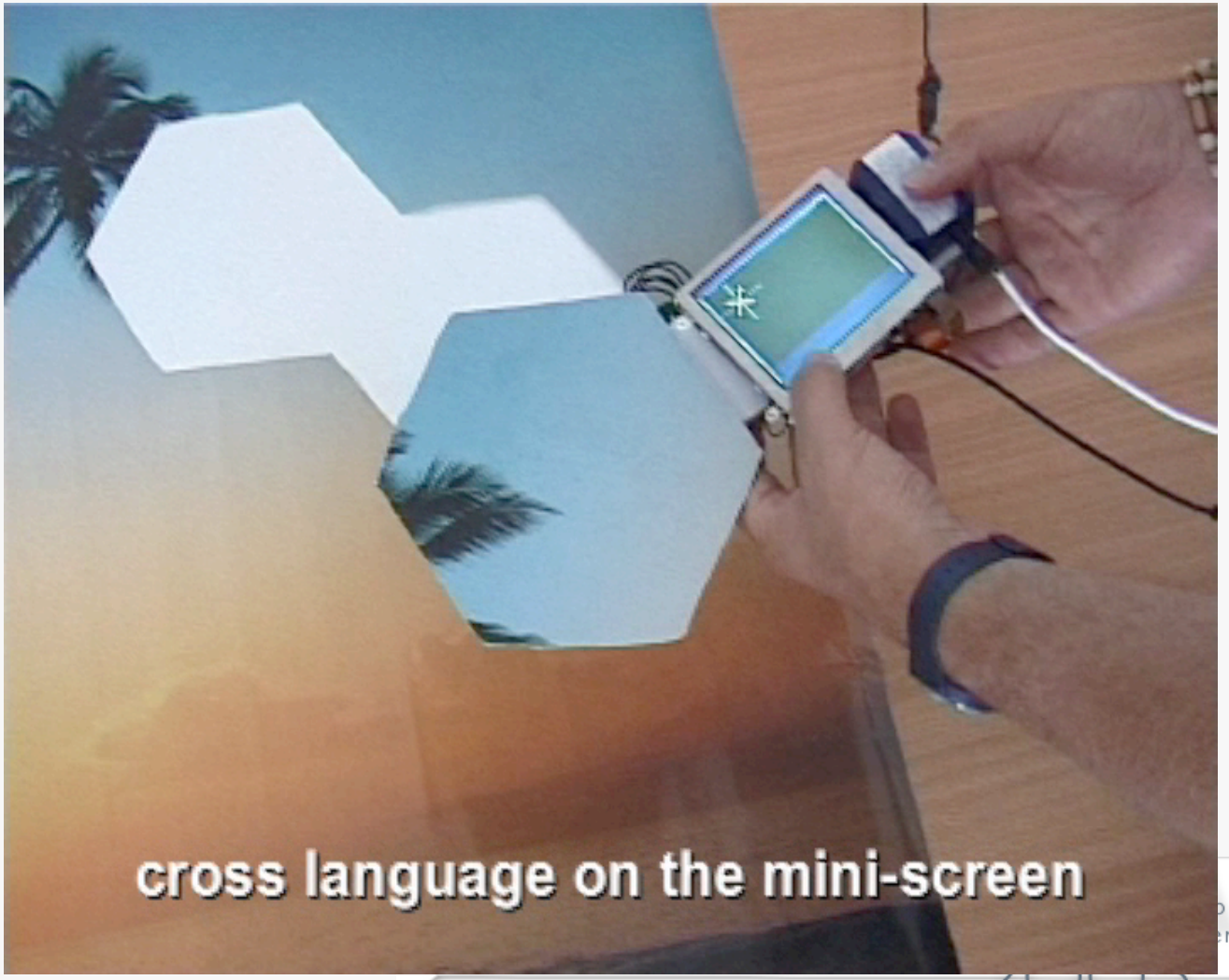
M1 = <screen, 2D image>

M2 = <screen, color>

M3 = <mini-screen, crosses>

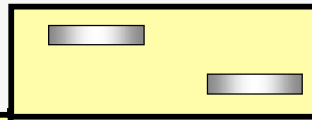
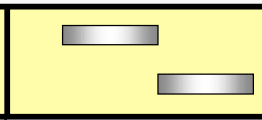
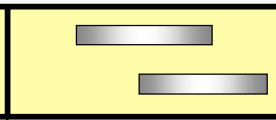
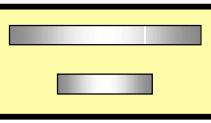
Multimodality: Combination of modalities

- Puzzle



Multimodality: Combination of modalities

Combination of
M2 = <wall, color> and M3 = <mini-screen, text>

					
Temporal	Anachronism	Sequence	Concomitance	Coincidence	Parallelism
Spatial	Separation	Adjacency	Intersection	Overlaid	Collocation
Articulatory	Independence	Fission	Fission Duplication	Partial Duplication	Total Duplication
Syntactic	Difference	Completion	Divergence	Extension	Twin
Semantic	Concurrency	Complementarity	Complementarity & Redundancy	Partial Redundancy	Total Redundancy

Outline

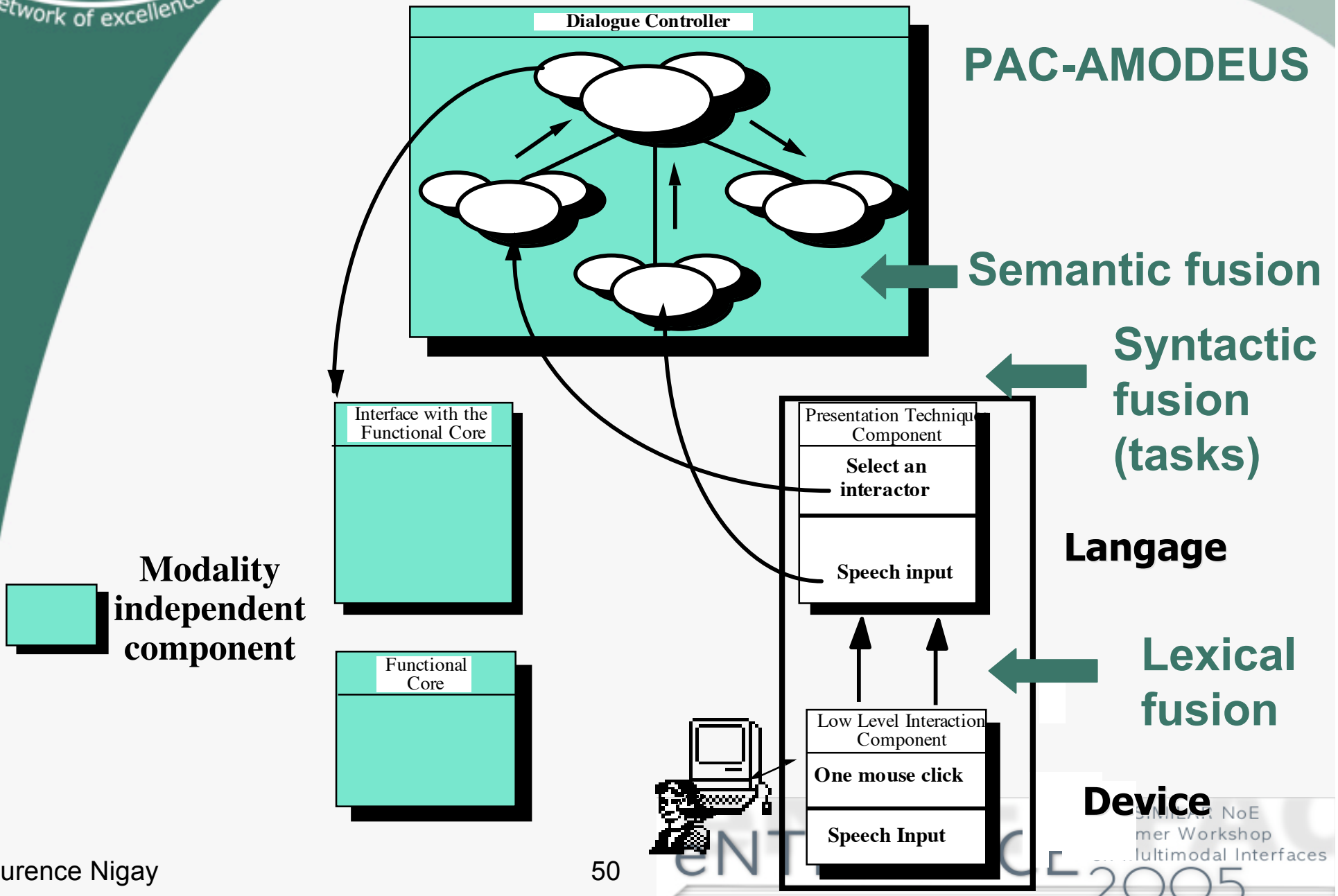
- Terminology
  - Design space
  - Interaction modality
  - Multimodality: combination of modalities
- Fusion/Fission mechanisms
- ICARE platform for input/output multimodal interaction
- Grand Challenges

Implementational Issues: Fusion mechanism

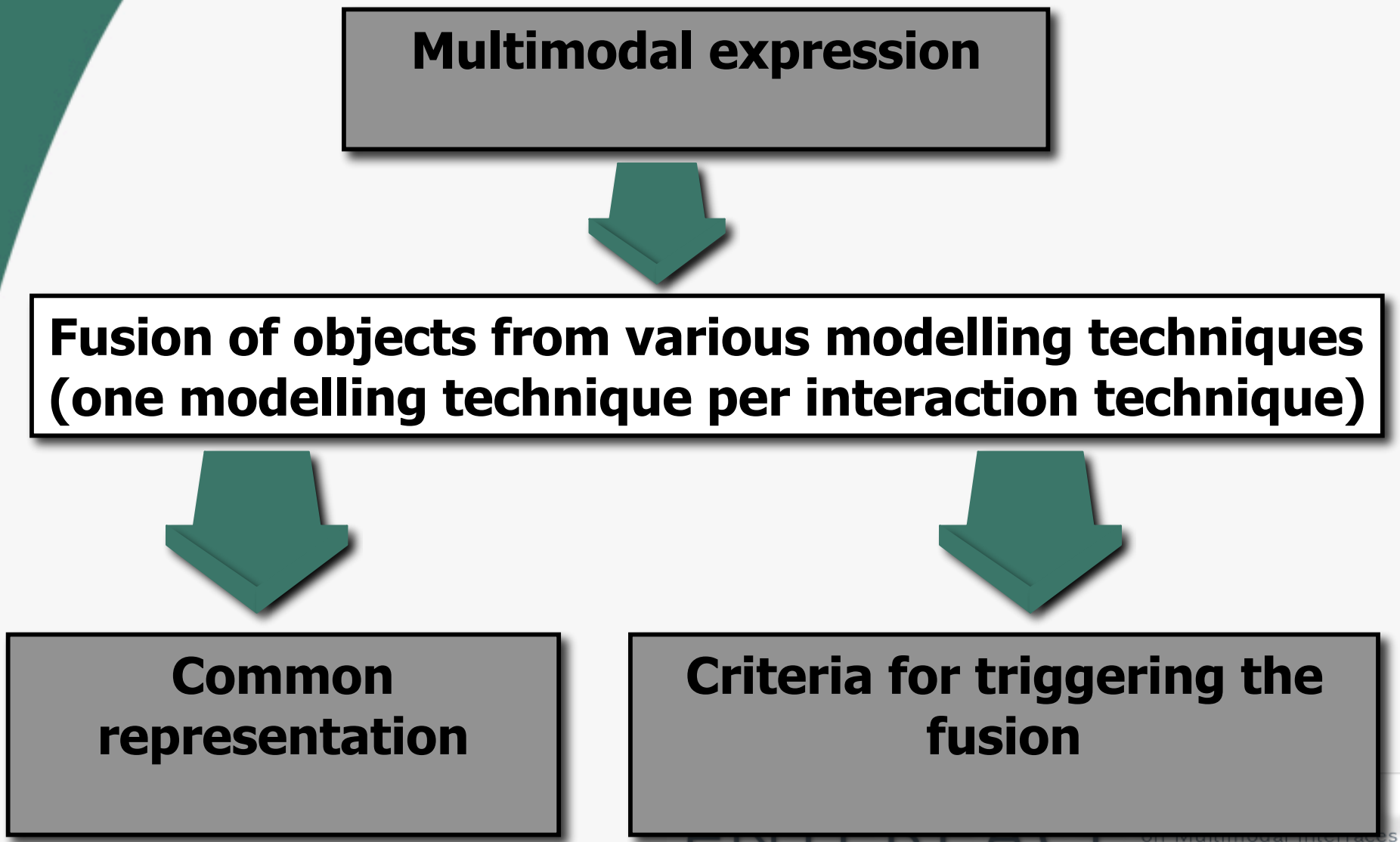
- CARE properties
  - Complementarity Redundancy => Fusion of data

- Implementational issues
  - Reusable code
  - Domain independent
    - (description of the semantic outside the code)

A generic fusion mechanism

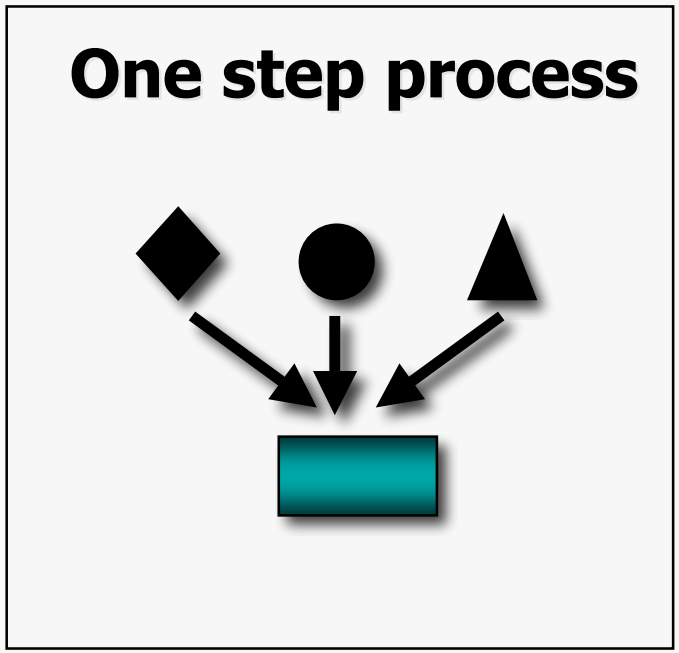


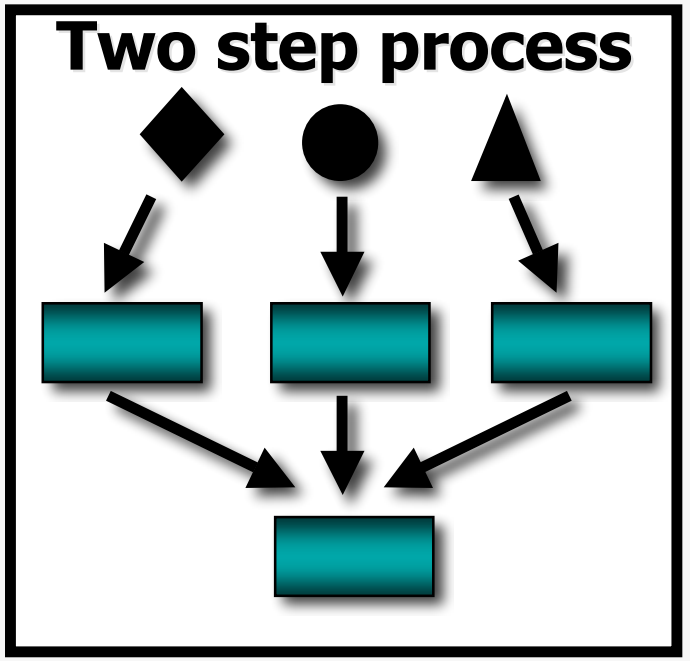
Multimodal interaction handling



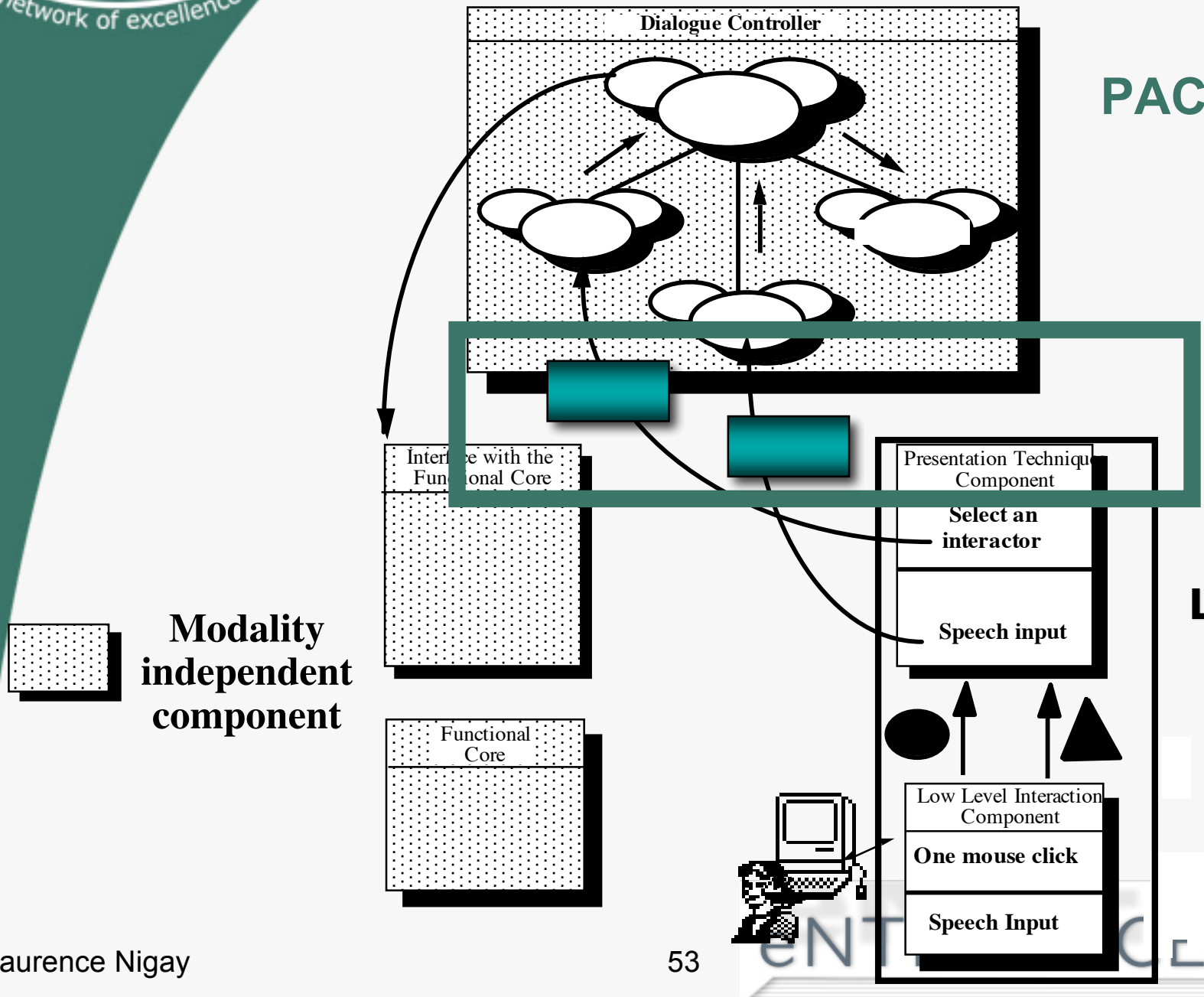
Fusion mechanism: Common representation

- Objects from various modelling techniques: 
- Common representation: 
- Fusion mechanism:



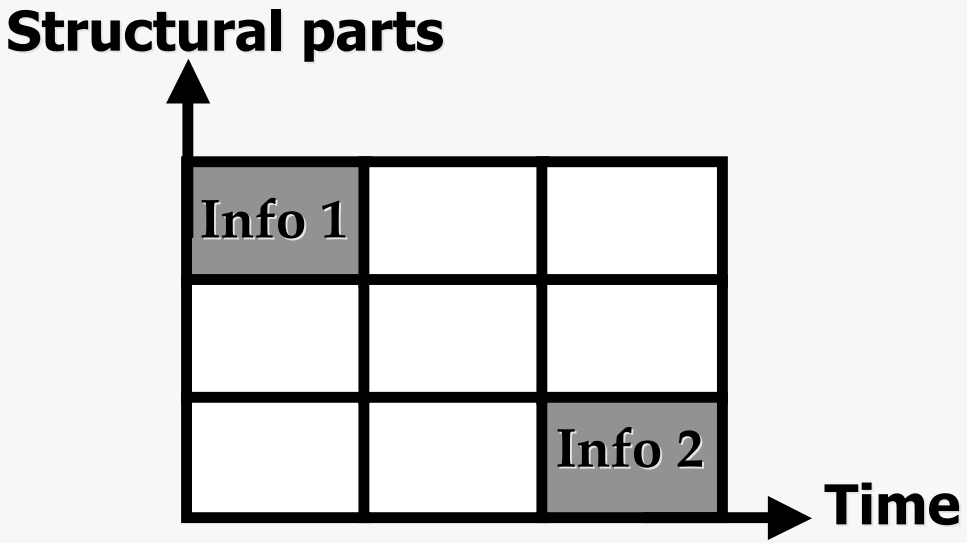


A generic fusion mechanism

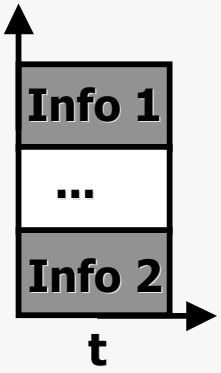


Fusion mechanism: Common representation

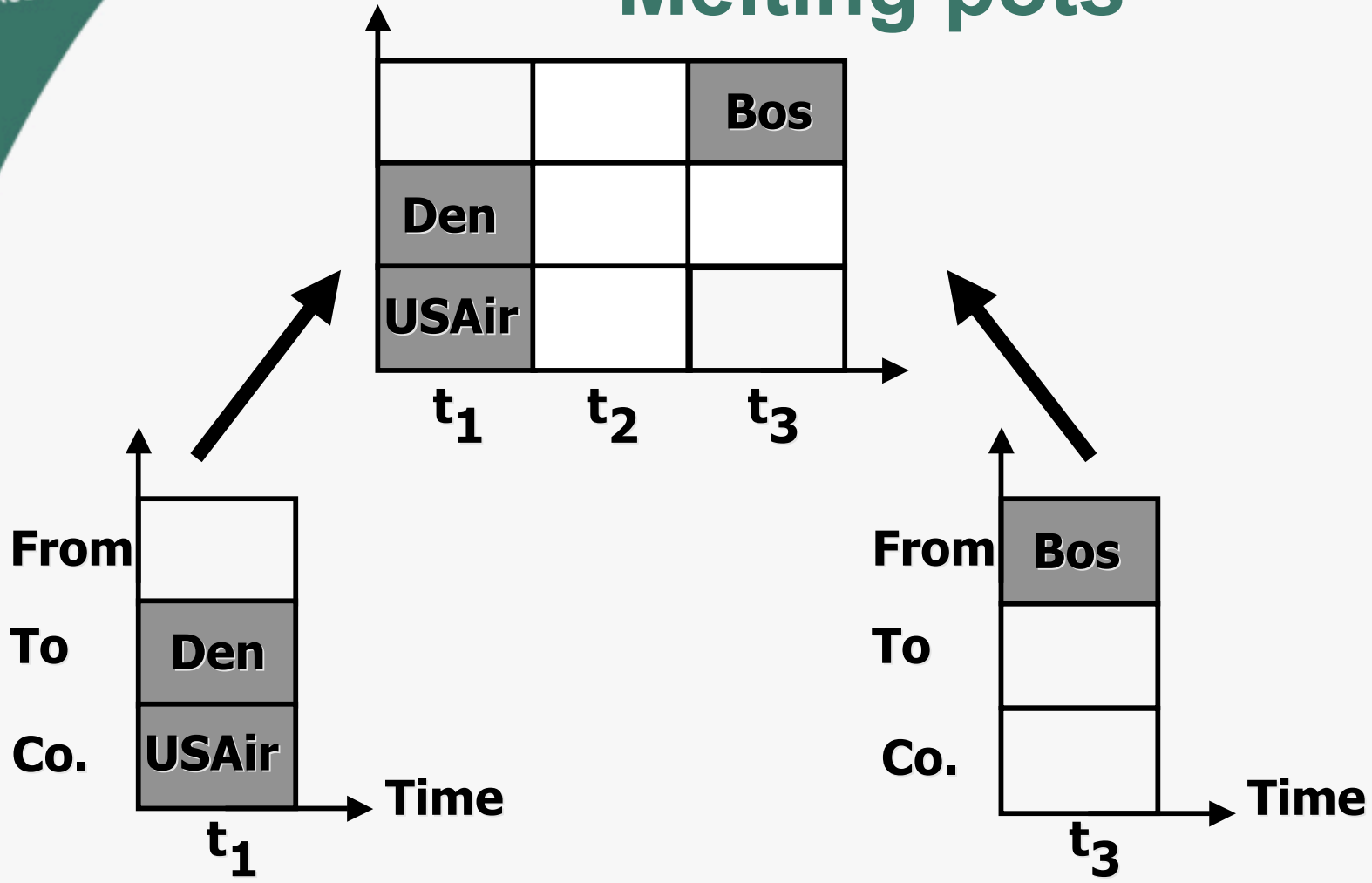
- A melting pot: 2-D structure



- User's event mapped with the structural parts of a melting pot defines a new column.



Fusion mechanism: Melting pots

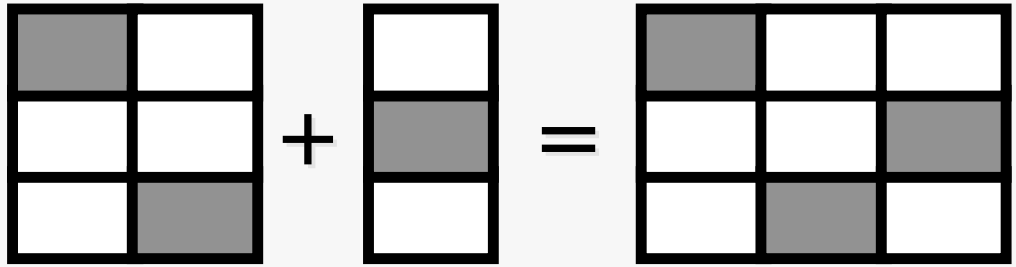


<USAir flights to Denver>

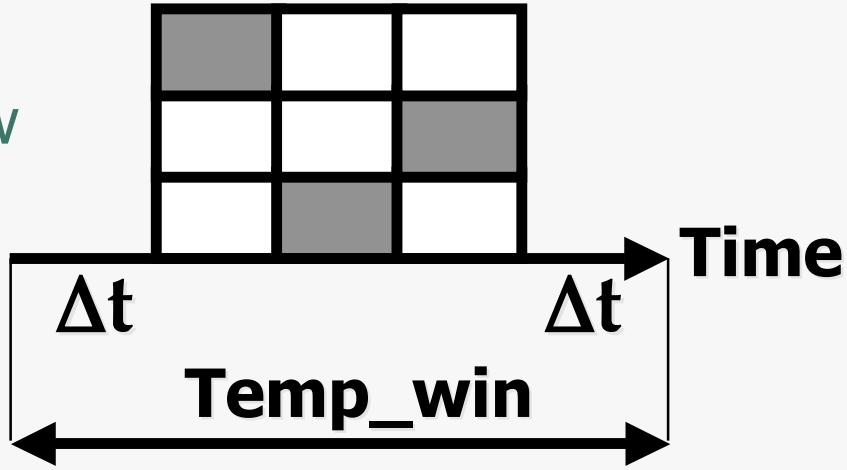
<Selection of Boston>

Fusion mechanism: Criteria

- Structural complementarity



- Time
  - Temporal window



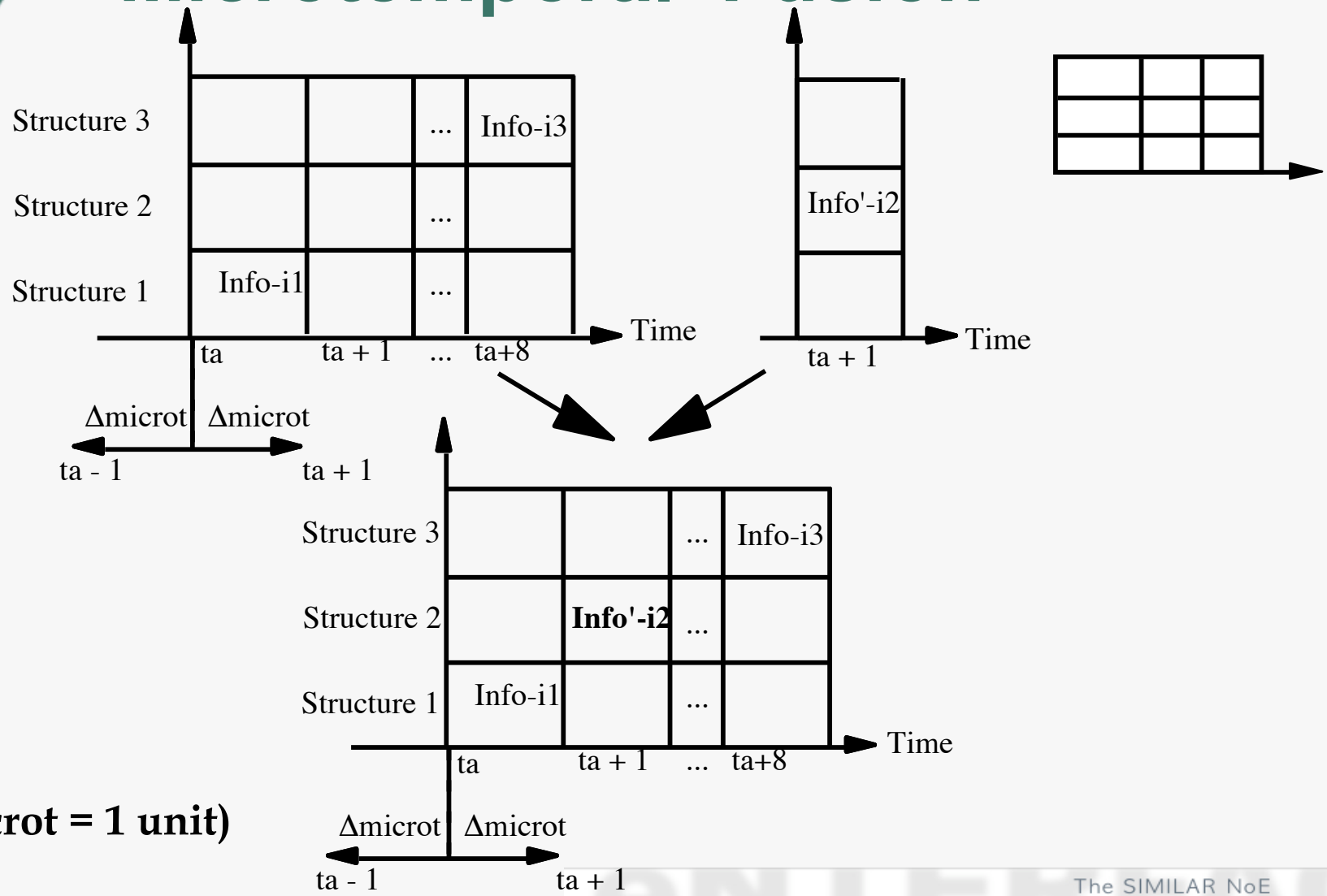
Fusion mechanism: Three levels of fusion

- Microtemporal fusion
  - combining melting pots produced in parallel manner.

- Macrotemporal fusion
  - combining melting pots close in time (when the time intervals of these melting pots do not overlap but their temporal windows do overlap.

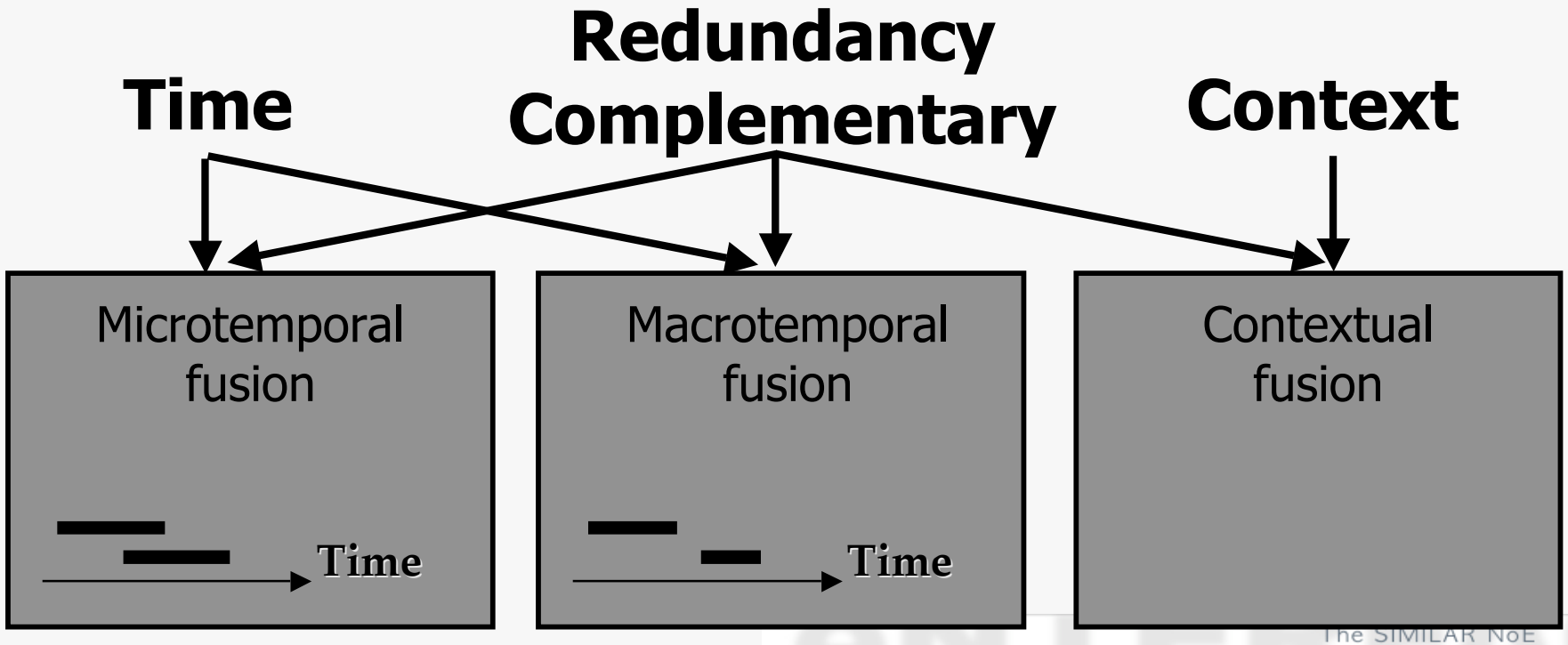
- Contextual fusion
  - based on the context (no temporal constraint)

Complementarity: Microtemporal Fusion



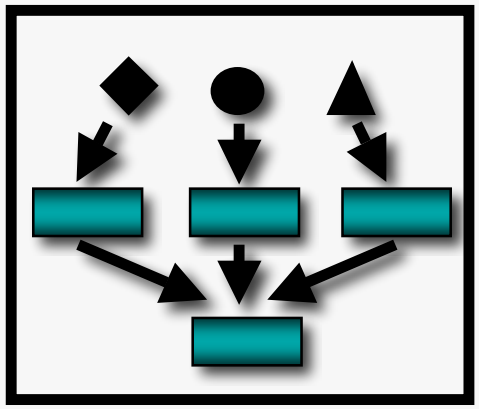
A generic fusion mechanism

- Three levels of syntactic fusion



Fusion mechanism: conclusion

- Two step process



- Criteria for triggering the fusion: **time**
- Representational format
  - Feature structures: melting pot / Quickset
  - Frames

Fusion mechanism: conclusion

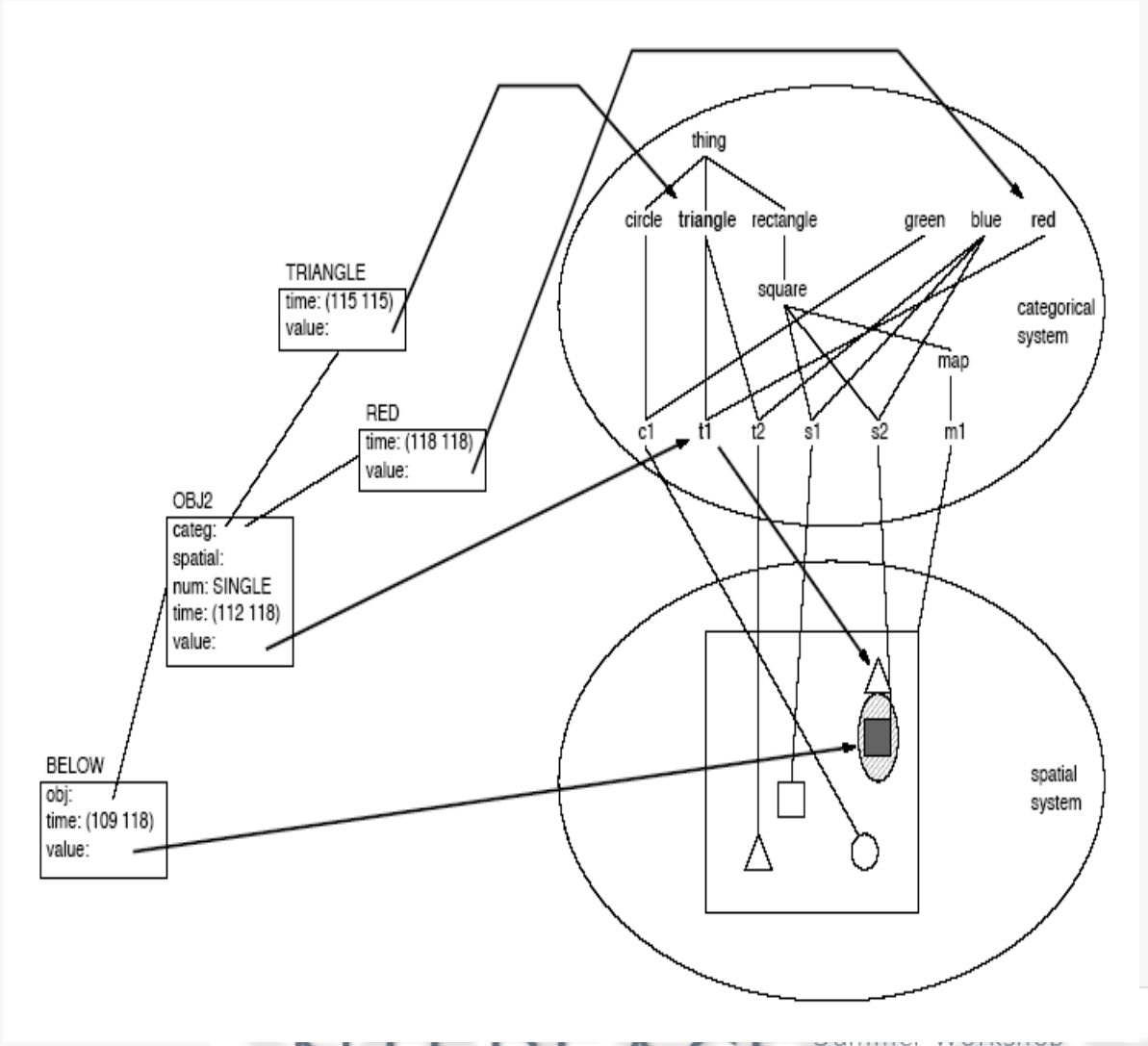
- Representational format
  - Feature structures: melting pot / Quickset

$$\left[\begin{array}{ll} object: & \left[\begin{array}{ll} type: & m1a1 \\ echelon: & platoon \end{array}\right]_{unit} \\ location: & \left[\begin{array}{ll} xcoord: & 95305 \\ ycoord: & 94365 \end{array}\right]_{point} \end{array}\right]_{create\_unit}$$

Fusion mechanism: conclusion

Representational format

- Frames
- Embedded frame representing "below the red triangle"



Outline

- Terminology
  - Design space
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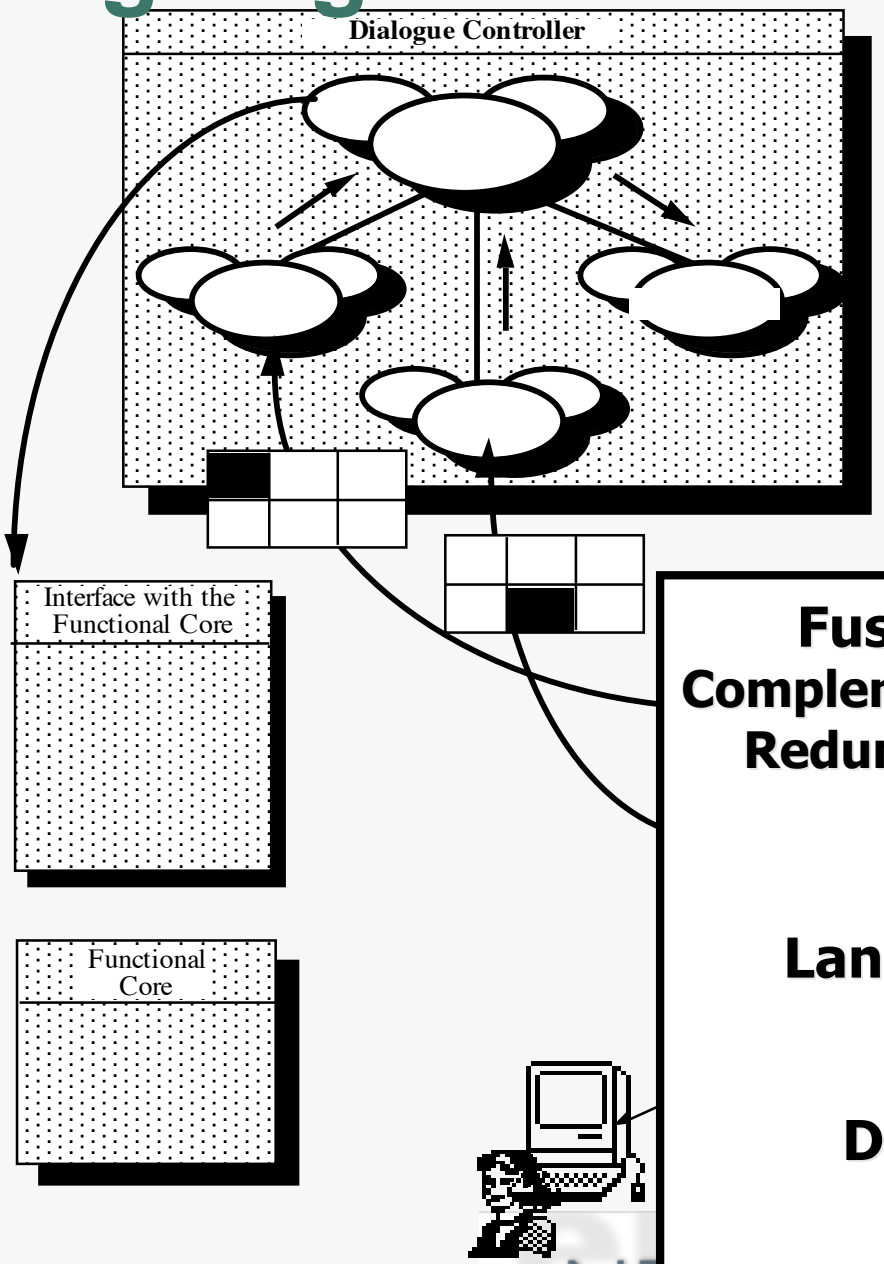
  - Multimodality: combination of modalities
- Fusion/Fission mechanisms
- ICARE platform for input/output multimodal interaction
- Grand Challenges

On-going work: ICARE

- ICARE:
- A component-based approach for the design and development of multimodal interfaces (CHI'04)
  - elementary components that describe pure modalities
  - composition components (Complementarity, Redundancy and Equivalence)
- Editor to graphically assemble components
- Automatic generation of the code (fusion mechanism)

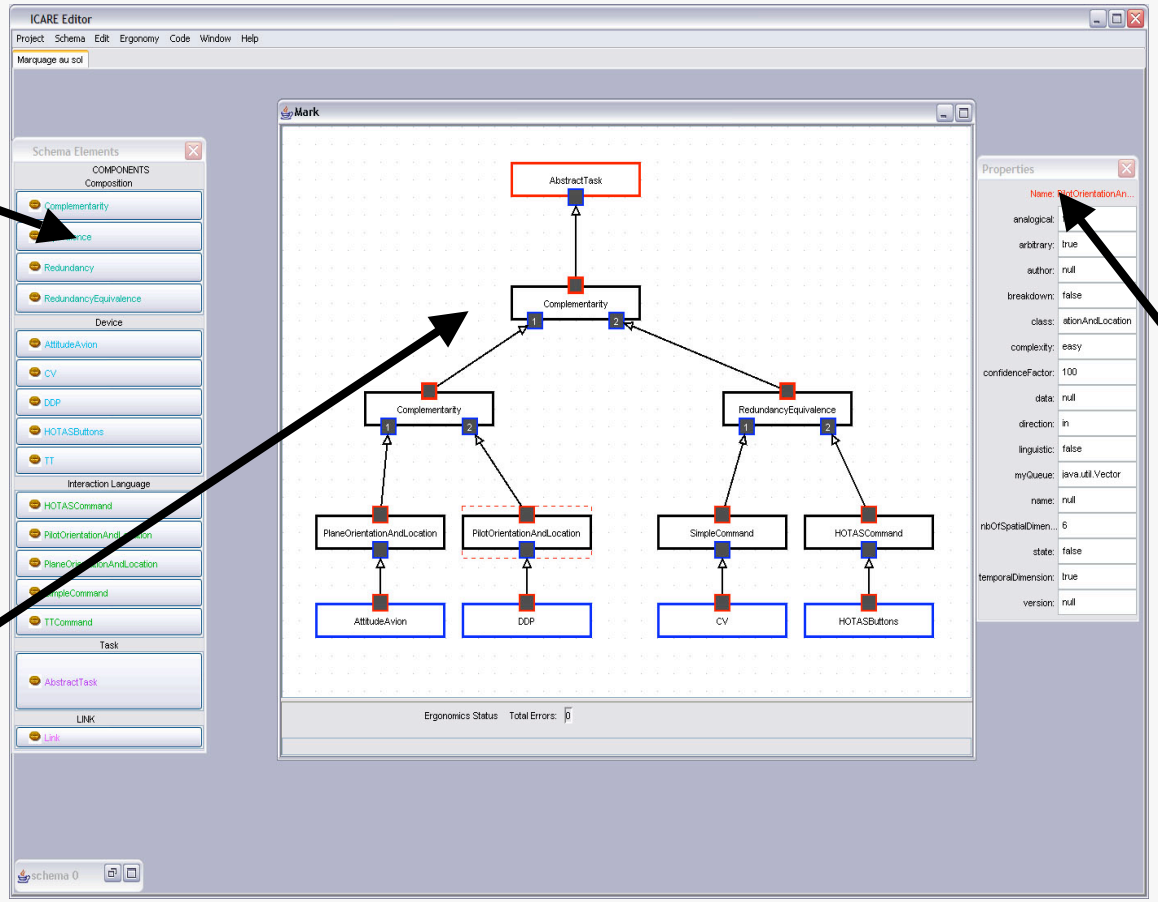
On-going work: ICARE



ICARE

On-going work: ICARE

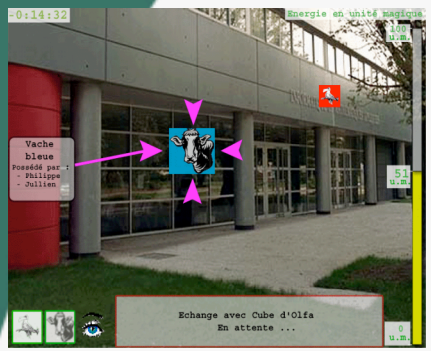
Components



Assembly of components

Properties of the selected component

On-going work: ICARE



Task:
Update position & orientation of User

Tasks:
Manipulation of Note (create, pick, and remove)

CARE combination

Complementarity 2

Complementarity 1

Redundancy / Equivalence

Languages

3D orientation (radians)

3d location

Mouse Notes commands

Speech Notes commands

Devices

Magnetometer

Localization sensor

Mouse

Microphone

On-going work: ICARE

MEMO RA / PDA

Aircraft cockpit simulator

Puzzle in RA

Multimodal IDentification

Outline

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- Conclusion: Grand Challenges

Multimodality: HCI Challenges

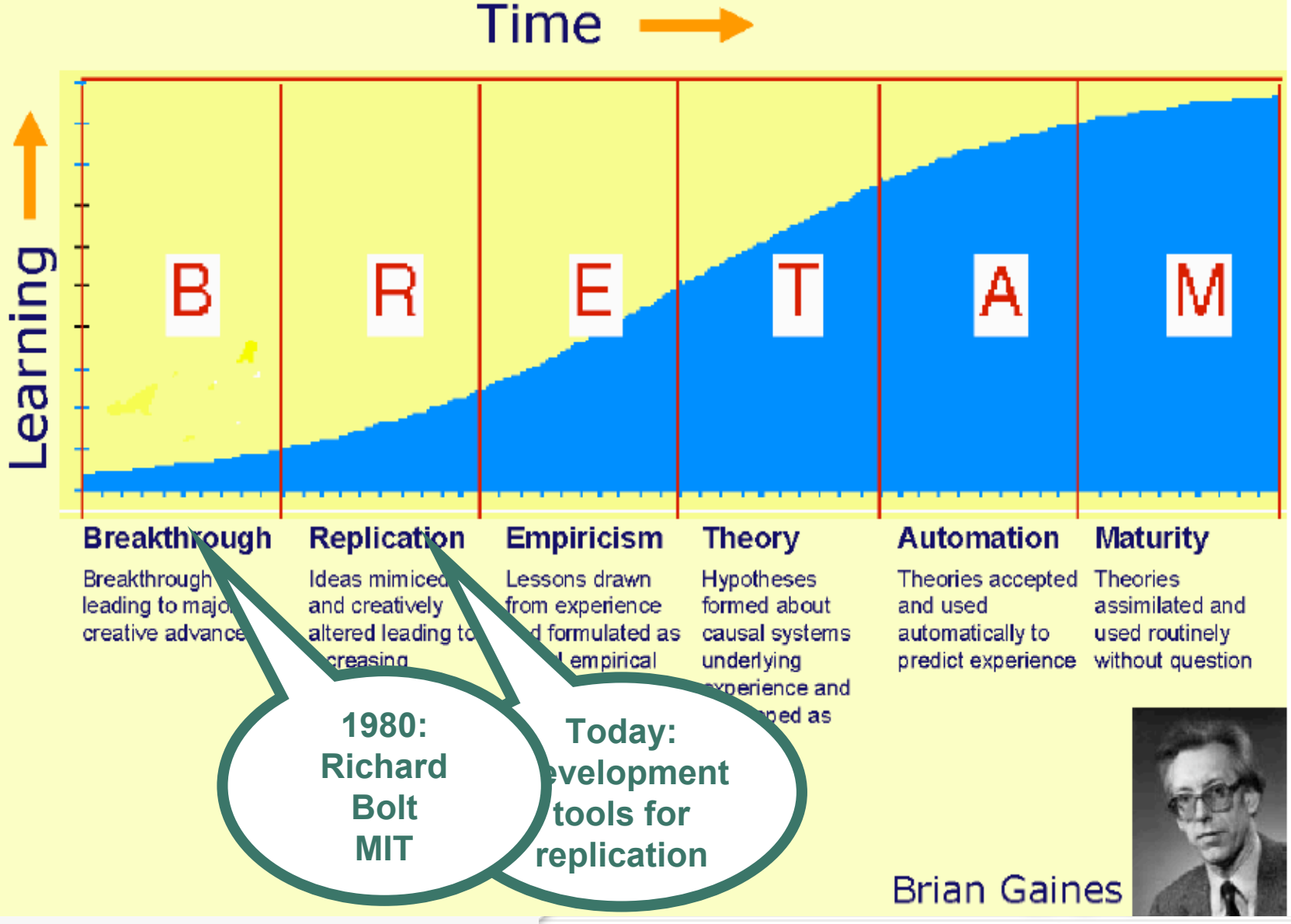
- HCI challenge 1: Theory of modality and multimodality
  - a vast world of possibilities
    => Characterization of the modalities
- HCI challenge 2: Fusion mechanism
  - Criteria for triggering the fusion: time and ? … space
  - Ambiguity and the fusion mechanism (interactive solution: human in the loop)
  - Uncertainty of the data processed by the fusion mechanism
- HCI challenge 3: Pervasive computing
  - Dynamicity
    => Plugging at runtime new modalities to the fusion mechanism
- HCI challenge 4: Development tools
  - Tools for quickly developing multimodal interaction
    - ICARE , context-toolkit for passive-implicit modalities, quickset …

Multimodaly: Path to evolution

- Since 1980 “Put that there” paradigm R. Bolt MIT

In the 80's, Brian Gaines introduced a model on how science technology develops over time

Brian Gaines's Model

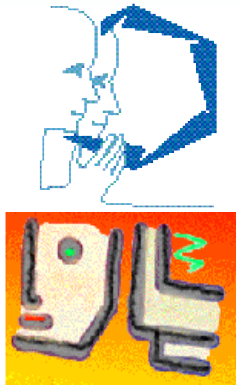


Laurence Nigay

Human-Computer Interaction (HCI)

Interaction modality and Multimodality

Laurence Nigay



University of Grenoble
CLIPS-IMAG Laboratory

User Interface Engineering Team

The SIMILAR NoE Summer Workshop on Multimodal Interfaces
eNTERFACE 2005