ADE - An Architecture Development Environment for Virtual and Robotic Agents

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Overview

- Why another agent architecture development environment?
- Overview of ADE
- Example of using ADE with a robot
- Status quo and future work
- References to our work on agent architectures

A Case for Distributed Agent Architectures

- Suppose you have to design an architecture for a robot that needs to operate in real-time with the following restrictions (at any given time):
  - The robot need to process several different, computationally intensive input channels from onboard sensors in parallel and be react to them quickly (e.g., if a case of emergency is detected)
  - Multiple onboard computers are involved in the processing, but computational resources of each are very limited
  - Additional offboard processing needs to be done (e.g., using wireless ethernet connections)

SAS or MAS, that's the question

- What system would be appropriate for this kind of setup - *SAS* (single agent systems) or *MAS* (multi agent systems)?
- *Claim:* neither one alone is sufficient, but rather a combination of both is required
- A brief note on terminology:
  - by “SAS-agent” we mean an agent in the sense of an autonomous robot
  - by “MAS-agent” we mean an agent in the sense of a computational component of a distributed system

Multi-Agent Systems (MAS)

- Multiagent systems provide the infrastructure for the distributed agent-based systems:
  - registry, white page, yellow pages, communication protocols, load balancing, movability of agents, etc.
- Some examples:
  - Jade (Bellifemine et al. 2000)
  - Retsina (Sycara et al. 2003)
  - ZEUS (Nwana et al. 1997)
  - AgentBase (http://www.sics.se/~market/toolkit/)

Single-Agent Systems (SAS)

- Single-agent systems (or toolkits) provide components of agent architectures, for example:
  - *Cognitive architectures:* knowledge representation, reasoning, learning (e.g., chunking)
  - *Behavior-based architectures:* behavior representation, sensory processing, learning (e.g., reinforcement)
- Some examples:
  - SimAgent (Sloman and Logan 1999)
  - Saphira (Konolige 2002)

Integrate SAS and MAS Functionality

- Want to implement computationally demanding realtime architectures for complex robots
  –> combine tools from SAS and MAS systems!
- Specifically, want to distribute components of "SAS-agents" using "MAS-agents" (i.e., the components of MAS systems)
- Need:
  - framework in which agent architectures can be expressed to allow implementation of different architecture paradigms (e.g., want to be able to implement rule-based systems as well as behavior-based systems)
  - multi-agent system that supports real-time interactions

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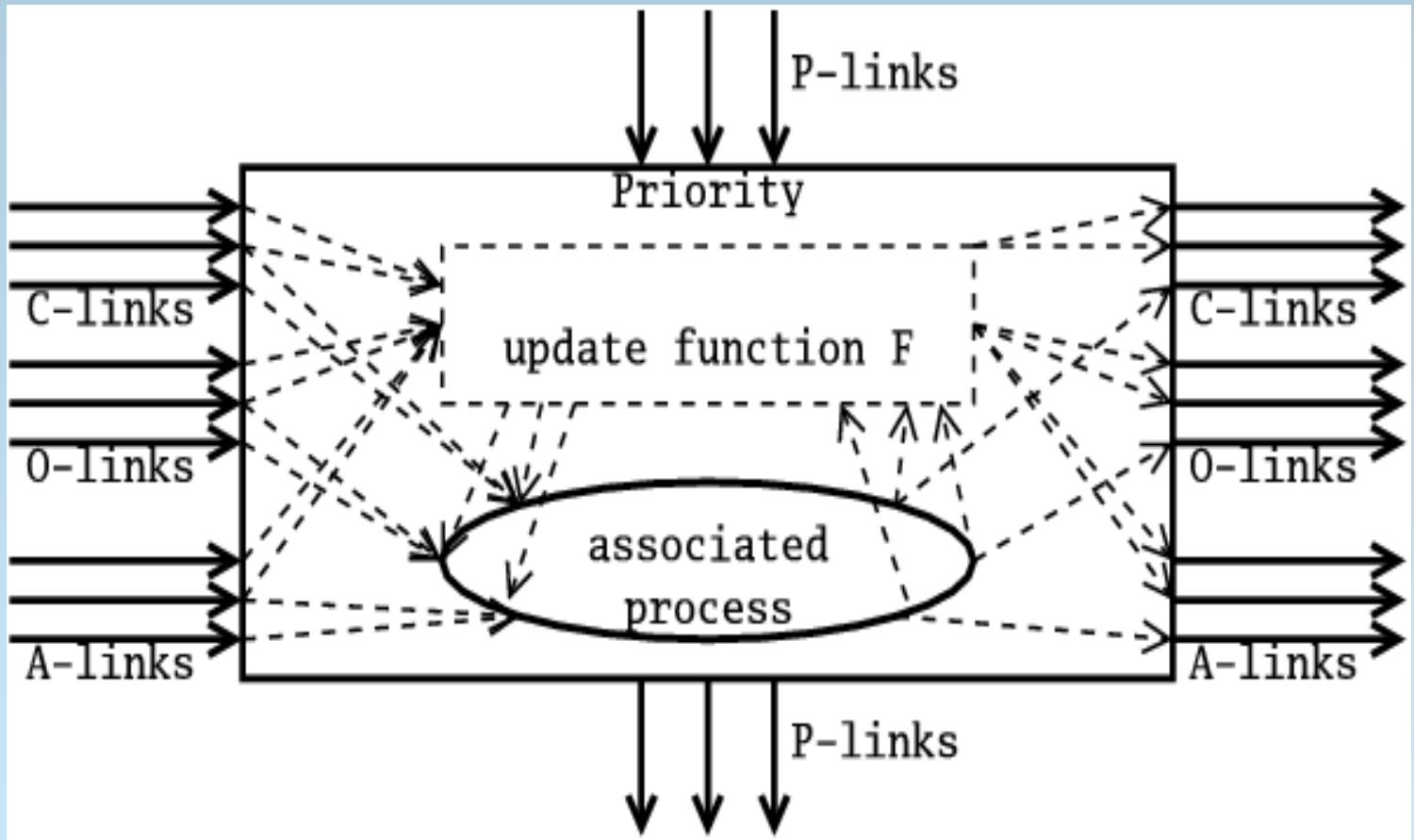
Our Proposed Solution: ADE

- ADE - "APOC Development Environment", which builds on and combines:
  - APOC – a generic agent architecture framework, in which other architectures can be expressed in a unified way
  - AGES – a distributed MAS system with emphasis on real-time robotic applications
- JAVA-based for platform-independence, threading, and RMI
- Multi-user distributed GUI for collaborative design, testing, and run-time supervision

SAS Aspects: the Agent Architecture Framework APOC

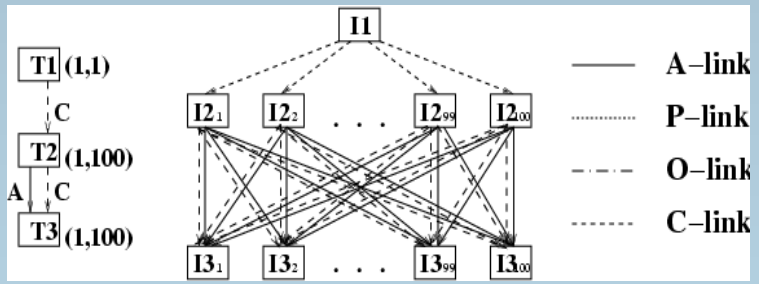
- APOC ("Activating", "Processing", "Observing", "Components")

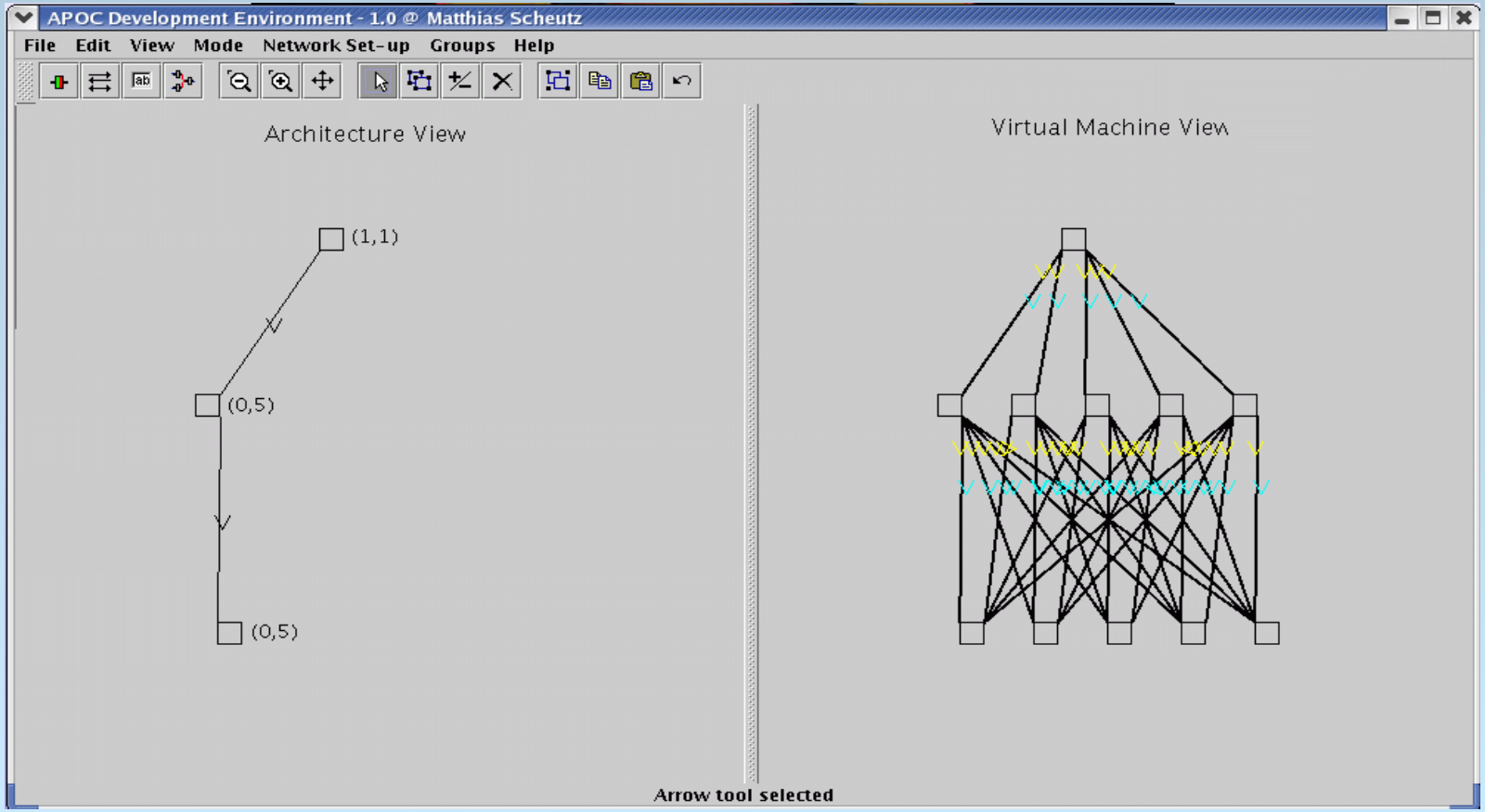
- One basic component type
- Four basic link types:
  - A-link
  - P-link
  - O-link
  - C-link



SAS Aspects: Expressing other Architectures in APOC

A neural network architecture type in APOC and one particular instance of it





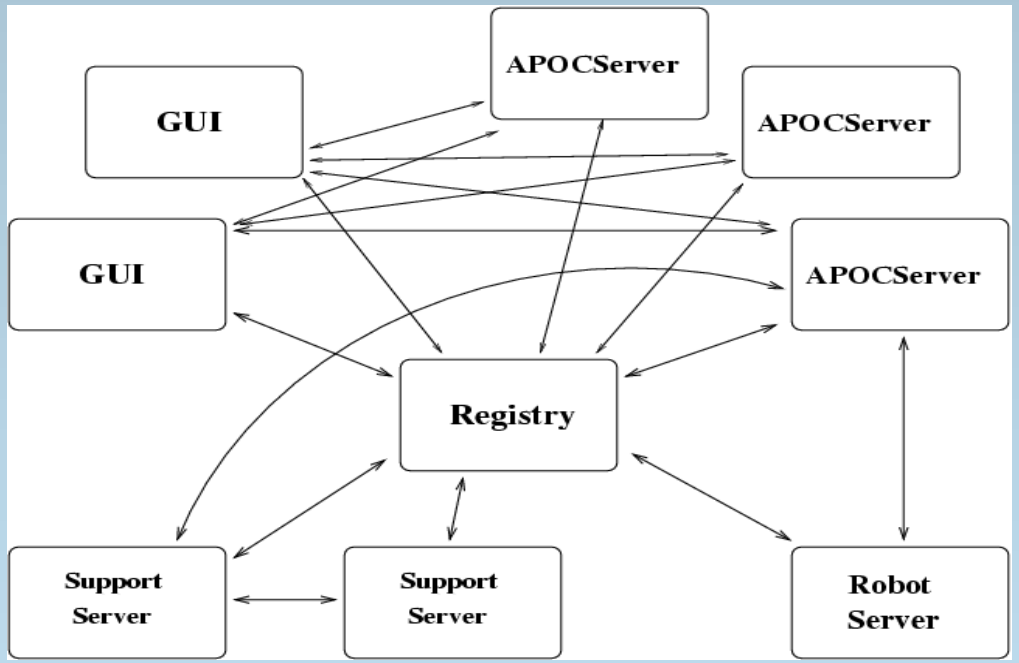
The ADE GUI

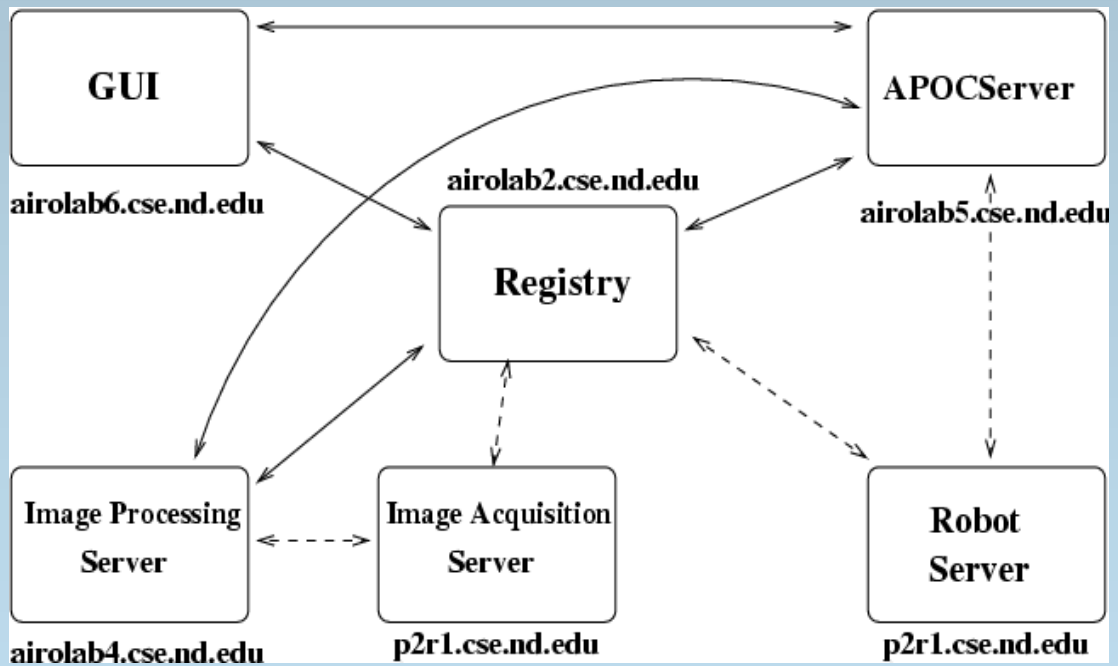
- Left: *the architecture view*
- Right: *the virtual machine view*

MAS Aspects: Servers in ADE

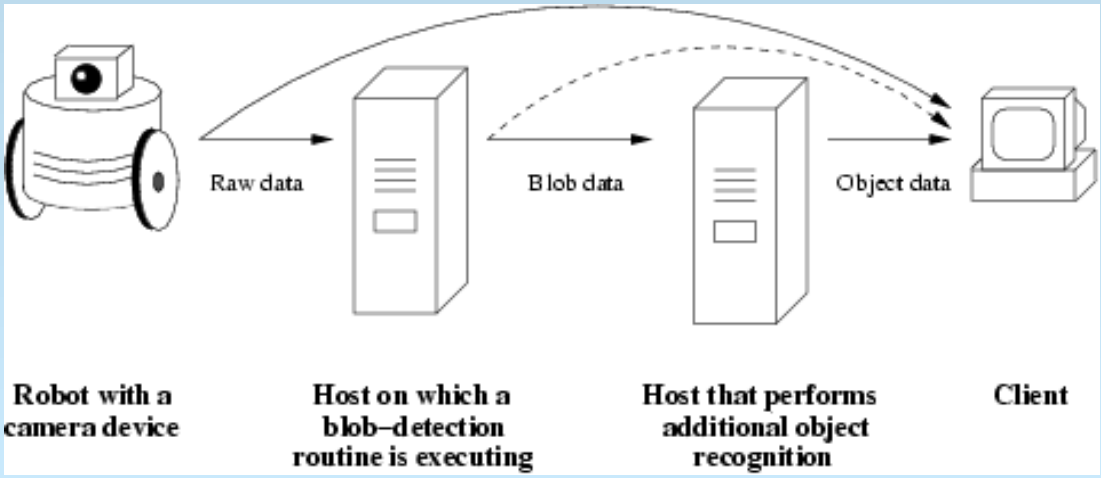
- A *server* in ADE is a computational unit that represents a computationally independent resource of the ADE system:
  - *APOC server:* the basic APOC virtual machine with capabilities for instantiating and deleting new components and links
  - *GUI server:* a visual resource which allows the user to view the architecture and its distributed instantiation in the virtual machine
  - *Agent server:* a representation of a virtual or robotic agent within ADE with access to its sensors and effectors
  - *Utility server:* provide a system-wide service which may be needed by one or more APOC components

MAS Aspects: Single-Robot Setup

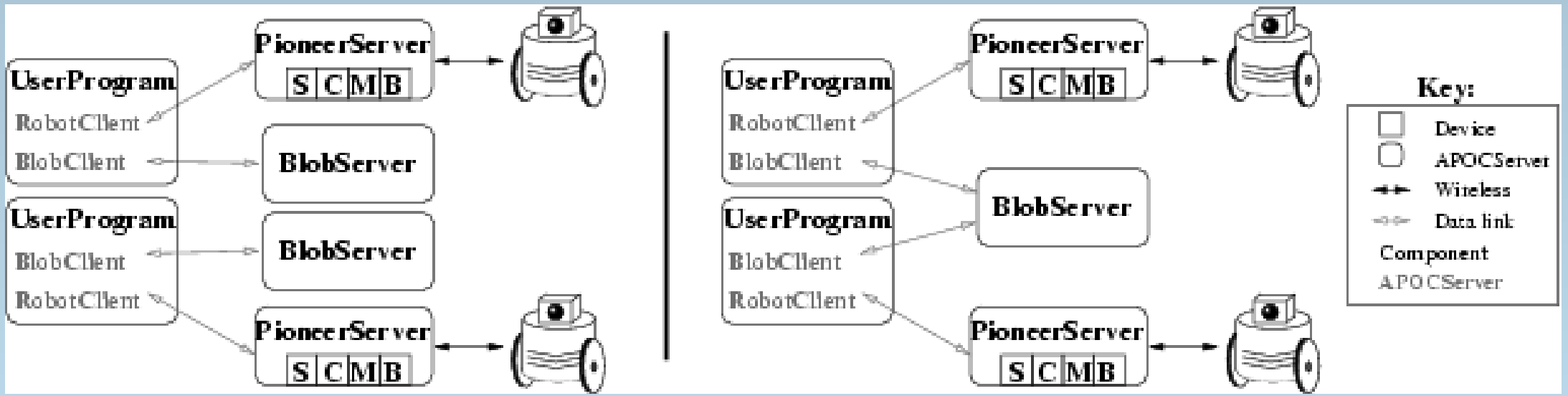




Generic and specific ADE setup for a distributed robotic architecture using one registry and various servers



MAS Aspects: Multi-Robotic Setup

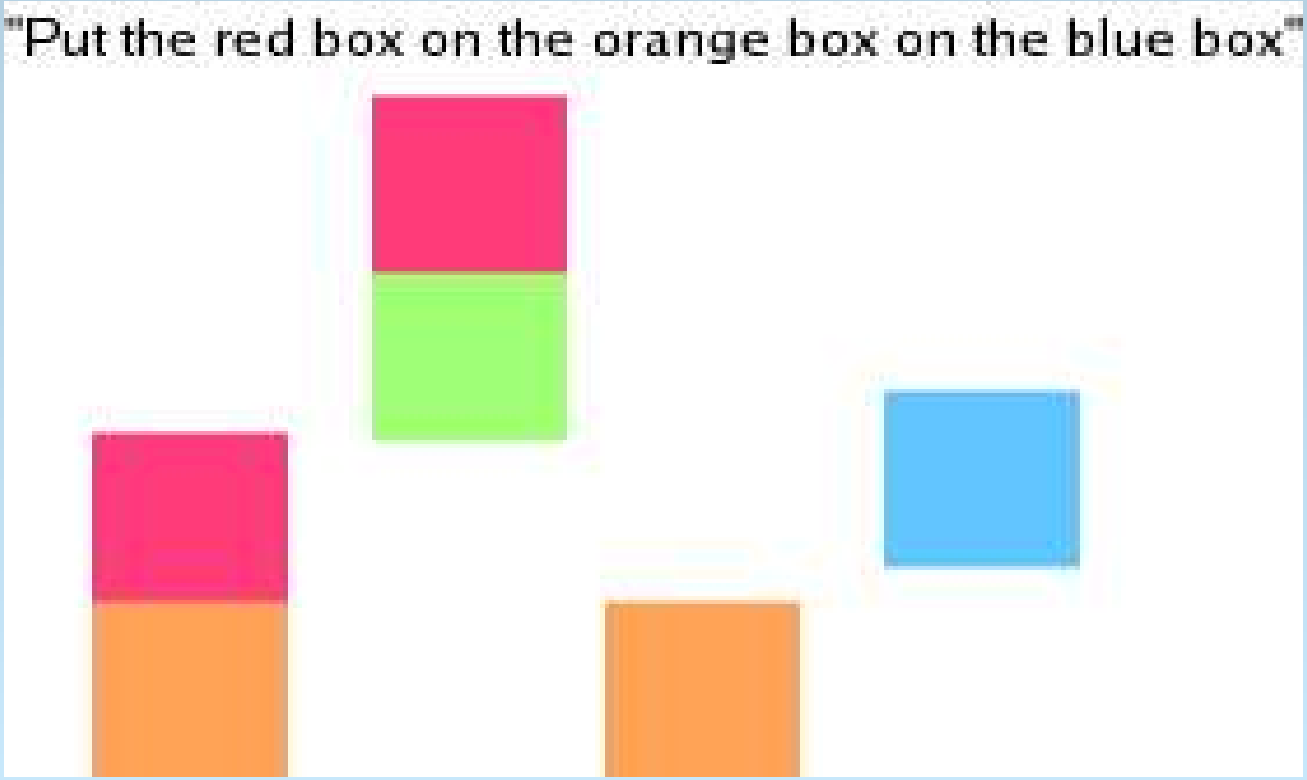


ADE setup for a distributed robotic architecture for tracking using two instances of the *BlobServer* for color blob detection

ADE setup for a distributed robotic architecture for tracking using one shared instance of the *BlobServer* for color blob detection

Example: Human Reference Resolution

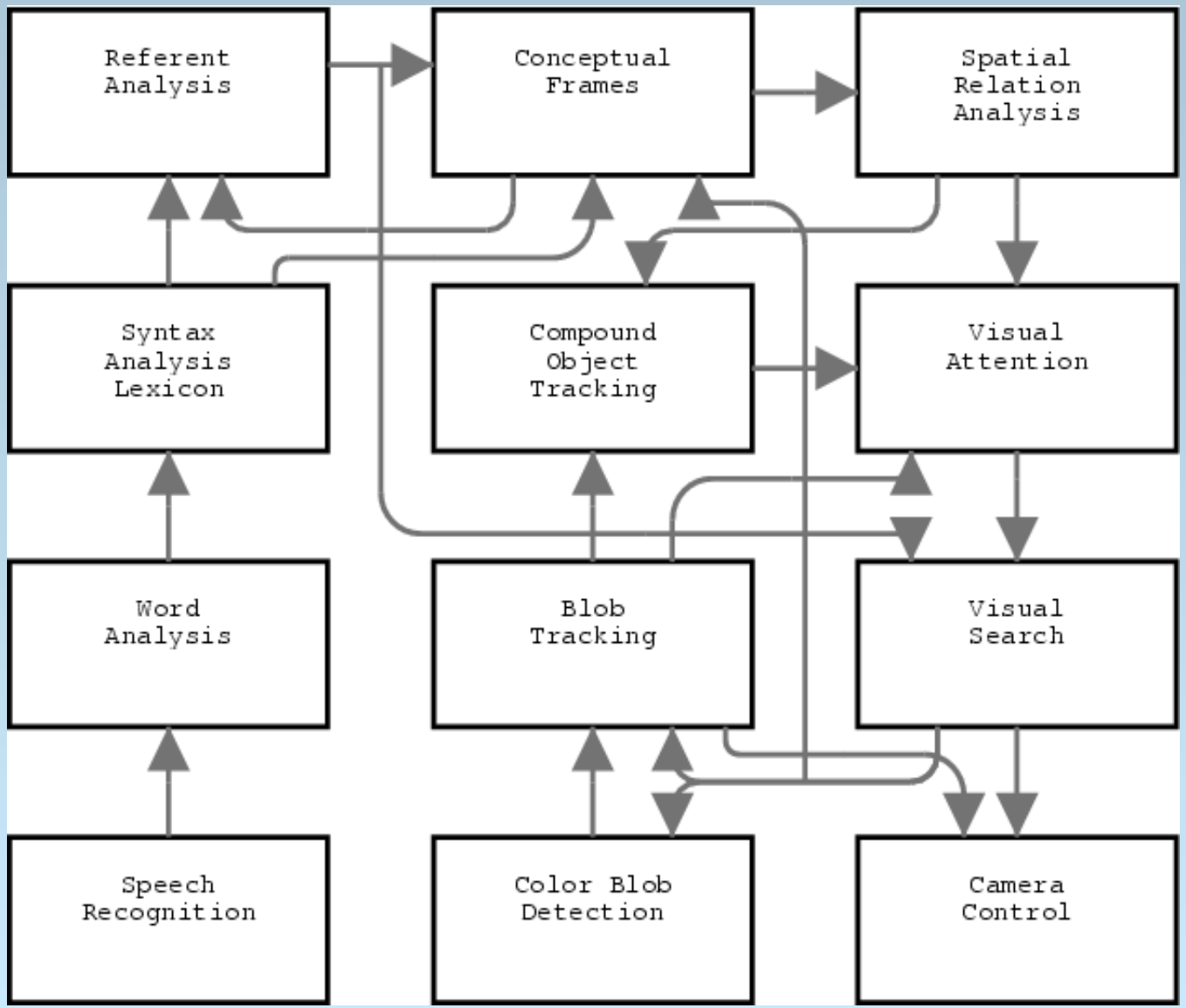
- Model in real-time the processes in humans when they try to make sense of ambiguous spoken sentences like this using visual cues:



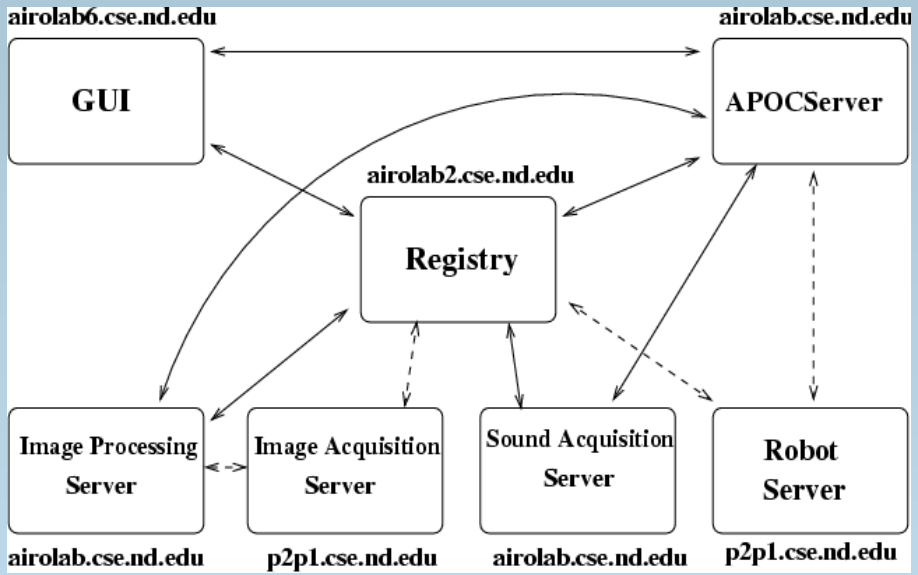
Human Reference Resolution: Processing Architecture

High-level view of the processing architecture:

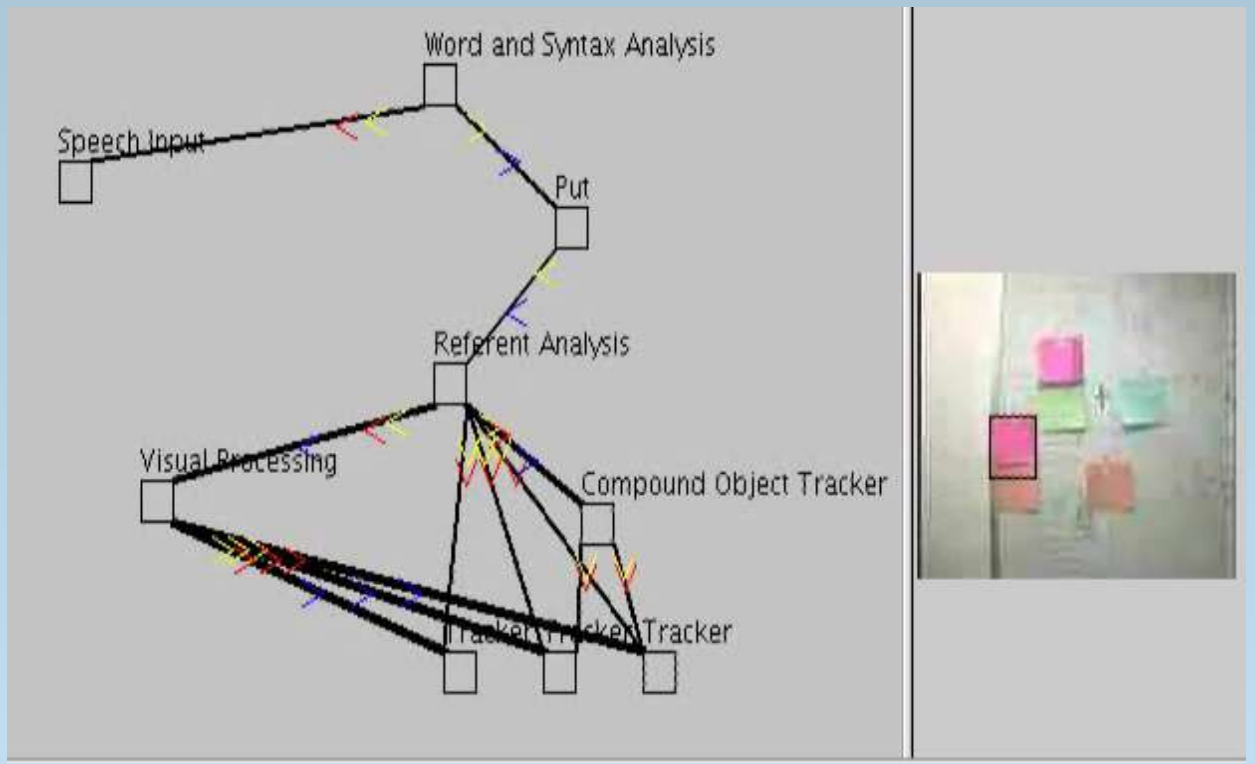
- boxes depict components that are active in parallel
- arrows represent flow of information through the architecture)



In ADE ...



- 4 hosts (including robot)
- dashed lines are wireless
- solid lines are ethernet
- mixed Solaris/Linux



- C-links (yellow)
- A-links (blue)
- O-links (red)

Camera View

Attention Box

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Status Quo and Future Work

- First prototype ready, so far used
  - for several research projects ("ND Hexapod", "People Tracking", "Multi-robot ball following", "Hybrid agent architectures", etc.)
  - for teaching (CSE 498F "Behavior-based Robotics" in Spring 04)
- More debugging, monitoring, and testing tools (+ GUI) in the works (+ better support for real-time control)
- More architectures to be translated in APOC, which will then be available in ADE (e.g., SOAR, ICARUS)
- Implementation of ADE on special, highly parallel PIM hardware (currently in prototype phase at ND)

References to Our Recent Work on Agent Architectures

- Andronache, V. and Scheutz, M. (2004) "Integrating Theory and Practice: The Agent Architecture Framework APOC and its Development Environment ADE" In *Proceedings of Autonomous Agents and Multiagent Systems 2004*.
- Scheutz, Matthias (2004) "The APOC Framework for the Comparison and Evaluation of Agent Architectures". *Proceedings of AAAI 2004 Workshop on Intelligent Agent Architectures.*
- Scheutz, Matthias (2004) "APOC - An Architecture Framework for Complex Agents". In Darryl Davis (ed.)*Visions of Mind*. Idea Group Inc.
- Andronache, Virgil and Scheutz, Matthias (2003) "Growing Agents - An Investigation of Architectural Mechanisms for the Specification of 'Developing' Agent Architectures". In *Proceedings of FLAIRS2003*, AAAI Press, 22-26.
- Andronache, Virgil and Scheutz, Matthias (2003) "APOC - a Framework for Complex Agents". In *Proceedings of AAAI Spring Symposium 2003*, Standford, AAAI Press, 18-25.
- Sloman, Aaron and Scheutz, Matthias (2002) "A Framework for Comparing Agent Architectures". In Proceedings of UKCI'02, 169-176.
- Scheutz, Matthias and Andronache, Virgil (under review) "Architectural Mechanisms for Dynamically Modifiable Behavior Selection Strategies in Behavior-Based Systems".
- ADE can be downloaded from `http://www.nd.edu/~airolab/software`