Mobile and Context-aware Interactive Systems

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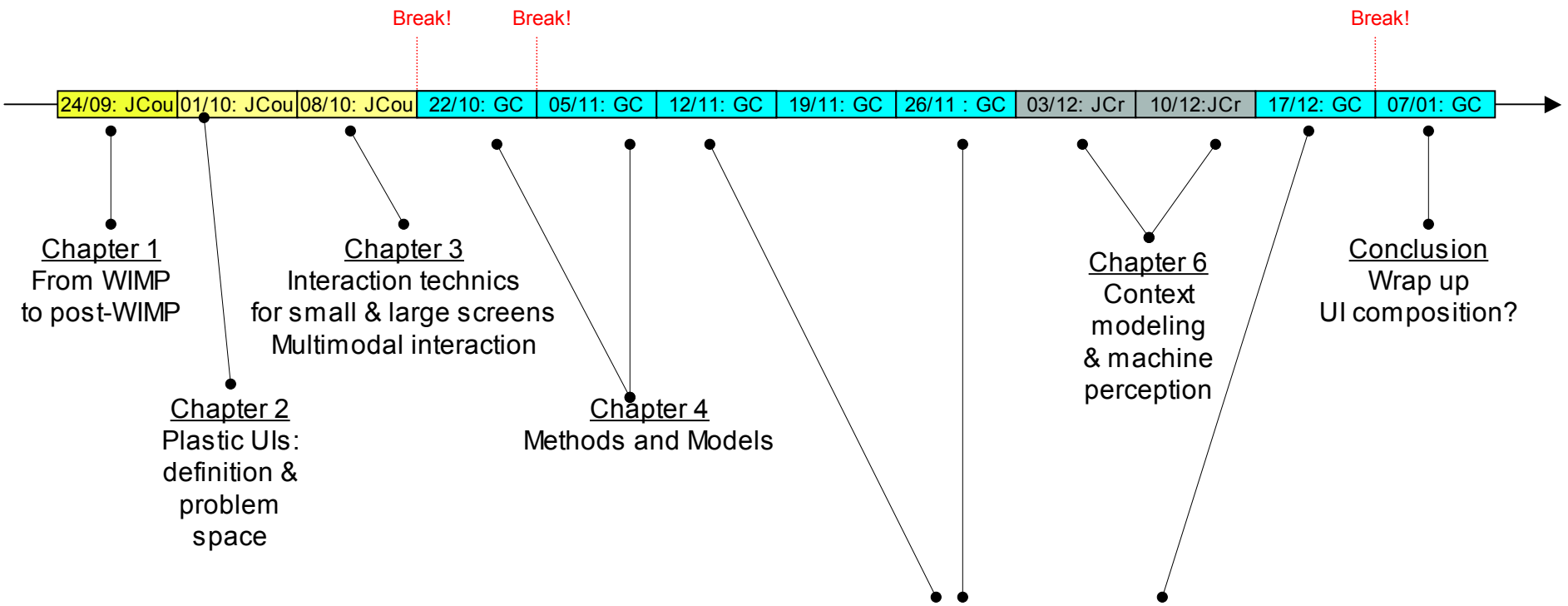
Outline and schedule



GC: Gaëlle Calvary
JCou: Joëlle Coutaz
JCr: James Crowley

Lesson Plan

1) Introduction: Context Aware Systems and Services
2) Software components for perception, action and interaction
3) Situation Models: a formal foundation for context modeling
4) Acquiring situation models
5) Autonomic methods for software components

Lesson Plan

1) Introduction: Context Aware Systems and Services
   - Evolutions of Computing
   - Intelligent Systems and Services and Social Common Sense
   - Service Composition
2) Software components for perception, action and interaction
3) Situation Models: a formal foundation for context modeling
4) Acquiring situation models
5) Autonomic software components

Evolution of Computing

Moore's Law for Transistor Denisty:
Transistor Density on IC's (per m^2) doubles every 18 months.

Law for Digital Device Density:
The number of networked programmable digital devices per person doubles every 3 years

Epochs in computing:

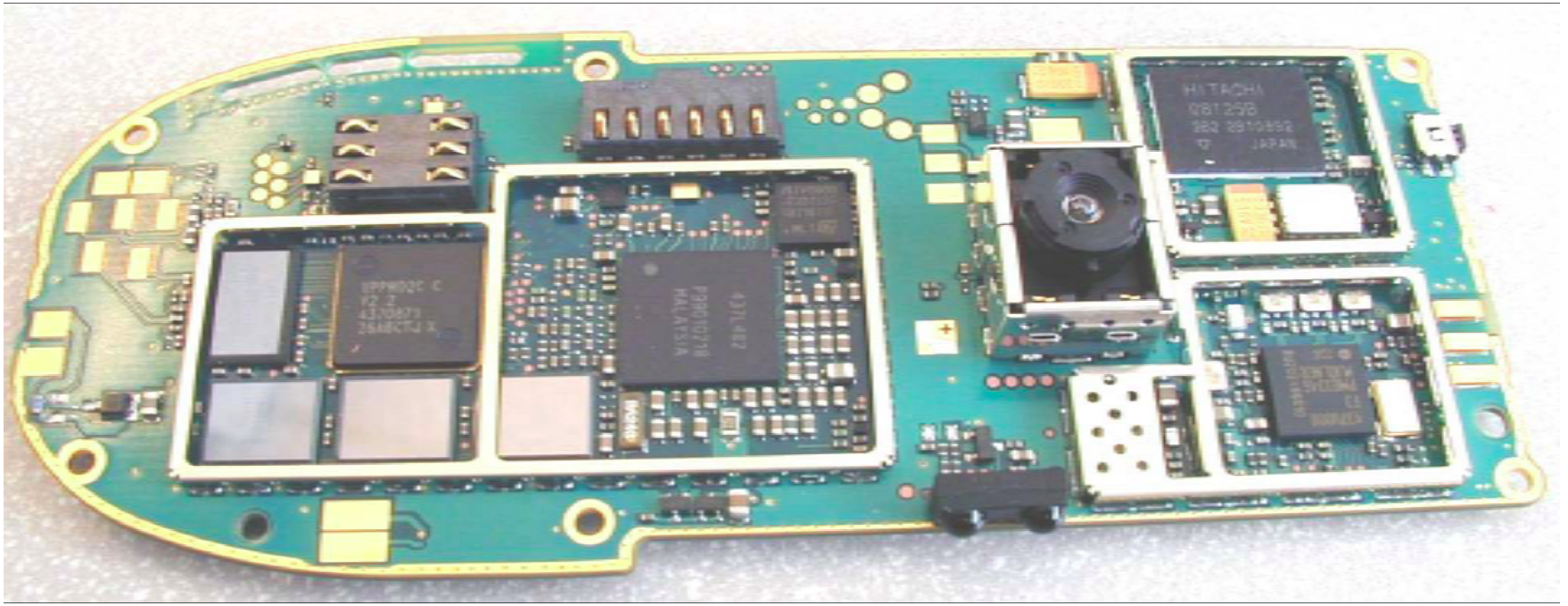
Main-Frame Computers: (1960-1980): 1 digital devices per 100 to 1000 persons
Mini-Computers (1970-1990): 1 digital devices per 10 to 100 person
Personal Computing (1980 - 2000): 1 digital devices per 1 to 10 persons
Mobile Computing (1990 - 2010) : 1 to 10 digital devices per person
Internet Computing (2000 - 2020) : 10 to 100 digital devices per person

Next Big Thing: Ambient Intelligence

Ambient Intelligence (2010 - 2030) : 100 to 1000 digital devices per person

Embedded Sensors and Actuators

Embedded Vision systems technologies in Mobile Phones
(ST MicroElectronics)



Embedded Systems

Technological Foundations:

- DSPs and Multi-core processors
- Low cost sensors and actuators
- Batteries and low-energy computing
- Low cost, High-bandwidth communications (wired and wireless).

Economic Drivers:

- Mobile Computing
- Mobile Telephones
- Mobile Devices: Ipods, GPS Systems, Electronic Books….

Challenge:

- Context aware services.
- Social Awareness and polite interaction
- Privacy and personal spaces
- Distraction and "Disruption"

Affective Communicating Objects

Examples: Nabastag, AIBO

- Small, autonomous, “cute” devices
- With embedded Perception, Action, Computation and Transmission.
- Using speech, vision, gesture, lights and other modes for interaction
- Wireless Net communications (devices are on the internet)

Ambient Intelligence = Ubiquitous Distraction

Problem:

Spontaneous action by "intelligent" systems disrupt human activity.

What do we mean by Intelligent?

Intelligence describes the interaction of an entity with its environment.*

*Cognitive Systems Research Roadmap (2002), European Commission, ECVision Network (David Vernon, Editor).

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Intelligence is a description (an ascribed property)

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What do we mean by Intelligent?

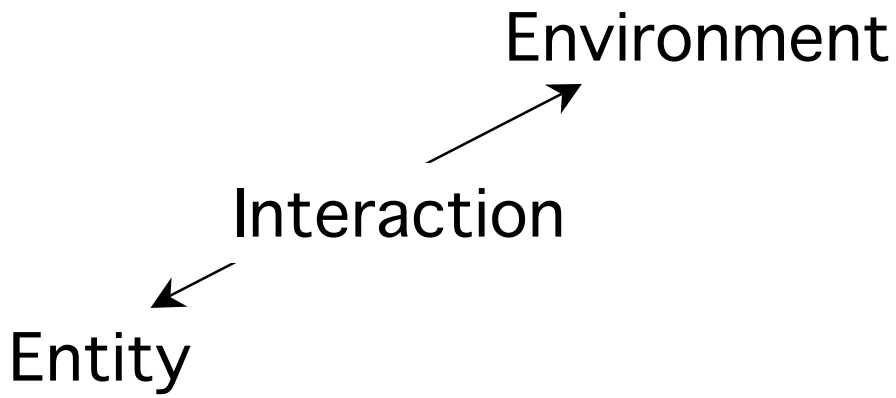
Intelligence describes the interaction of an entity with its environment.*

Intelligence is a description (an ascribed property)

Intelligence describes an entity that interacts.

*Cognitive Systems Research Roadmap (2002), European Commission, ECVision Network (David Vernon, Editor).

What do we mean by Intelligent?



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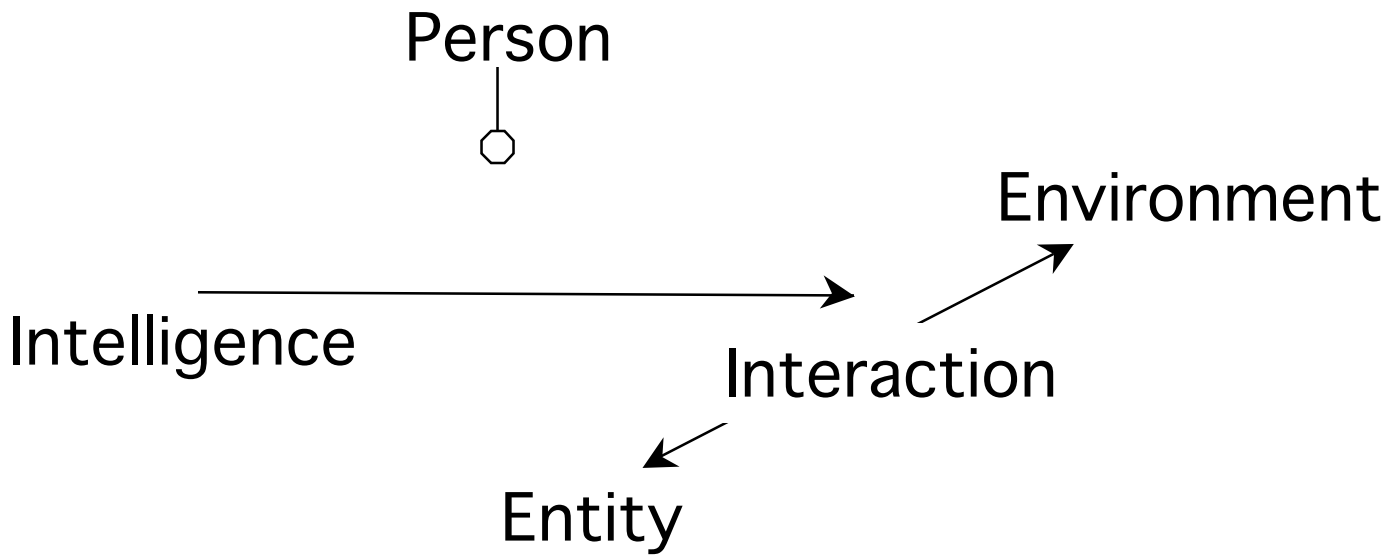
What do we mean by Intelligent?



Intelligence describes the interaction of an entity with its environment.*

What do we mean by Intelligent?

To be considered "intelligent", a system must be embodied, autonomous, and situated. *

Embodied:	Possessing a body (sensory/motor components)
Autonomous:	Self-governing;
	Have independent existence
Situated:	Behaviour determined by the environment

*C. Breazeal, Designing Sociable Robots, MIT Press, 2002.

L. Steels, and R. Brooks, The artificial life route to artificial intelligence: Building Situated Embodied Agents. New Haven: Lawrence Erlbaum Ass., 1994.

Embodied Systems

Embodied: Incarnated. Possessing a body.

Body: A sensori-motor system for tightly coupled interaction with an environment.

Examples of Bodies:

Natural: Human, mammal, insects, bacteria, plants,

Artificial: Humanoid Robot, AIBO, mobile robots, roomba?

Abstract: none.

Embodied Systems

Embodied: Incarnated. Possessing a body.

Body: A sensori-motor system for tightly coupled interaction with an environment.

Environment: A system composed of multiple interacting entities.

Examples of Environments:

Natural: Jungle, desert, sea floor….

Artificial: Office, home, family, social network, computer games…

Abstract: Chess, mathematics, any academic discipline…

Ambient Intelligence = Ubiquitous Distraction

Problem:

Spontaneous action by "intelligent" systems disrupt human activity.

Reason: Intelligent systems are autistic

- No awareness of context or social situation
- No abilities for polite interaction

Proposal: A theory context aware systems and services

- A framework for modeling context and situation
- A framework for building robust, autonomous systems and services
- A framework for learning polite socially aware interaction.

Social Common Sense

Common sense: The collection of shared concepts and ideas that are accepted as correct by a community of people.

Social Common Sense: shared rules for polite, social interaction that govern behavior within a group

Situated Social Common Sense: Social common sense conditioned on a model of situation

Situated Social Common Sense

Assertions:

- Politeness is a problem of Situated Social Common Sense
- Politeness requires understanding social situation

Social Common Sense varies over individuals and groups.

⇒ Social Common Sense must be learned

⇒ learning Social Common Sense requires a theory

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Lesson Plan

1) Introduction: Context Aware Systems and Services
2) Software components for perception, action and interaction
   - A Layered Software Architecture
   - Modules, Components, Federations and Services
   - Streams, Events and Transactions
3) Situation Models: a formal foundation for context modeling
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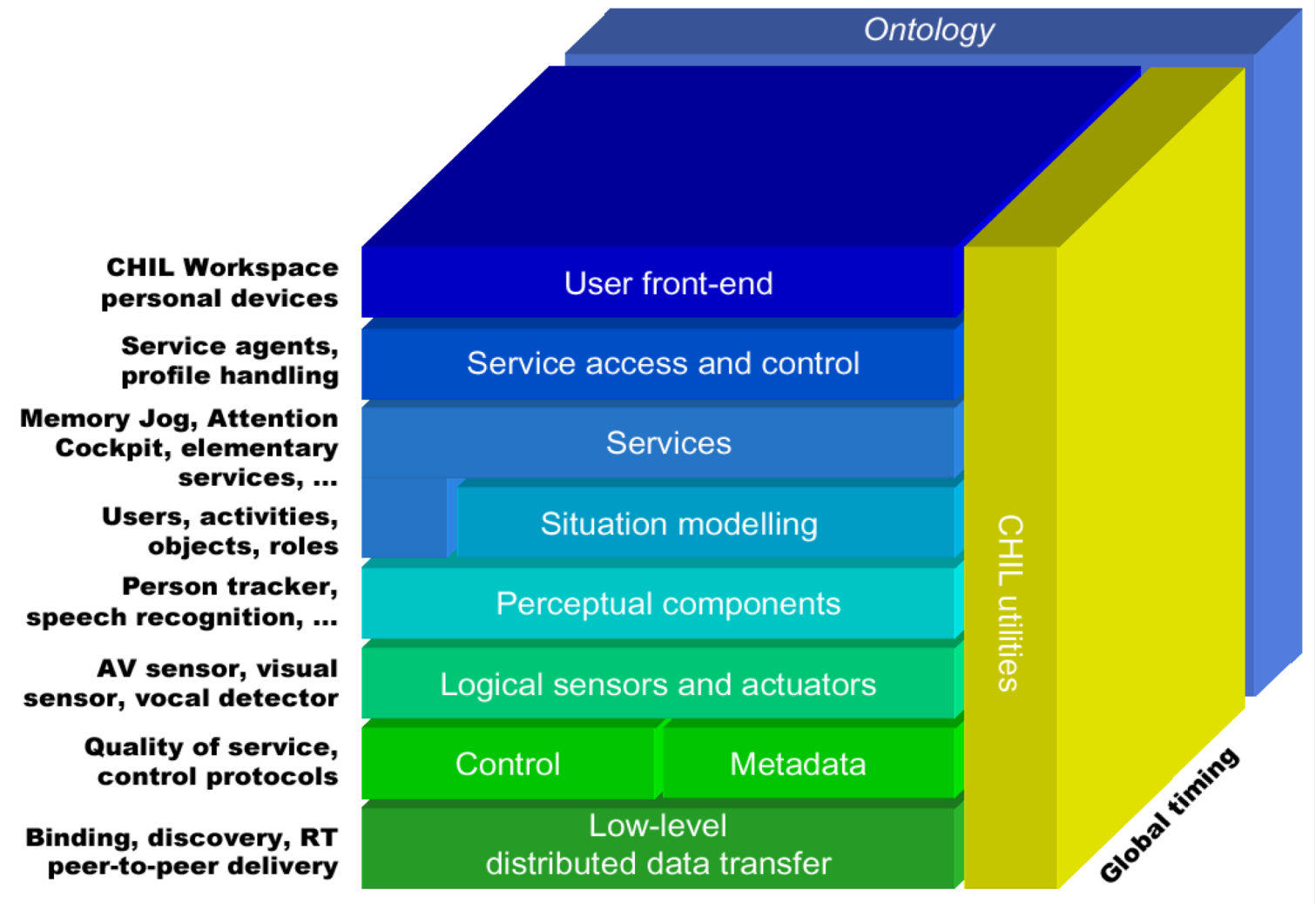
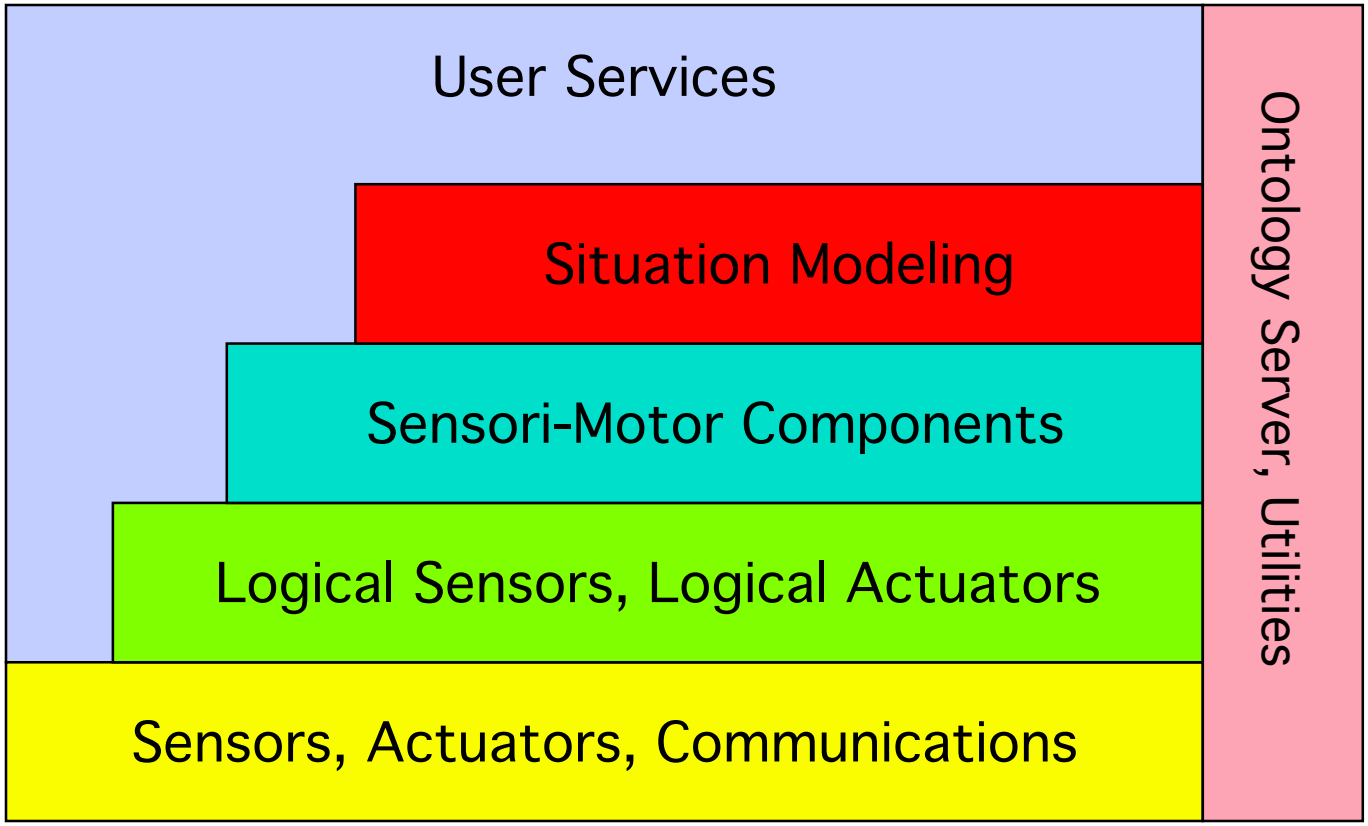
CHIL Layered Software Model Reference Architecture



Software Architectural Reference Model



CHIL Meeting Services

Services (e.g. JADE Agents) access the Situation Model to acquire information about the situation of people and the environment

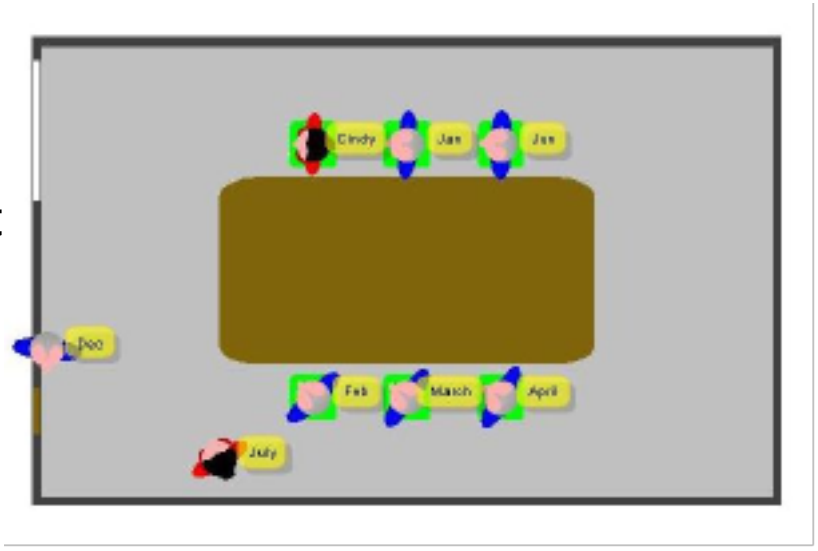
Services use the Roles to query and subscribe to information

Connector

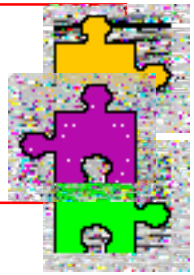
- Roles of people in the room (talker, audience)
- Meeting state (on, off, break, Q&A)

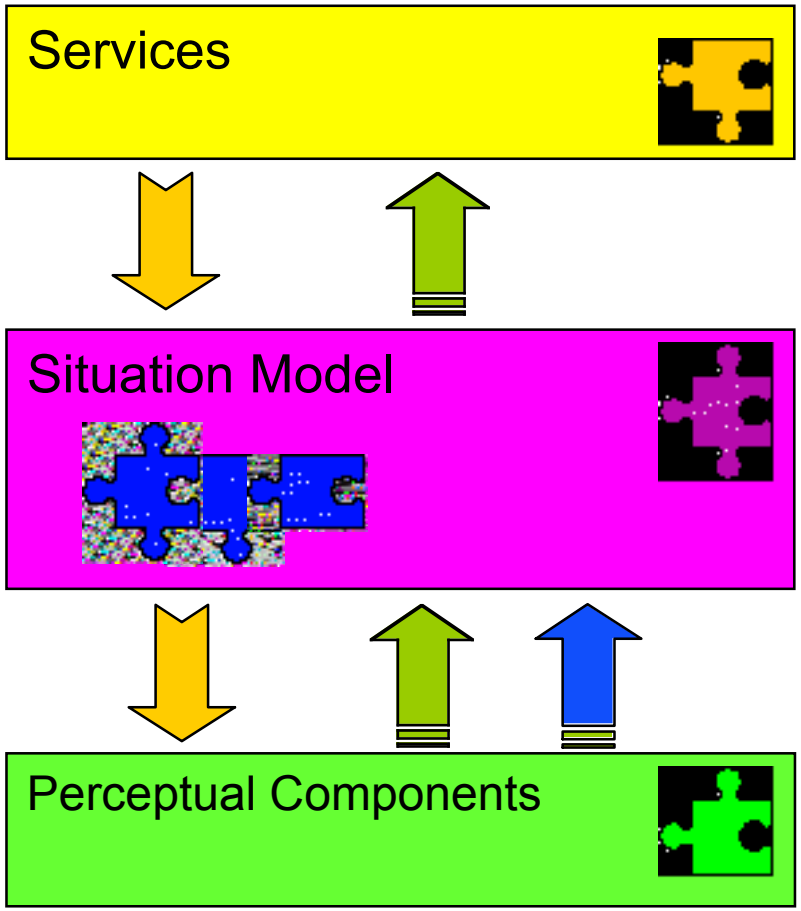
Memory Jog

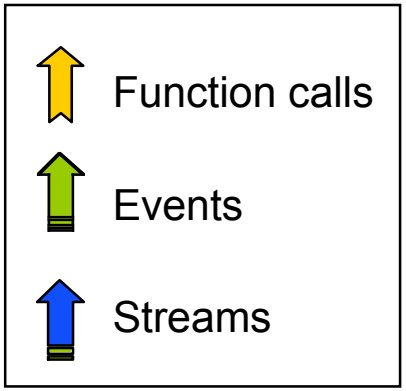
- List of attendees
- ID of a person in the region of interest



Core Component: Situation Model







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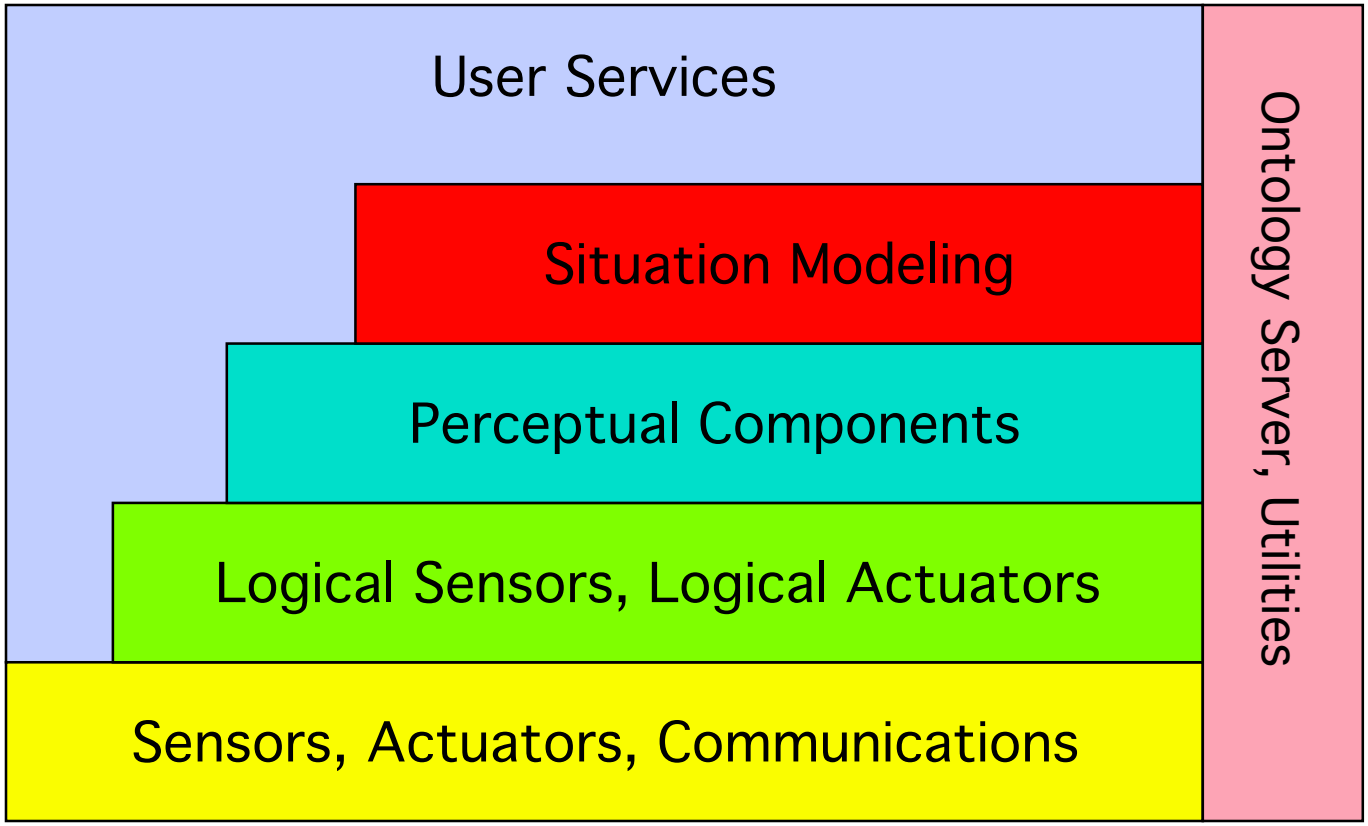
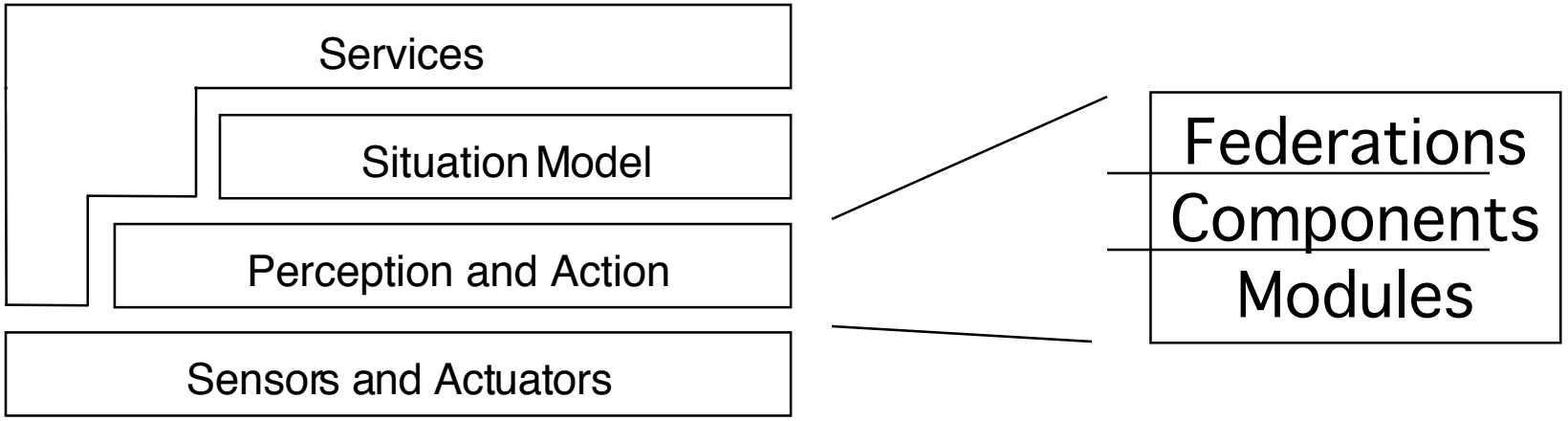


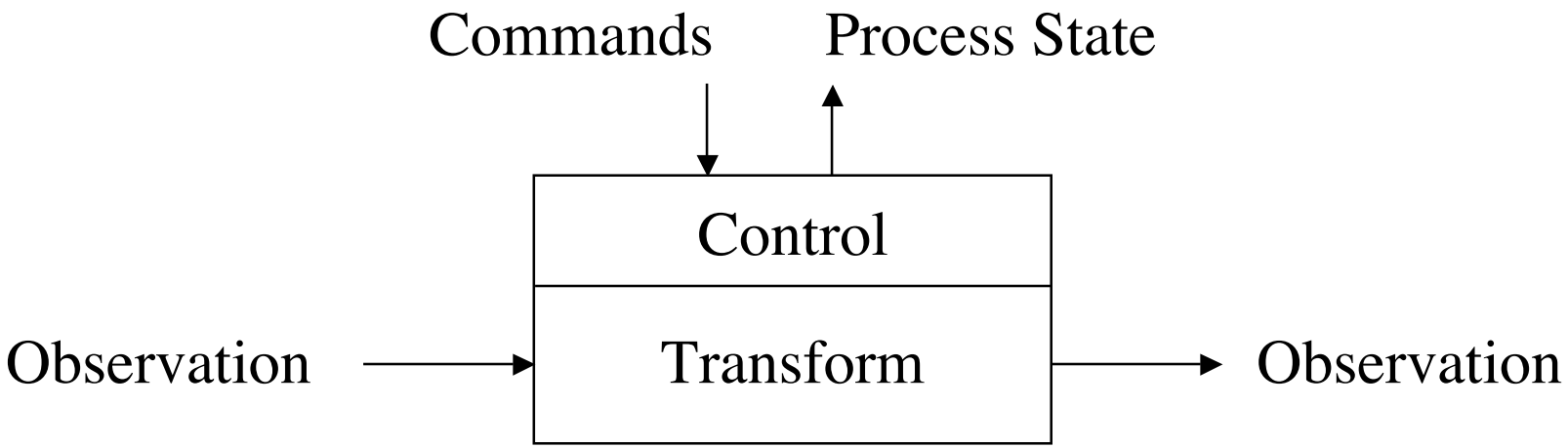
Components for Perception and Action



Perception - Action Layer:

Ad-hoc assembly of components to provide software services.

Sensory Motor Components



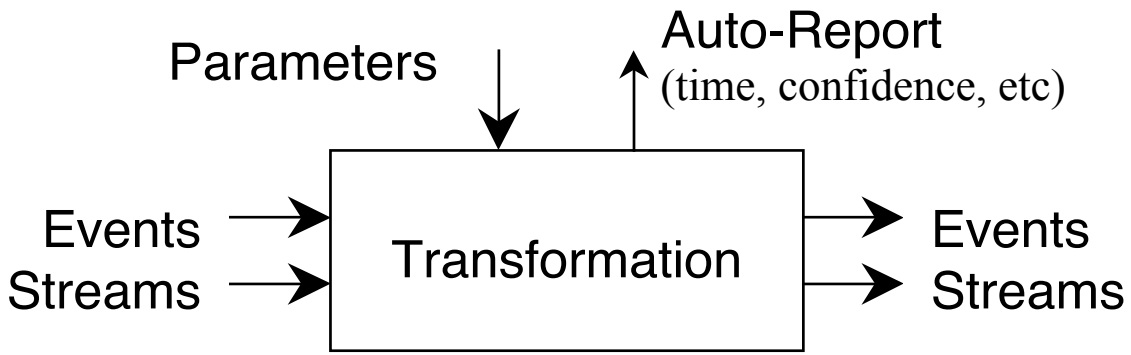
Process model (Finkelstein et al 94).

Data flow Software Architecture (Shaw-Garlan 96)

Process Federations (Estublier and Cunin 97)

Auto-Critical Software Modules

Perceptual Components are composed of modules.

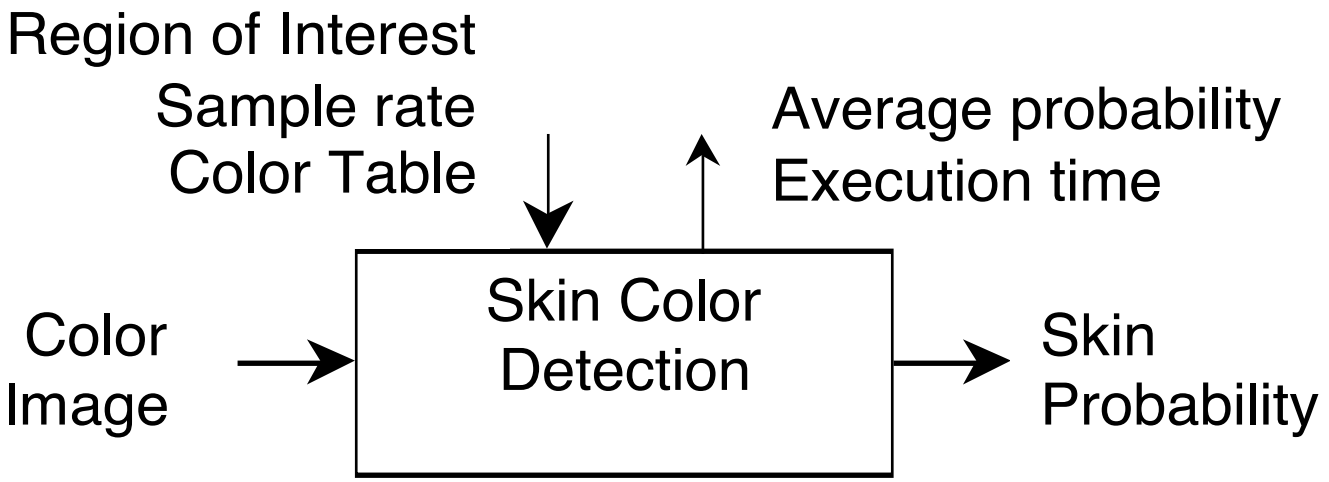


Module: Synchronous Data Transformation

Modules transform data and returns a report on results

Report describes resources used (time, memory) and quality of result

Example : Skin detection



Transform RGB pixels in to probability of skin

Theory: Bayes rule

Implementation: table lookup

Probabilistic Detection of Skin

Chrominance:

$$r = \frac{R}{R+G+B} \qquad g = \frac{G}{R+G+B}$$

Probability of all colors

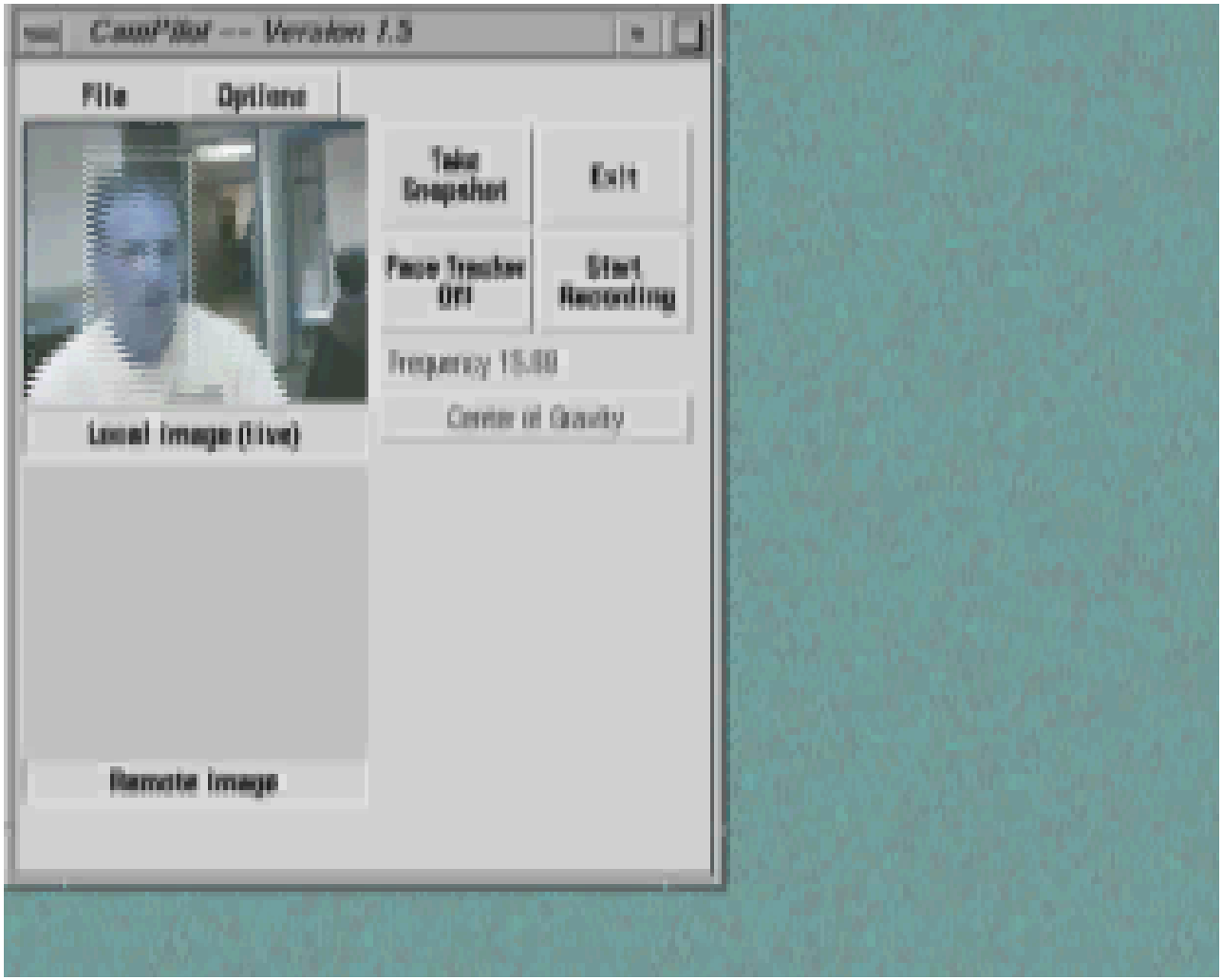
$$p(r,g) \approx \frac{1}{N_{Tot}} h_{Tot}(r,g)$$

Probability of skin

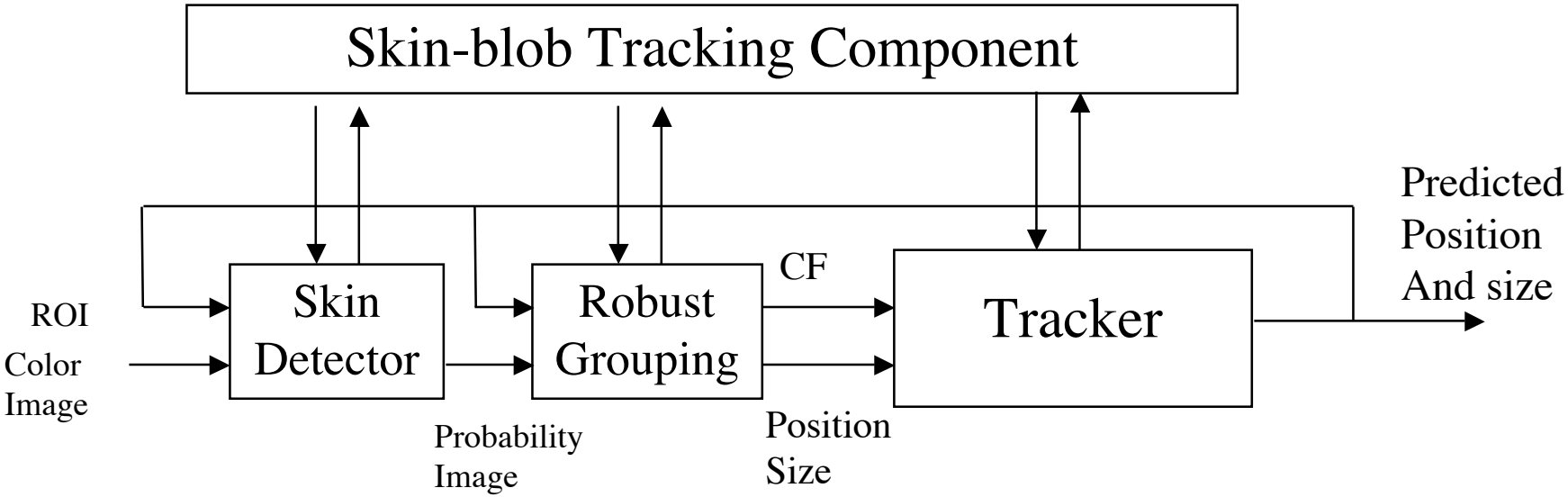
$$p(r,g \mid skin) \approx \frac{1}{N_{skin}} h_{skin}(r,g)$$

$$p(skin \mid r,g) = \frac{p(r,g \mid skin)p(skin)}{p(r,g)} \approx \frac{h_{skin}(r,g)}{h_{Tot}(r,g)} = h_{ratio}(r,g)$$

Skin Blob Tracking



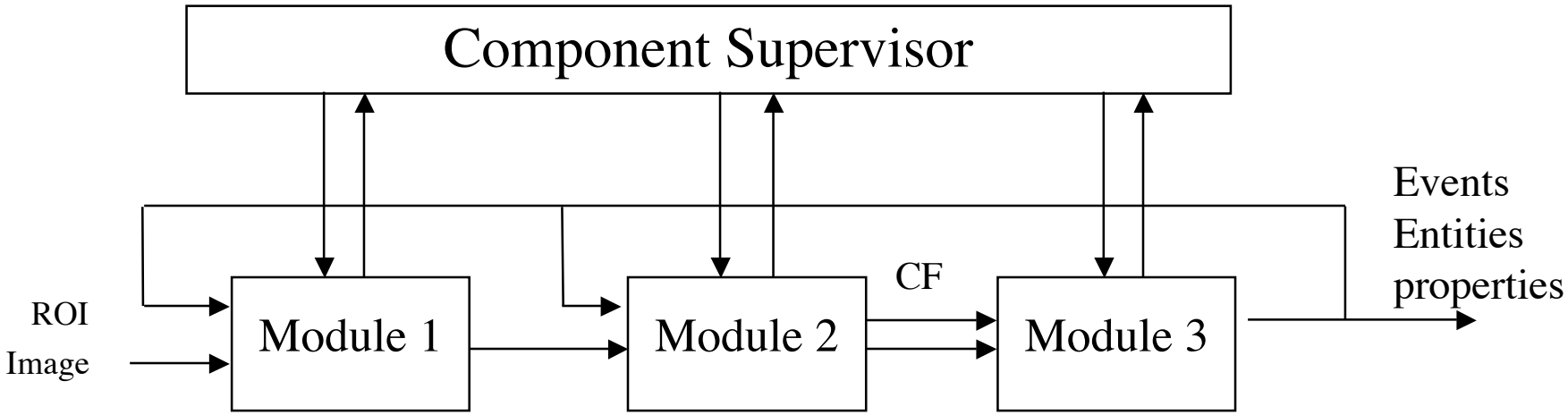
Perceptual Components



Example:

Skin blob tracker can be composed of skin detection module, robust grouping module and tracking module.

Sensory Motor Components

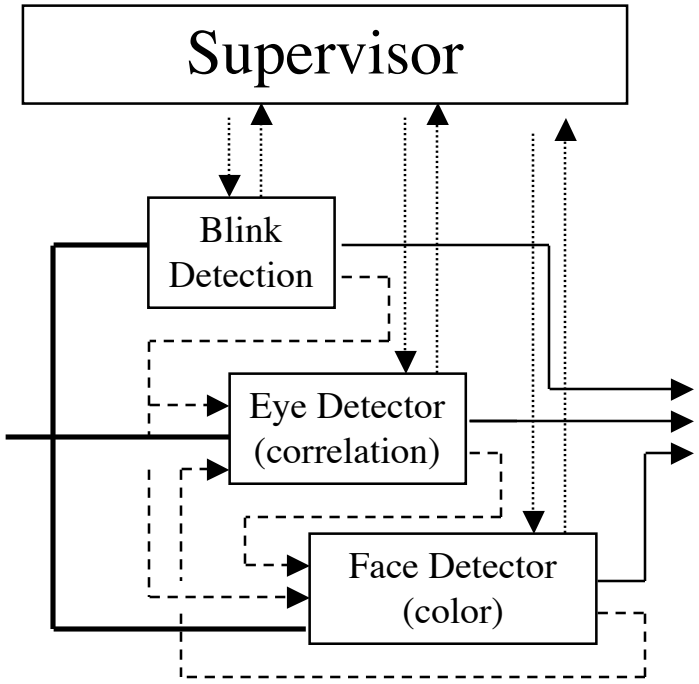


Components are autonomous assemblies of modules

Components are cyclic and asynchronous.

Components communicate via data streams, events and transactions.

Multi-Cue Face Tracking



Blink Detection:

- Precise but infrequent

Correlation:

- Fast and Precise but fragile

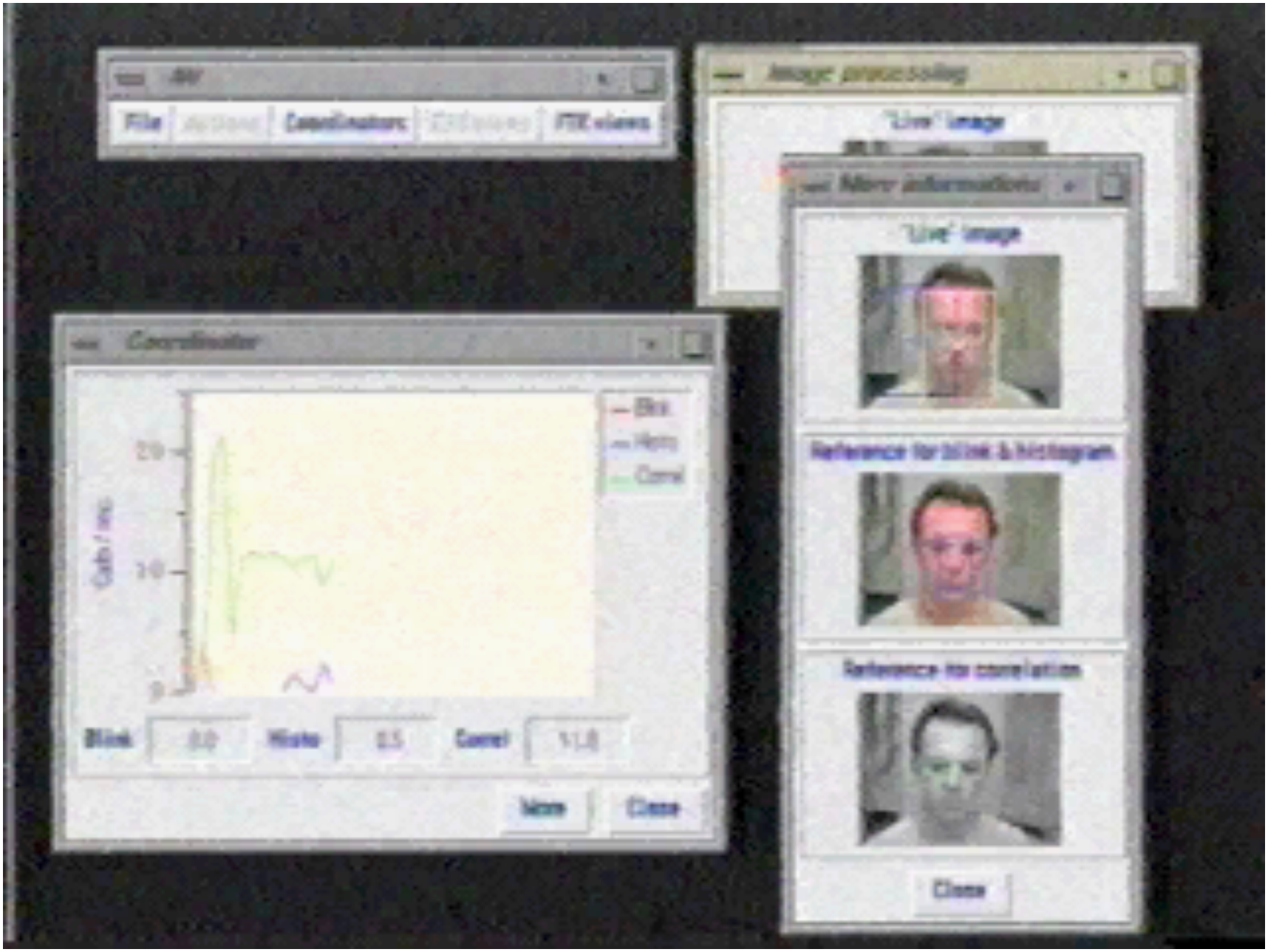
Probabilistic Chrominance:

- Slower and less precise, but reliable.

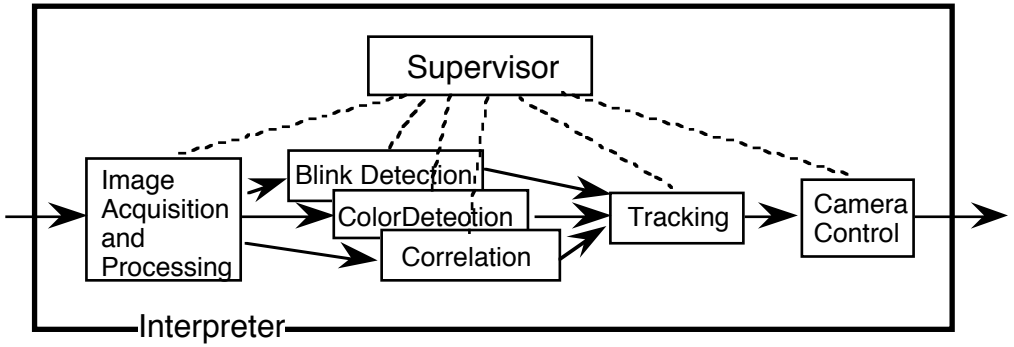
Approach:

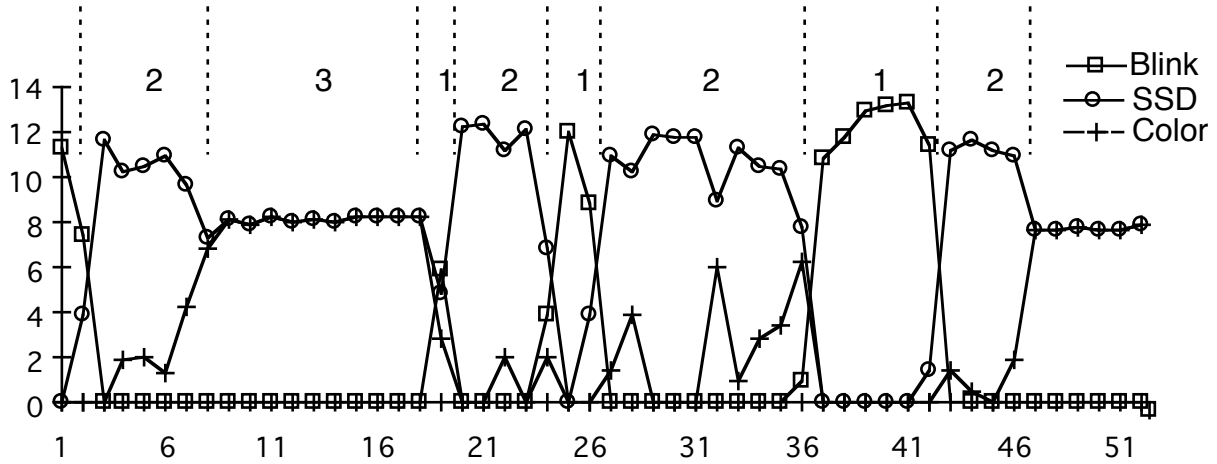
coordinate multipe redundant detection processes

J. L. Crowley and F. Berard, "Multi-Modal Tracking of Faces for Video Communications", IEEE Conference on Computer Vision and Pattern Recognition, CVPR '97, St. Juan, Puerto Rico, June 1997.

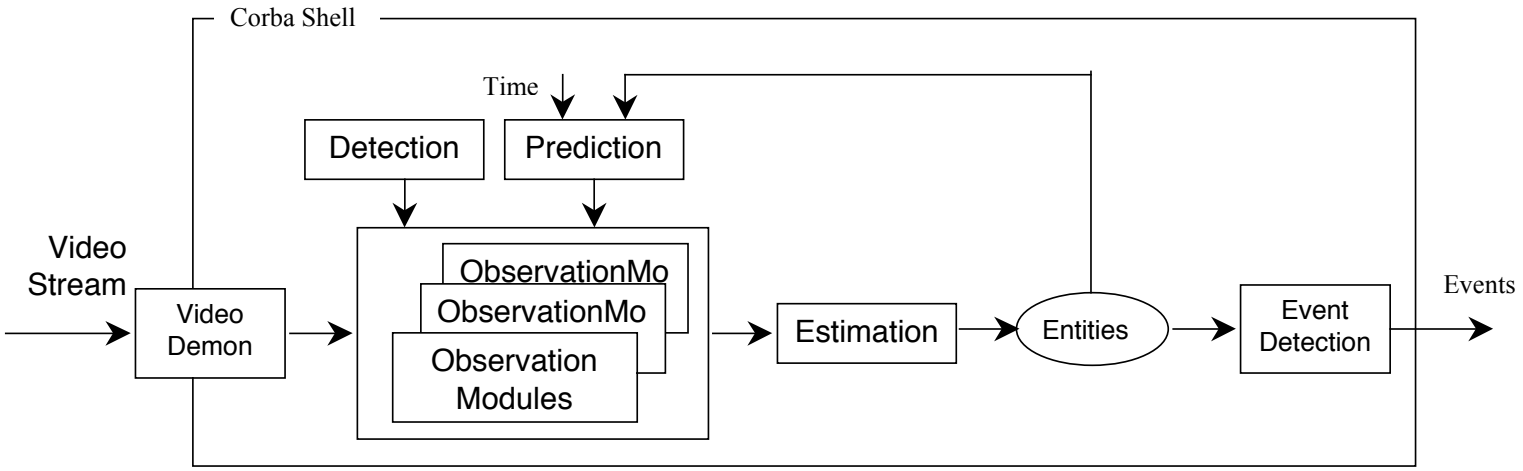

File
Coordinator
Image processing
'Live' image
'Live' image
Reference for blink & histogram
Reference for correlation
Close
Blink
Close

Multi-Cue Face Tracking





Blue Eye Video
Entity Detection and Tracking Process



- Hardwired Control in C++
- Observation Modules:
  - Color Histogram Ratio, Background Difference, Motion History Image,
  - Local Appearance, Receptive Field Histograms
- Industrial Grade System

Tracking, Recognition and Attention

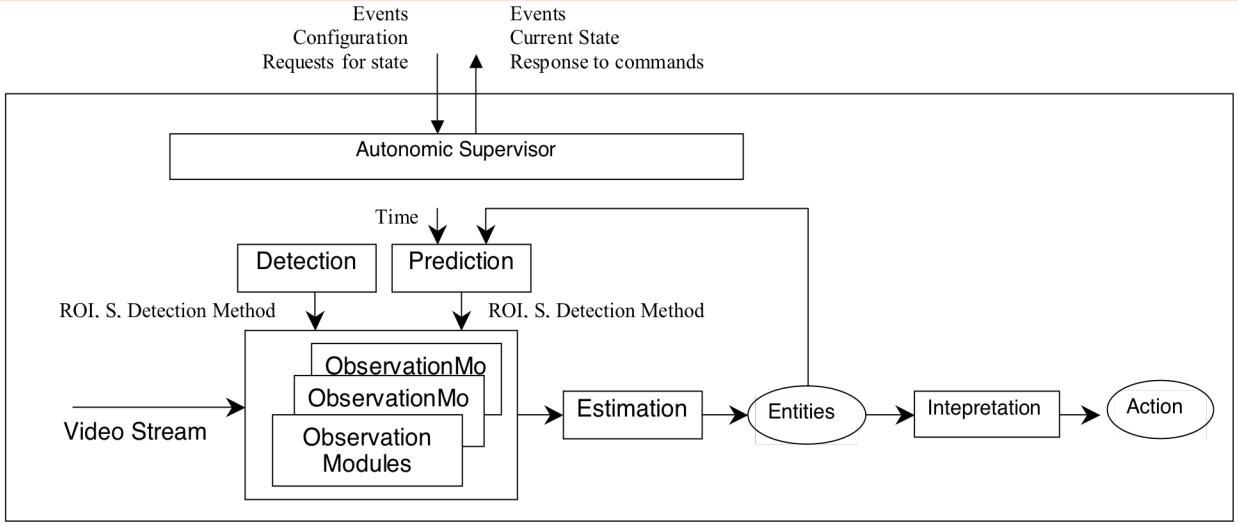
Lesson: Detect, Track then Recognize.

Tracking (constant time) focusses attention for recognition (Unbounded Time)

Tracking:

1) Conserves identity
2) Focusses Processing Resources
3) Provides Robustness to noise
4) Permits Temporal Fusion

Communications Channels



Perceptual Components use three kinds of communications

- Streams: Synchronous data channels (should be time stamped)
- Events: Asynchronous Messages
- Transactions: Query and response between components

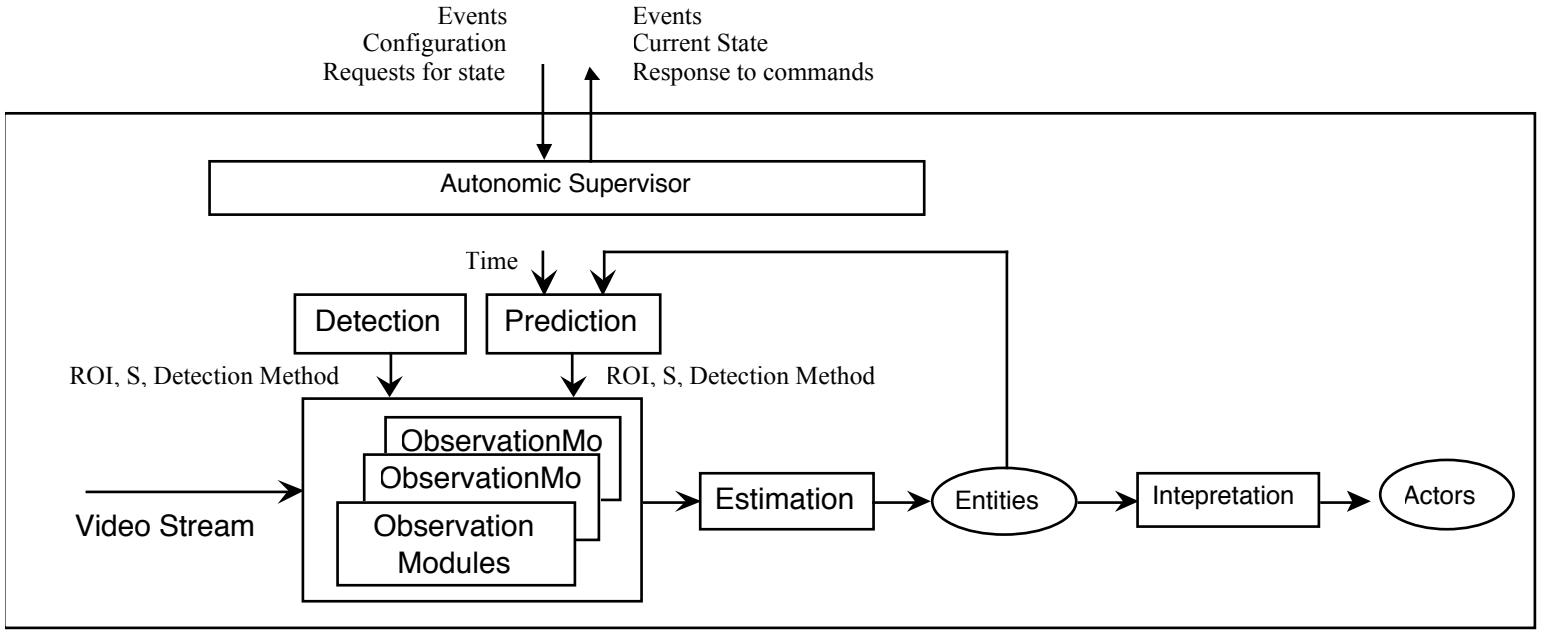
Examples

Streams: audio microphone channel, video channel

Event: Message that a person has spoken

Query: How many people are observed?

Supervised Perceptual Component



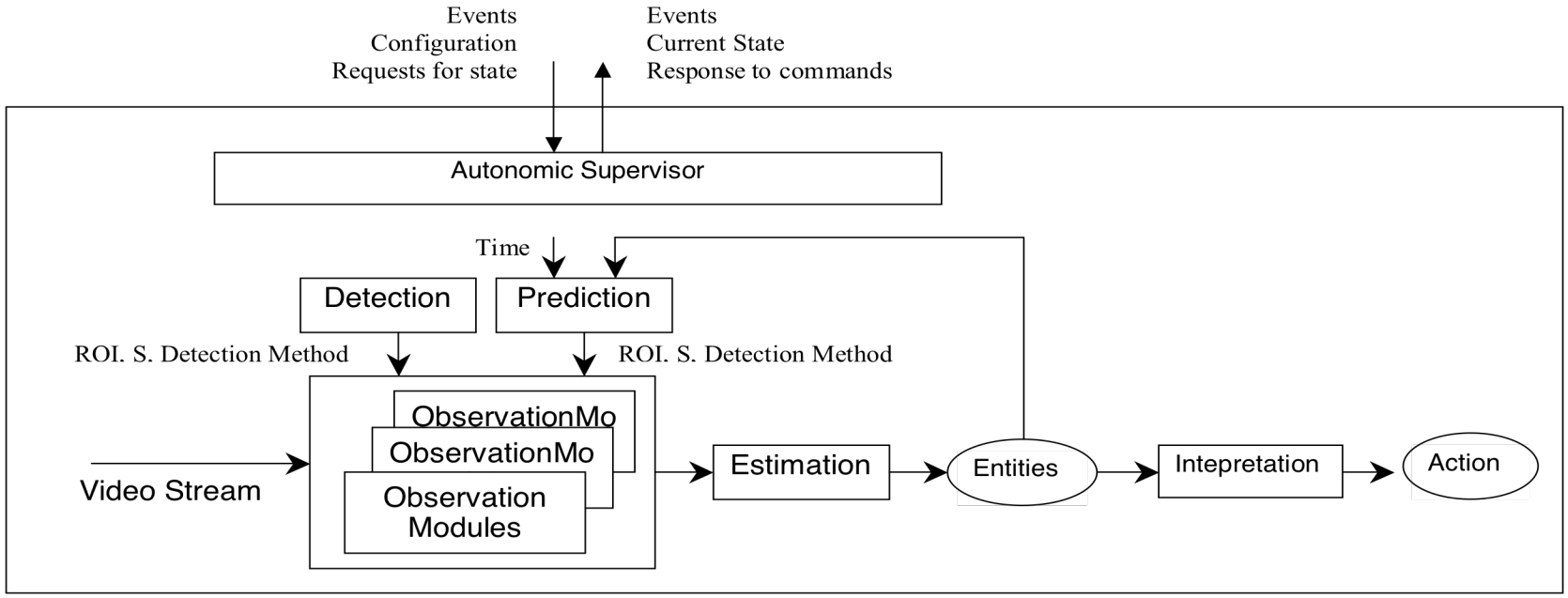
Supervisor Provides:

Execution Scheduler

Parameter Regulator

- Command Interpreter
- Description of State and Capabilities

Perceptual Components



Observation Modules:

- Color Histogram Ratio
- Receptive Fields
- Background Difference
- Motion History Image

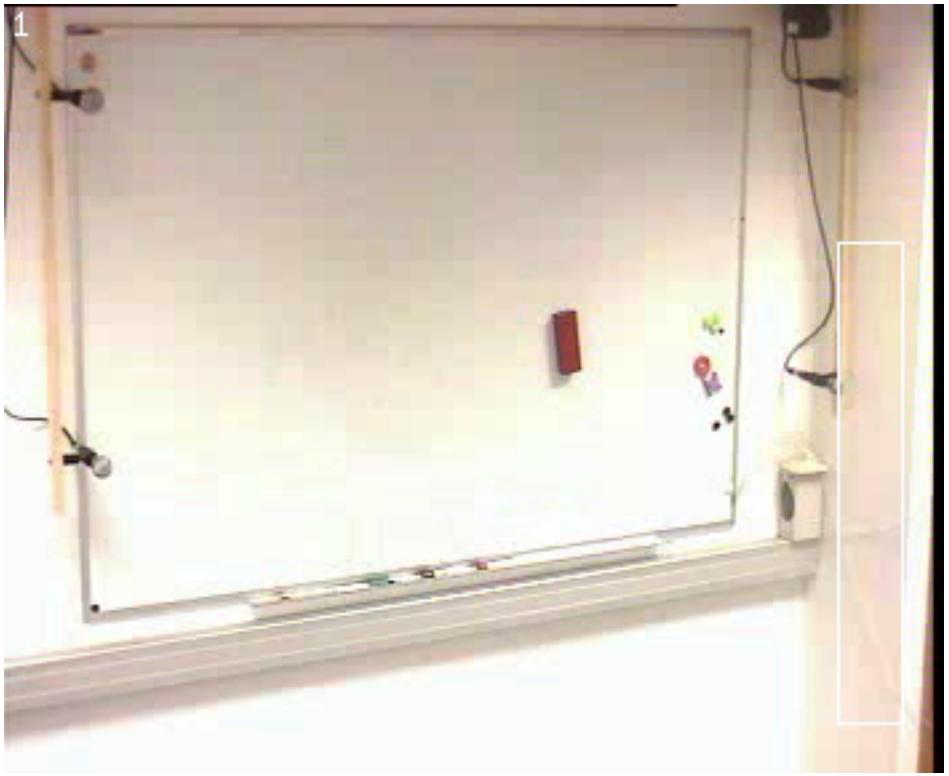
Supervised Perceptual Component

Process Phases:

While True Do

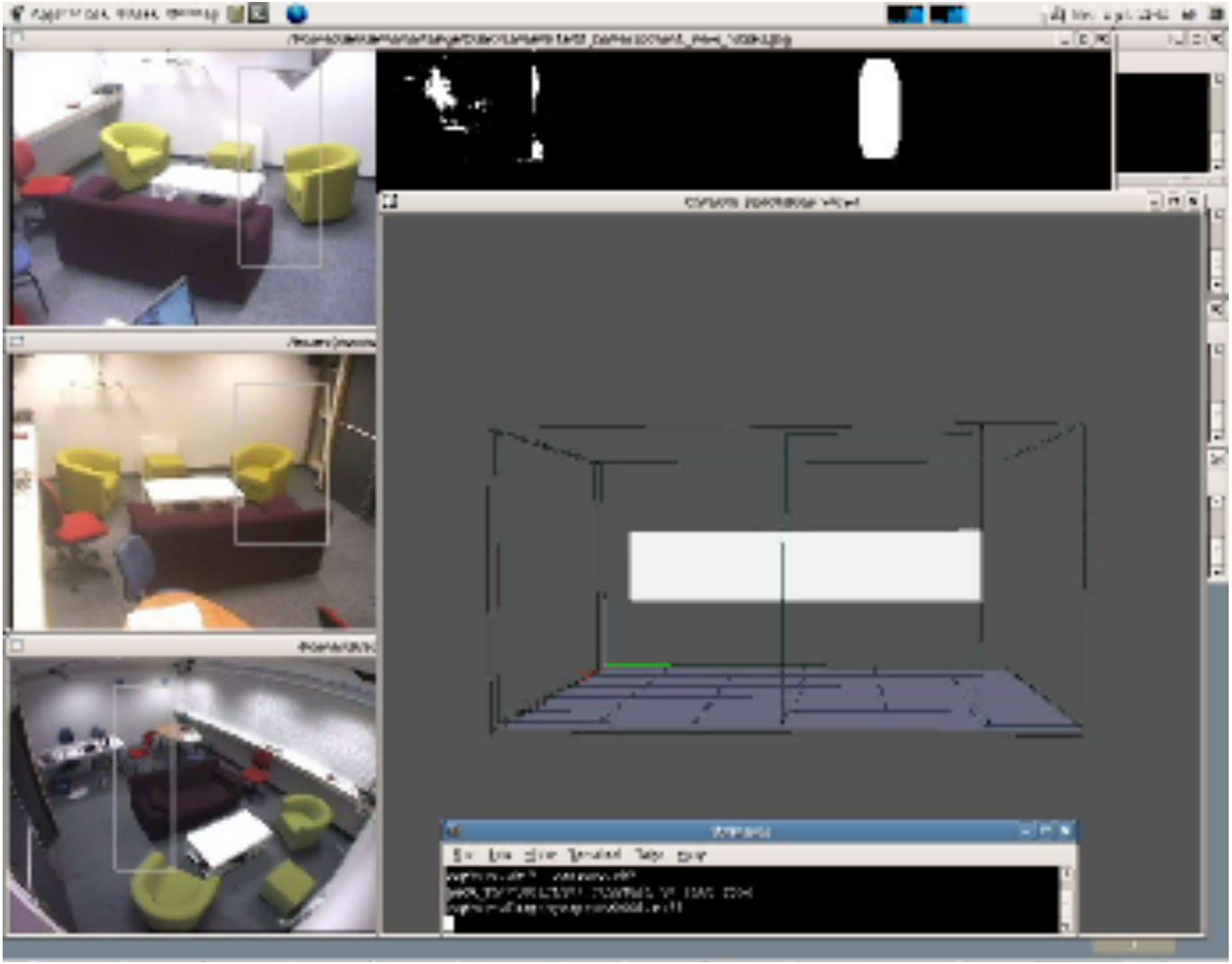
- Acquire next image
- Calculate ROI for targets
- Verify and update targets
- Detect new targets
- Regulate module paramet
- Interpret entities
- Process messages

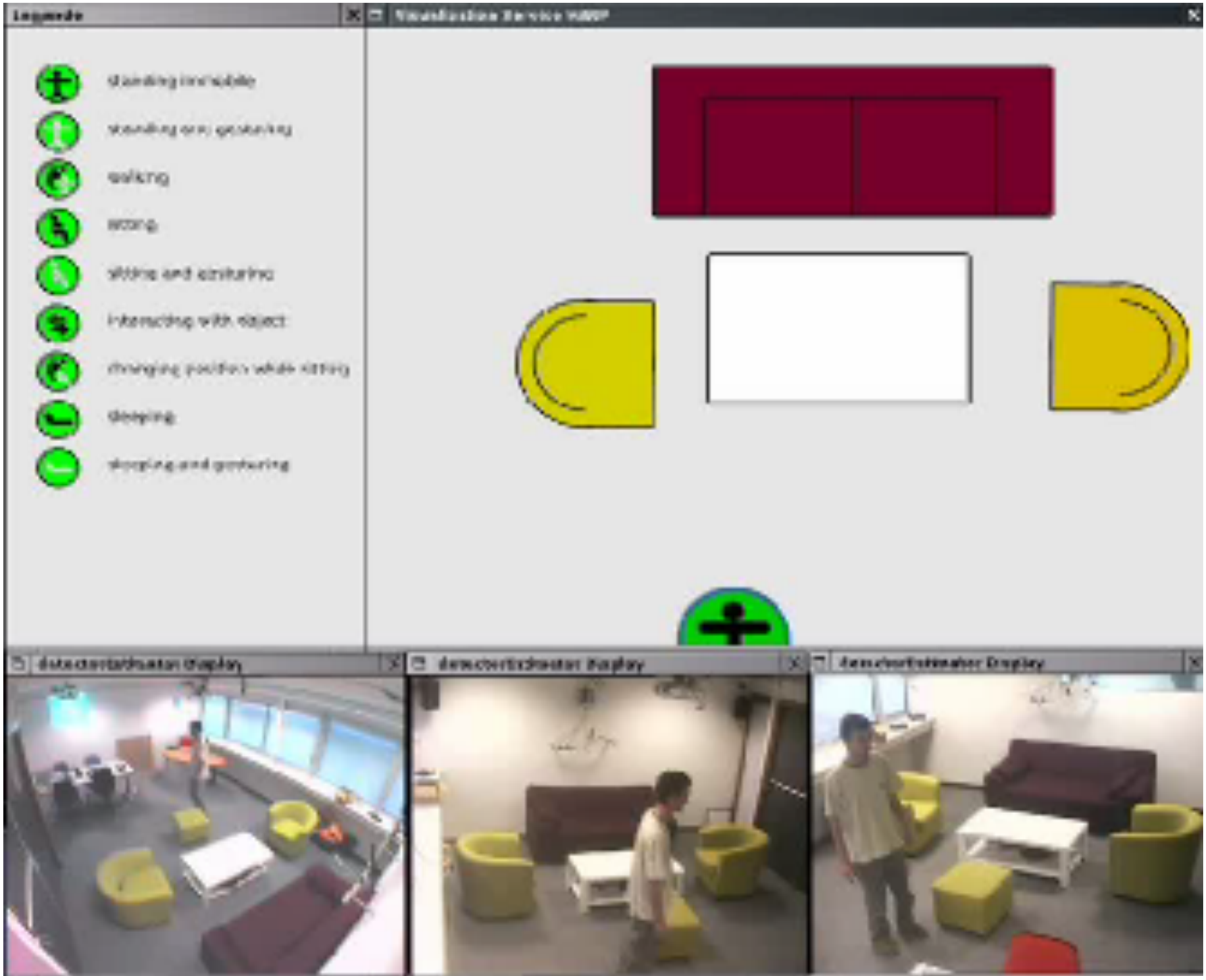
Detection and Tracking of Entities



Entities: Correlated sets of blobs

- Blob Detectors: Background difference, motion,color, receptive field histograms
- Entity Grouper: Assigns roles to blobs as body, hands, face or eyes




Legende

CHIL Perceptual Component Catalog

Output components:
1. Multimodal Speech Synthesis

2D visual components:
1. Person localization and tracking
2. Body detection
3. Head orientation
4. Face detection and recognition

3D visual components:
1. Person tracking
2. Gesture/posture recognition
3. Head & hand tracking using stereo
4. 3D Pointing gesture recognition using stereo

62 Perceptual Components provided by 8 different partners

Audio-visual components:
1. A/V person tracking
2. Person identity tracking
3. Activity recognition
4. AVSR - mouth (lips) observation
5. Emotion recognition

Audio components:
1. Speech recognition (including far-field)
2. Source localization
3. Speech detection
4. Speaker identification
5. Acoustic emotion recognition
6. Acoustic event classification
7. Beamforming

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Lesson Plan

1) Introduction: Context Aware Systems and Services
2) Software components for perception, action and interactive
3) Situation Models: a formal foundation for context modeling
   - Situation Models for Interaction
   - Entities, Relations, and Situation Graphs
   - Roles and Situations
   - Context and Situation.
4) Acquiring situation models
5) Autonomic software components

Situation Models:
a formal foundation for context modeling

Context:

- The situation within which something exists or happens, and that can help explain it [Cup];
- Any information that can be used to characterize situation. [Dey01]

Situation:

- the set of things that are happening and the conditions that exist at a particular time and place. [Cup].

[Cup] Cambridge University on-line dictionary of the English language

Situation Models:
An analytical tool for describing interactions

P. Johnson-Laird 1983 - Situation Model

An analytical tool to allow Human Psychologists to model human to human interaction.

Situation: Relations between entities

Entities: People and things;

Relations: An N-ary predicate (N=1,2,3 …)

Example: John is facing Mary. John is talking to Mary.

Situation Models for Interaction

Proposal: Use situation models as a software framework for systems and services that interact with humans

Situation:

- A configuration of relations between entities, with
- The appropriateness of actions for the situation.

Context:

- A situation network composed from
- A set of entities, relations, actions, and situations

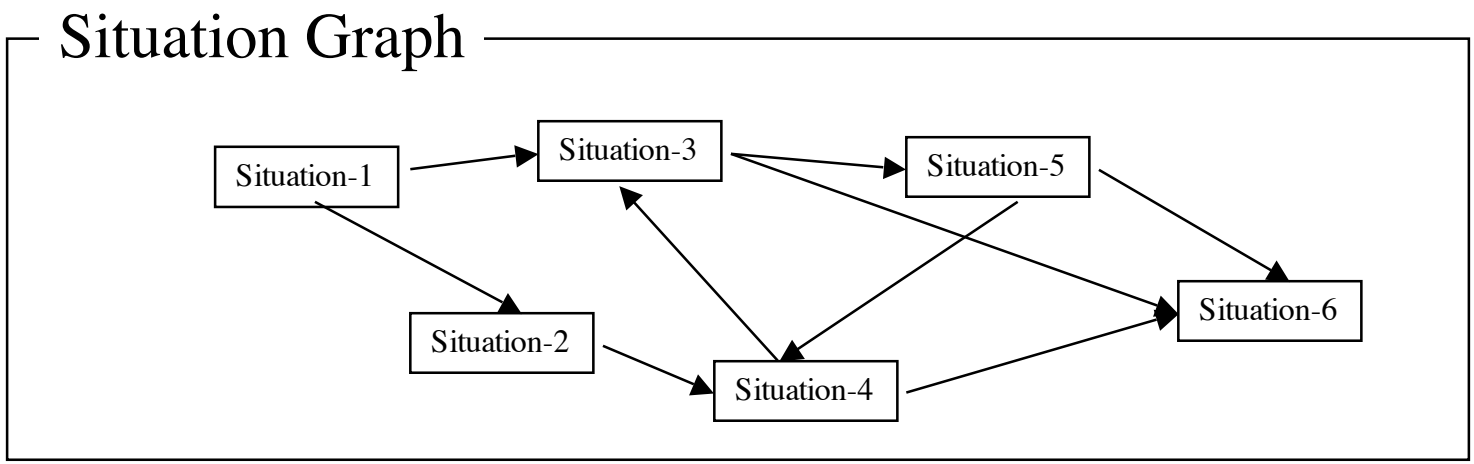
Situation Models for Interaction

In Theatre:
A script defines a linear sequence of scenes.
Actors use props to play roles
The roles define the space of action for an actor
(movements, expressions, etc)
The Script defines the appropriate spoken phrases for each scemne

In human activity
People play roles in shared interaction contexts
Roles define appropriate and inappropriate actions
Social interaction is not linear but includes alternatives and loops.
(A network rather than a sequence.)

Social interaction is modeled as a Situation Graph

Situation Graph

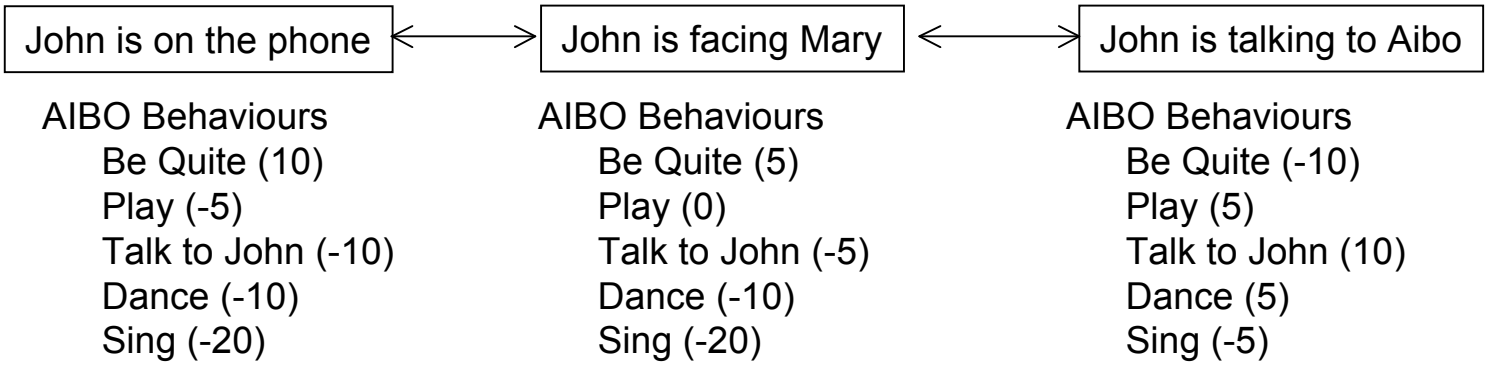


A <u>situation graph</u> describes a state space of situations

A Situation determines:

- System Attention: entities and relations for the system to observe
- System Behaviours: List of actions that are allowed or forbidden

Situation Models for Interaction



Each situation indicates:

- Transition probabilities for accessible situations
- The appropriateness or inappropriateness of actions.

Roles and Situations

Role: An abstract person or thing

A role predicts the actions that might be taken by an actor or the actions enabled by an object.

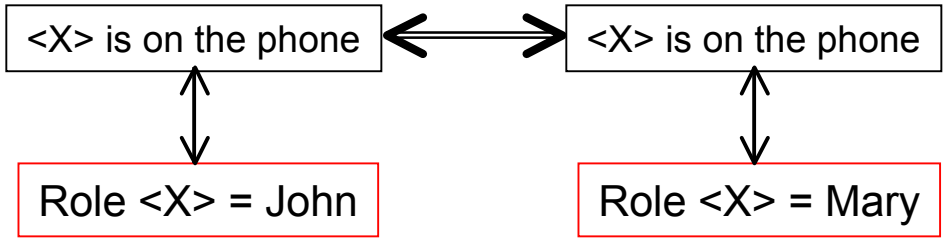
Entity: A correlated set of observed properties.

Two kinds of entities:

Actor: An entity that can spontaneously act to change a situation.

Prop: An entity that can not spontaneously act.

Roles and Situations

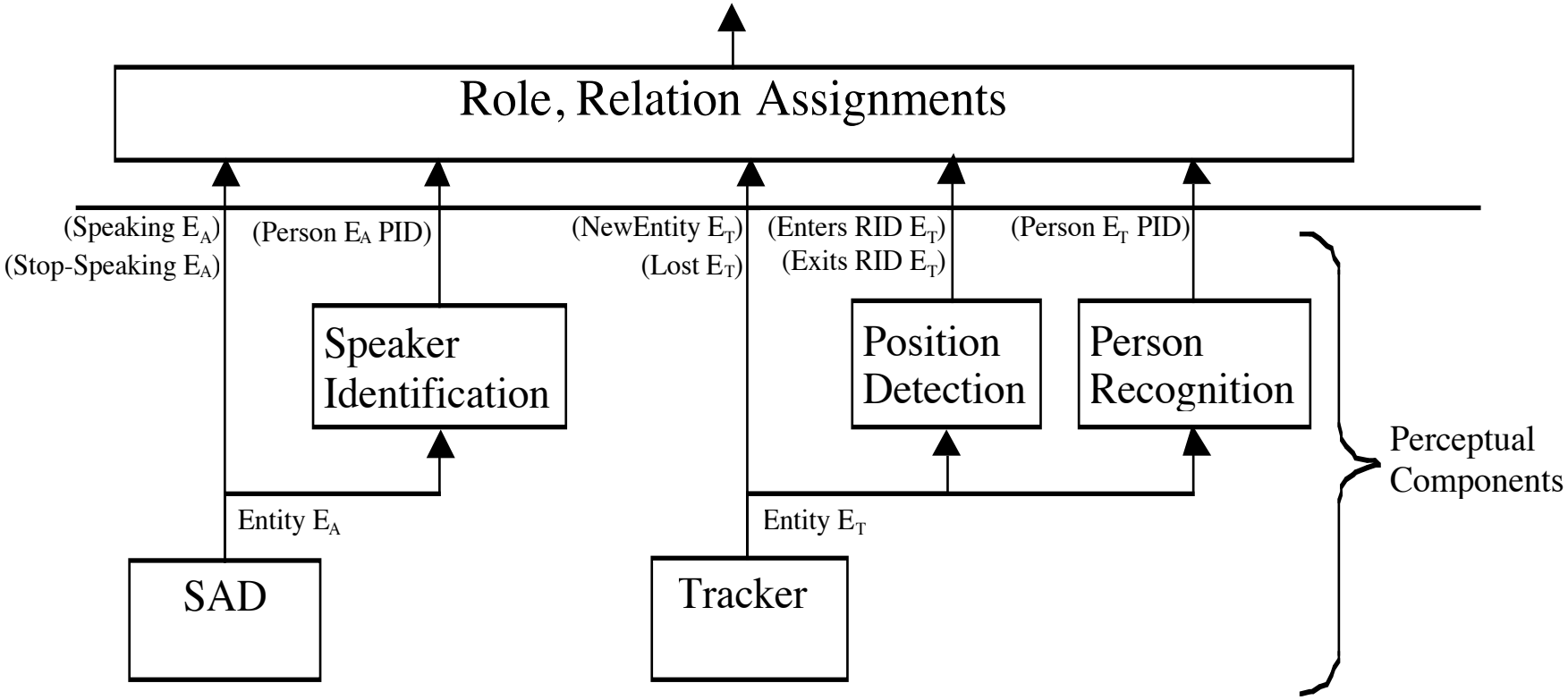


A role is a "variable" for entities.

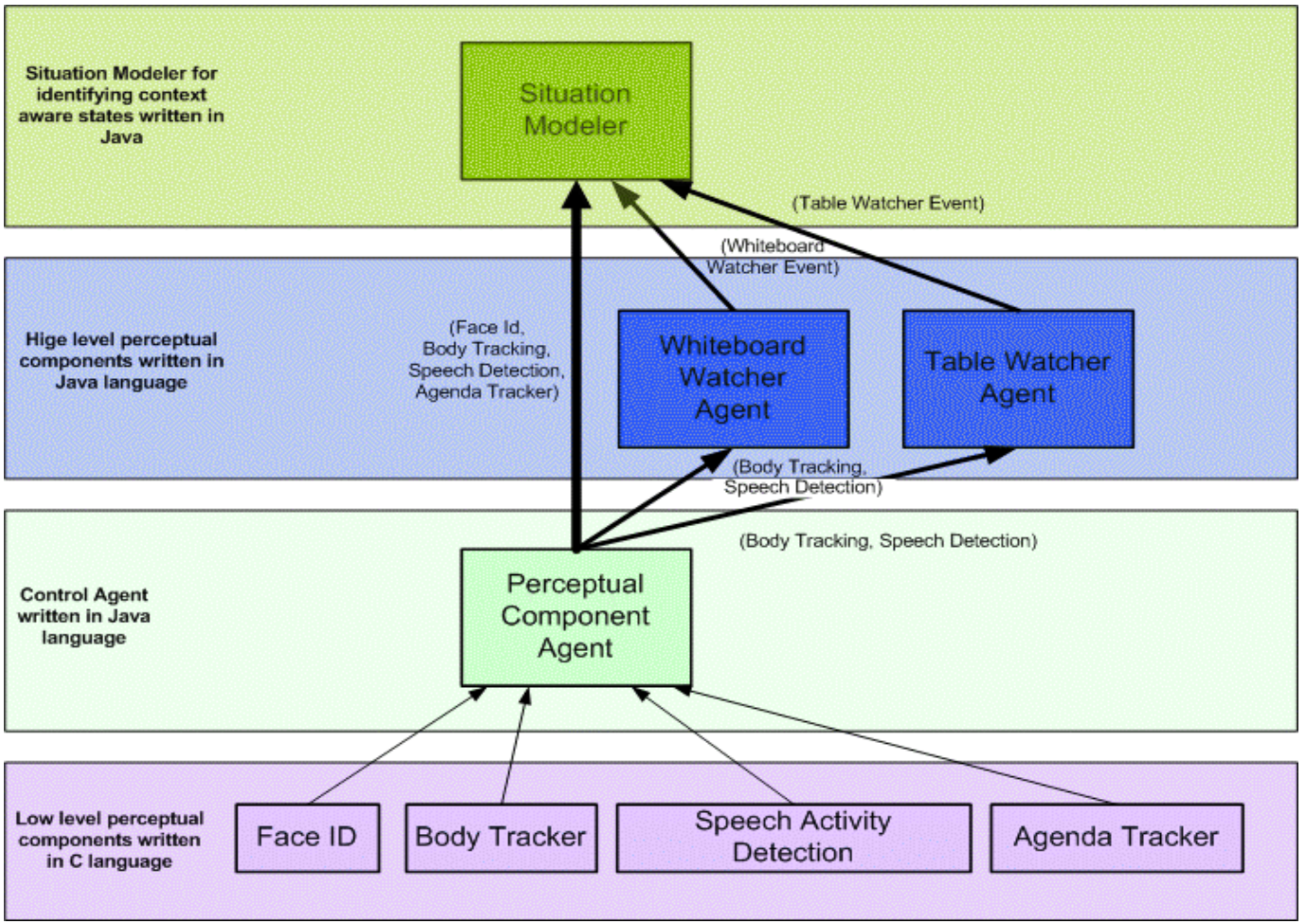
Roles allow generalizations of situations.

Roles enable learning by analogy

Perceptual Components



Context and Situation



CHIL Services using Situation Model

Services (e.g. JADE Agents) access the Situation Model to acquire information about user and environment context

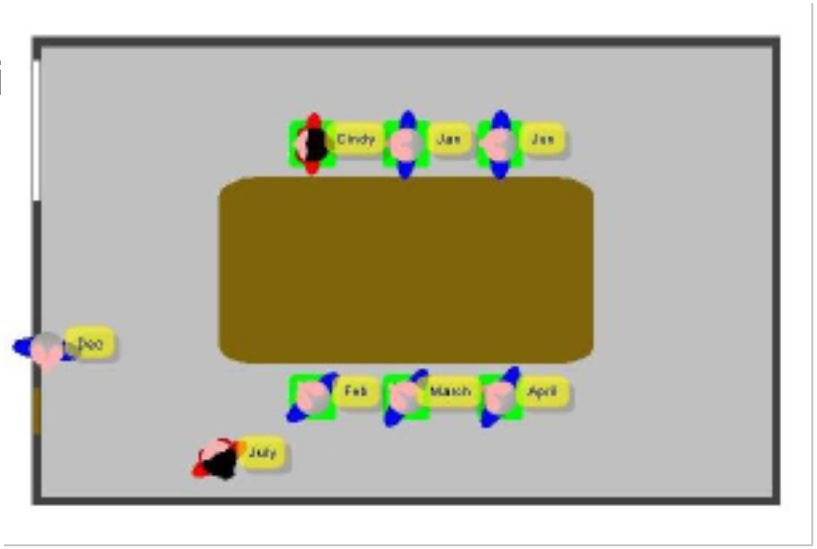
Services use the Roles to query and subscribe to information

Connector

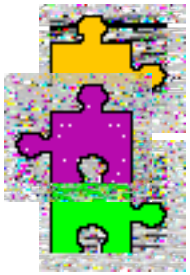
- Roles of people in the room (talker, audi
- Meeting state (on, off, break, Q&A)

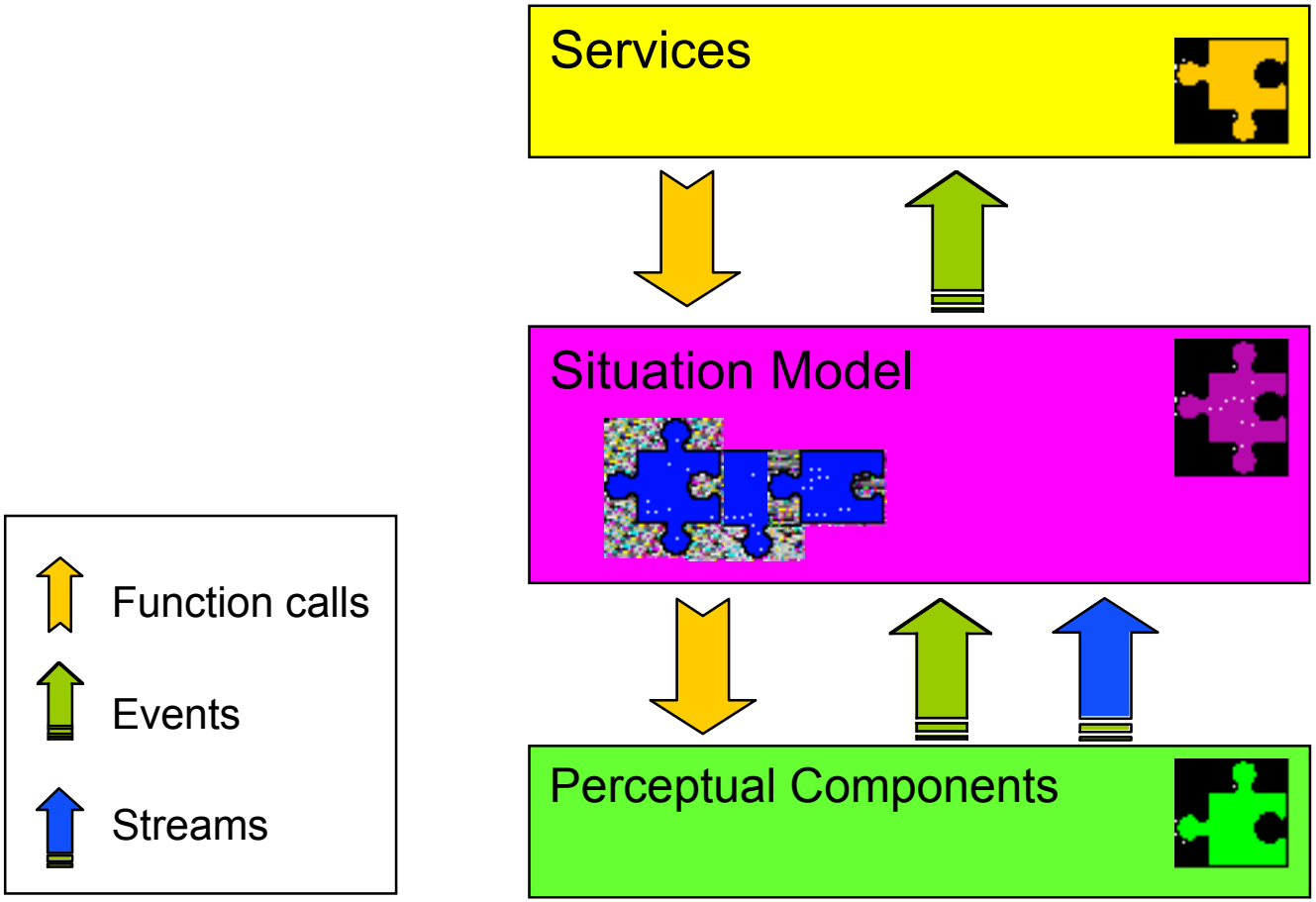
Memory Jog

- List of attendees
- ID of a person in the region of interest

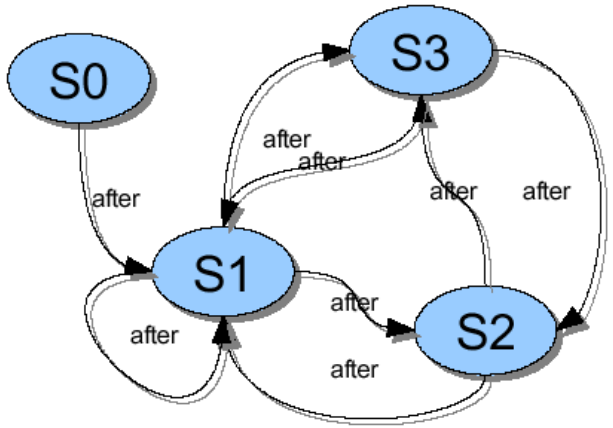


Core Component: Situation Model





Example: Context Aware Video Acquisition System



Situations:

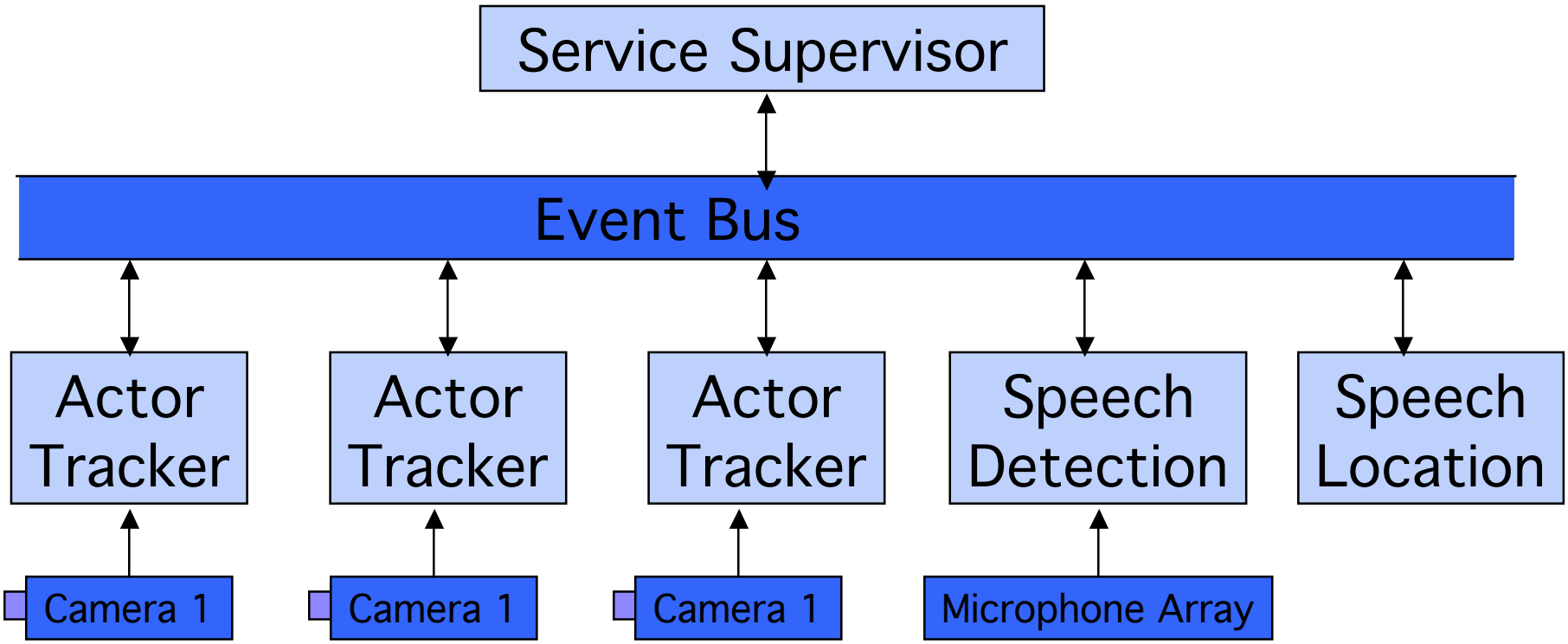
S_0 Empty room $\Rightarrow A_1$

S_1 Actor enters the room $\Rightarrow A_1$

S_2 Speaker (actor) speaks $\Rightarrow A_2$

S_3 Audience (actor) asks a question $\Rightarrow A_3$

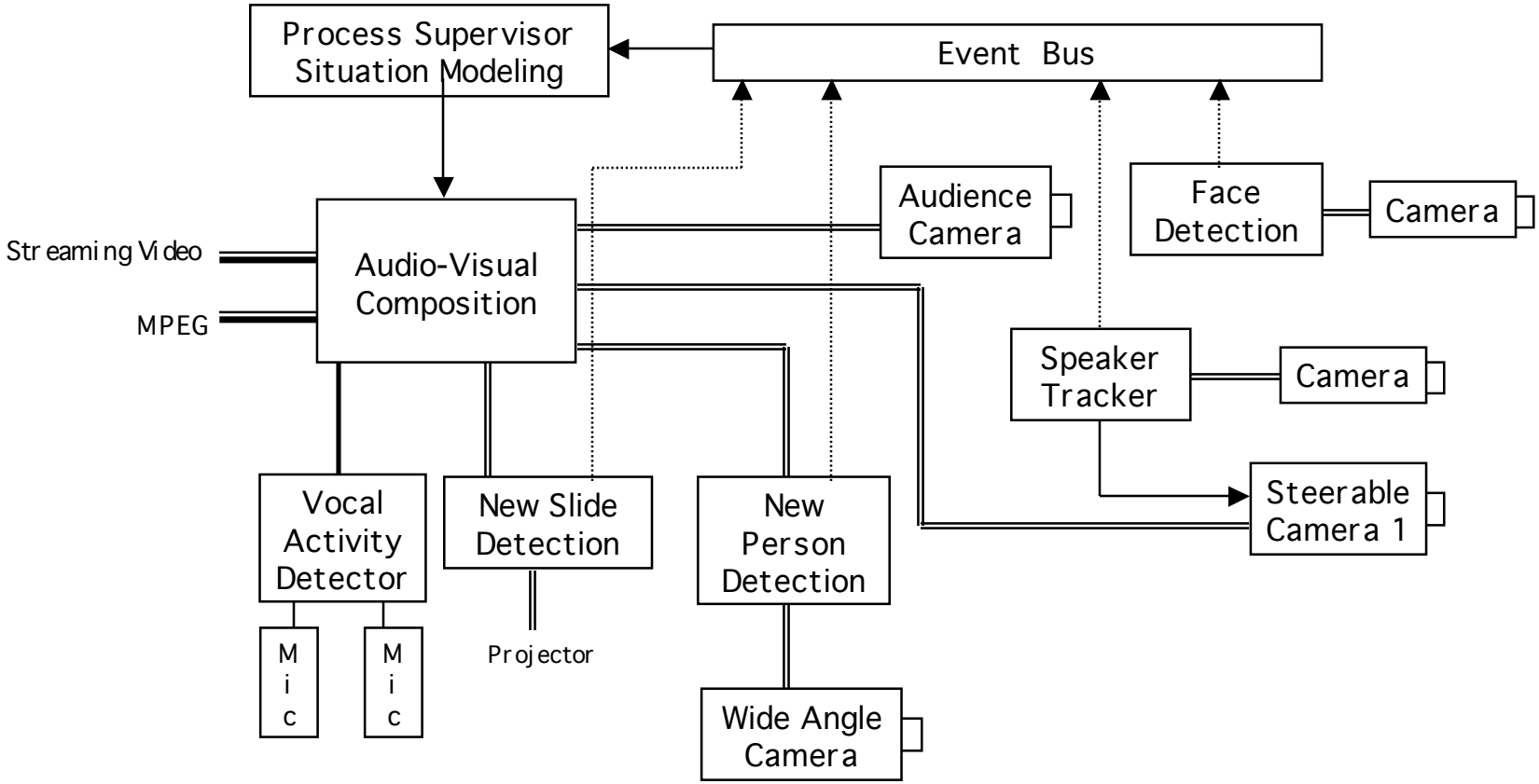
Video Acquisition Service



Automatic Video Acquisition System

(version 1.0 - Jan 2005)

Video Acquisition System V2.0



Lesson Plan

1) Introduction: Context Aware Systems and Services
2) Software components for perception, action and interactive
3) Situation Models: a formal foundation for context modeling
4) Acquiring situation models
5) Autonomic software components