Multi-agent approach to control

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- Escaping from hardware layout
- Multi-agent modularity
- Agent-space architecture
- Indirect communication
- Data flow many:many
- Time validity
- Implicit sampling
- Data packages
- Subsumption and priorities
- Comparison with iConnect
- Integration of traditional AI
- An example

Future of control

- Structure of control is exclusively implemented by software

  However:

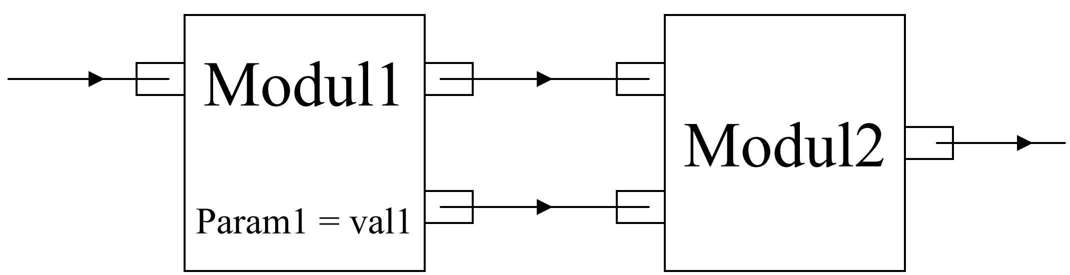
- Layout of the software modules still mimics hardware layout

  Question:

- Can we imagine more sophisticated and profitable layout ?

Traditional control

- modules have fixed number of inputs, outputs and parameters
- one output is linked to several inputs
- transformation of inputs to outputs is performed by a scheduler and it is often uninterruptible



Multi-agent modularity

- An alternative solution is application of multi-agent modularity which turns modules to agents and links to communication among them
- In this way we give to control system the same modularity as typical for distributed and decentralized systems

Multi-agent system example

- Typical example: robot-soccer

Multi-agent system

- It would be too difficult to write a program which controls all the players.
- It is much easier to code programs for individual players and let the team control to emerge from their interaction
- Such interacting programs are called agents

Decentralization

Such solution is decentralized:

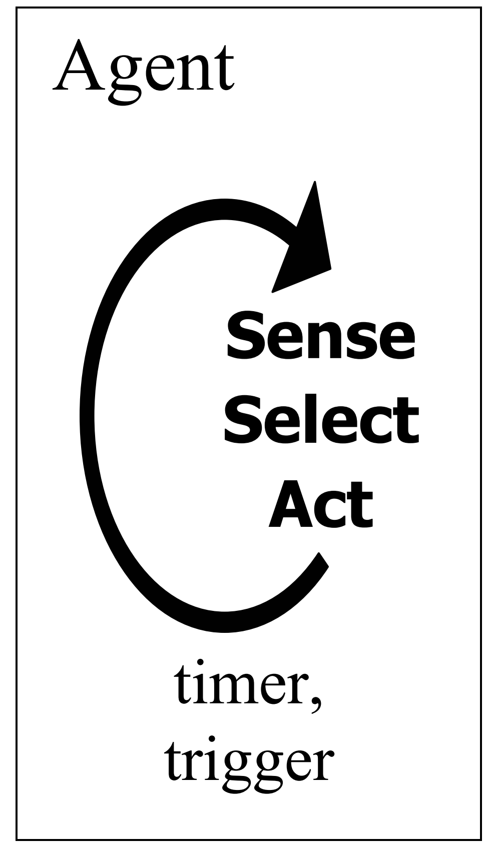
- for example, if we remove midfielder from the team, striker does not stop (endlessly waiting for a pass from the removed midfielder), just probably scores a goal less frequently. Even if the striker never got a pass, he is still moving and ready to shoot ball whenever it is available to him.

Nature of agents

- agents can be implemented as objects equipped with an own thread of control and a mechanism of a mutual data exchange including sensation and action of the system environment

Nature of agents

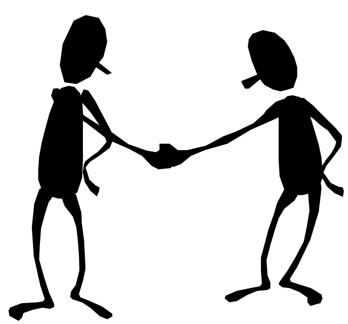
- each agent is endlessly running a sense-select-act cycle. Any course through this cycle calculates some actions upon information sensed from environment or provided by other agents

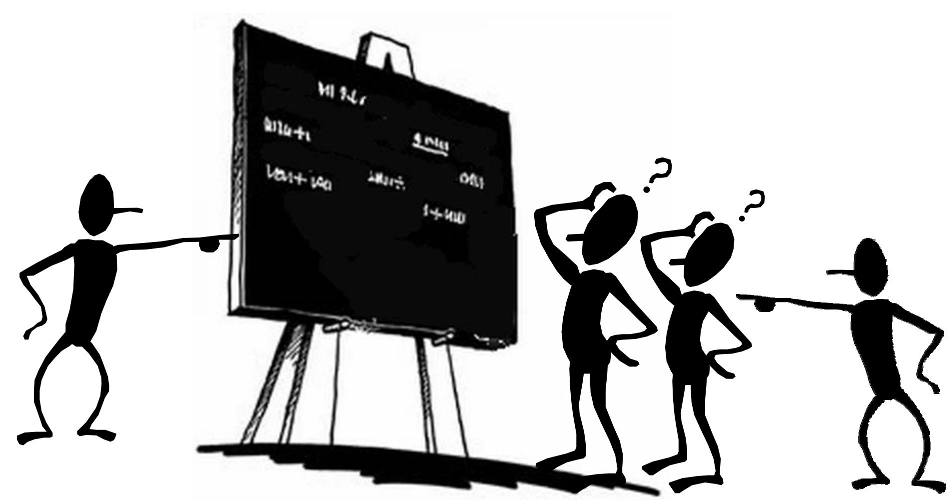


Communication among agents

The communication mechanism can be based on

- direct message passing
- indirect communication through a more or less sophisticated blackboard (called also space)





Back to architecture of control

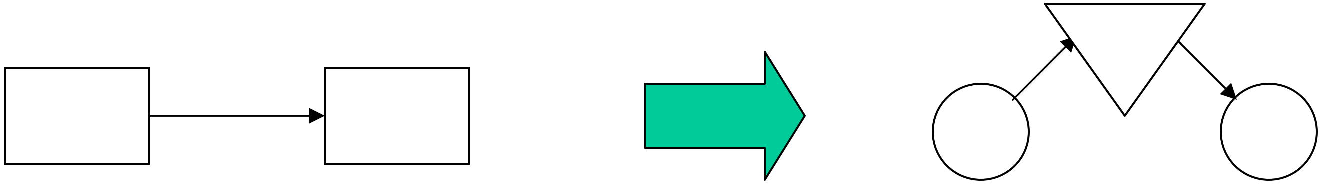
- Can we use the same modularity for implementation of one player ?
  (i.e. on lower level)
- Can we organize internal modules of one player in similar way as cooperating players in the team ?
- Can we use multi-agent modularity for building of control ?

Yes, we can

Agent – Space architecture

We transform:

- modules to agents
- links among modules to indirect communication via blocks in space (on blackboard)



Indirect communication

Agents:

- can read, write or delete particular blocks in space
- know nothing about other agents, just know names and structure of the blocks they manipulates with
- perform their code on timer and/or trigger (a change of selected blocks in space)

Indirect communication

Details of read, write and delete operations are:

- no method for block creation
- reading of non-existing blocks is handled by returning a default value specified by reader
- value stored in block can have a limited time validity specified by writer; after its expiration the block becomes automatically empty
- value stored in block can have a priority specified by writer; such value overwritten only by value with same or higher priority
- space has no knowledge about value meaning; the reader is responsible for correct interpretation

Code example

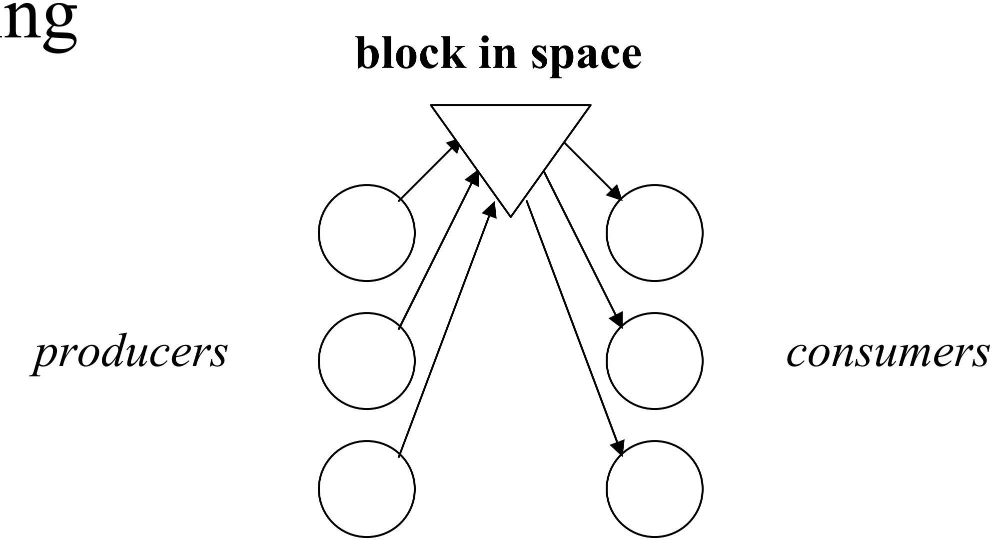
```
package com.microstepmis.agentspace.demo;
import com.microstepmis.agentspace.*;

public class Agent1 extends Agent {

  int i = 0;

  public void init(String[] args) {
    attachTimer(1000);
  }

  public void senseSelectAct() {
    System.out.println("write: "+i);
    write("a",i++);
  }

}
```

```
public class Agent2 extends Agent {

  int i;

  public void init(String args[]) {
    attachTrigger("a");
  }

  public void senseSelectAct() {
    i =  (Integer) read("a",-1);
    System.out.println("read "+i);
  }

}
```

```
public class Starter {
  public static void main(String[] args) {
    new SchdProcess("space","com.microstepmis.agentspace.SpaceFactory",new String[]{"DATA"});
    new SchdProcess("agent1","com.microstepmis.agentspace.demo.Agent1",new String[]{});
    new SchdProcess("agent2","com.microstepmis.agentspace.demo.Agent2", new String[]{});
  }
}
```

Data flow many:many

- each block can be written by many producers and read by many consumers
- consumers do not know how much producers generates the value or from whom the read value is coming

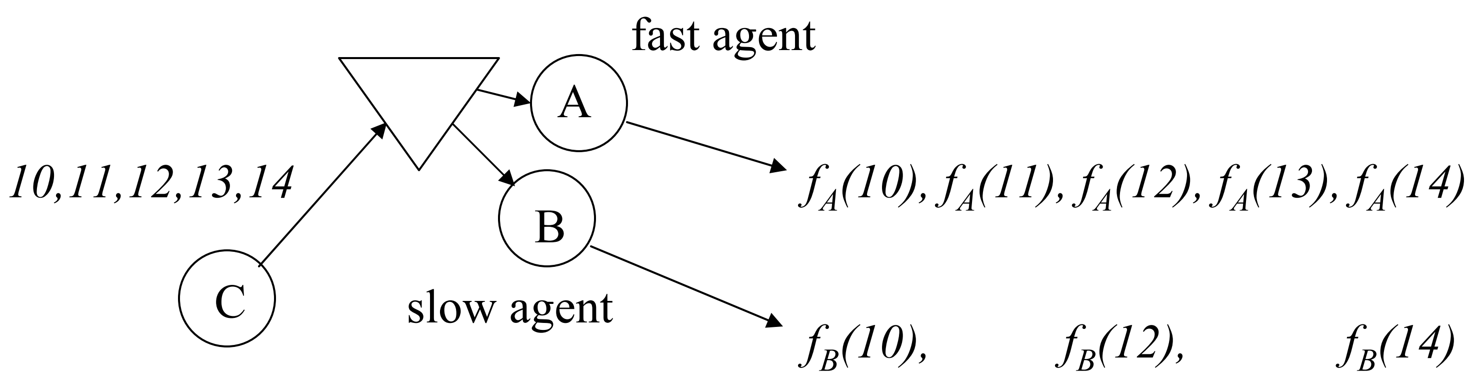


Time validity

- When we have more producers, neither of them can write “bad values”
- Rather such producer does not write a value at all
- But then it can happen that an old value persists in space and it is taken by consumers as valid
- Ideal solution is to define time validity for any written value. After its expiration, the value disappears from space (without agent intervention)
- Thus it can happen that block is empty, so consumer have to handle this state. Ideal solution is to use a default value specified when consumer calls read operation

Implicit sampling

- Since write operation overwrites data stored in a block regardless their consumers have undertaken them or not, any data flow is inherently (potentially) sampled.



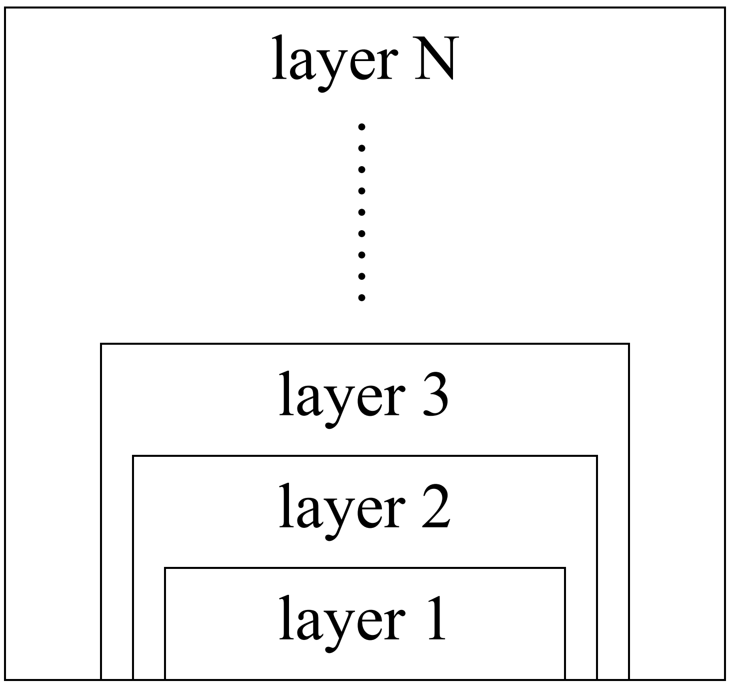
Why no packages

- What to do if data are too frequent to be communicated one by one ? What to do if no data can be lost by implicit sampling ?
- One solution: turn blocks to queues, process data in packages
- Problem 1: not clear semantics of more producers
- Problem 2: more complicated processing (additional loops)
- Solution: Rather special triggers than packages, or multiply blocks

Soft crash landing

- each agent can be restarted without impact on system operation, mainly if they have no inner state (rather they can have analogical information in space)
- thus we can easily to add subsystem which starts crashed agents again and thus provide recovery from errors
- (each application specific code is concentrated in agents, space is independent from application domain)

Subsumption



- a design principle of control which mimics simplified biological evolution
- any complex control has an origin in a simpler ancestor
- descendant mechanism subsumes the mechanism of its ancestor
- higher levels rather inhibit and regulate than active the lower levels

Subsumption

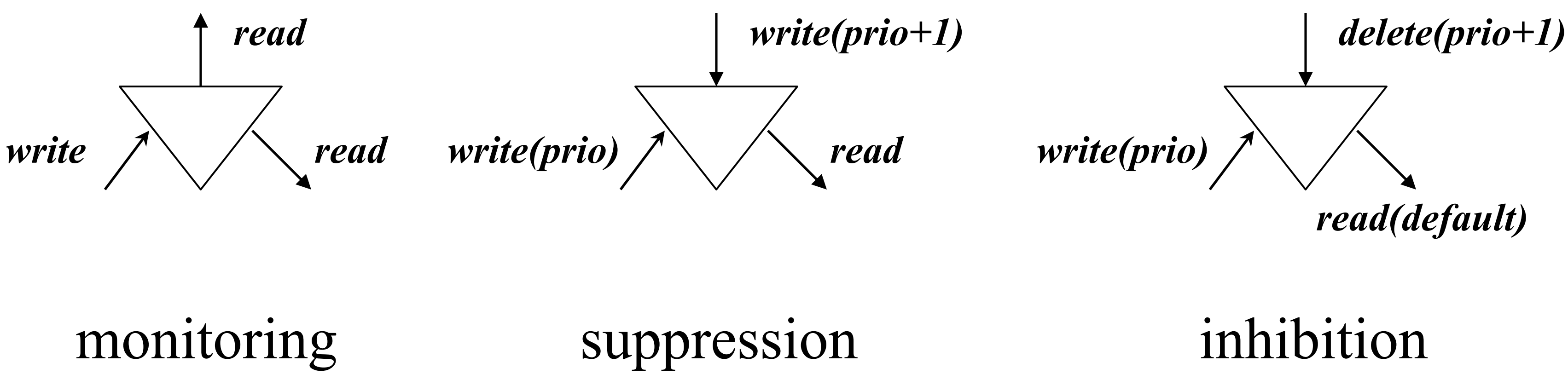
Question: How could the newer levels influence the older ones? The older levels have been designed for particular use and have no interfaces for future development!

Answer: they have to have modular structure which enables it !

Solution: concept of indirect communication is suitable to provide that

Priorities

- However, blocks need to be associated also with priorities



Integration of traditional AI

Agent modularity

- perfectly separates codes of modules
- enables to integrate slow modules into the system

Thus it is suitable to integrate slow cognitive structures on higher levels which subsumes fast but just reactive processing on lower levels

- reinforcement learning
- neural networks
- rule-based systems

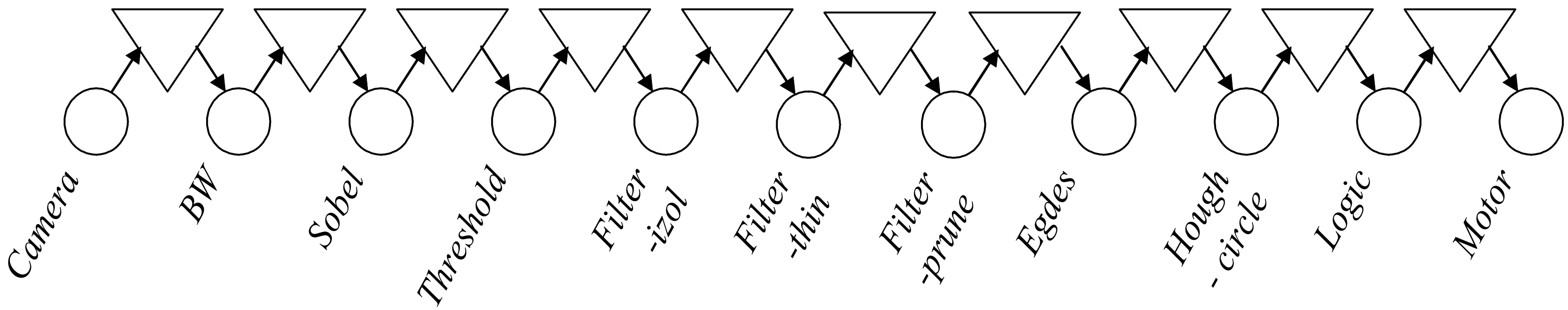
Comparison to iConnect

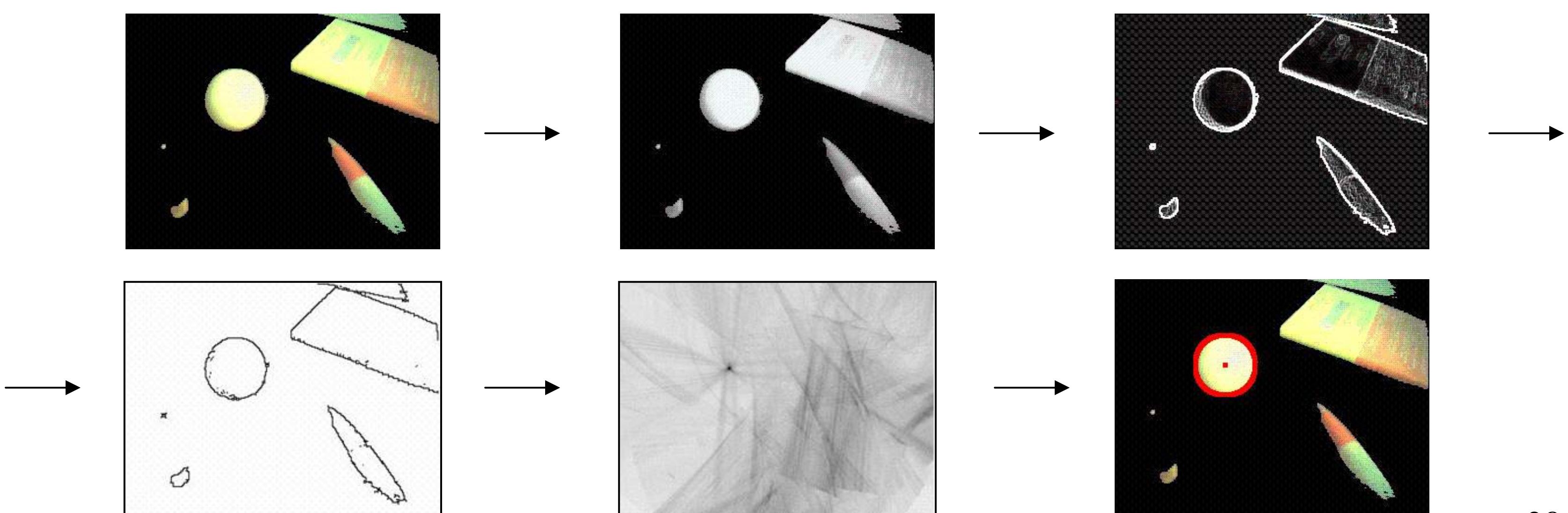
Agent (or several agents)	SignoGraph
Real-time, combining slower with faster - OK	Real-time, combining slower with faster - OK
Block	MultiCom
No data packages	Data packages only
Implicit sampling	Explicit sampling
Time validity of data	Timestamp only
More producers of block, priority	Multiplexer, ?
Recovery from errors	?
Any data structures	Arrays of basic types

An example

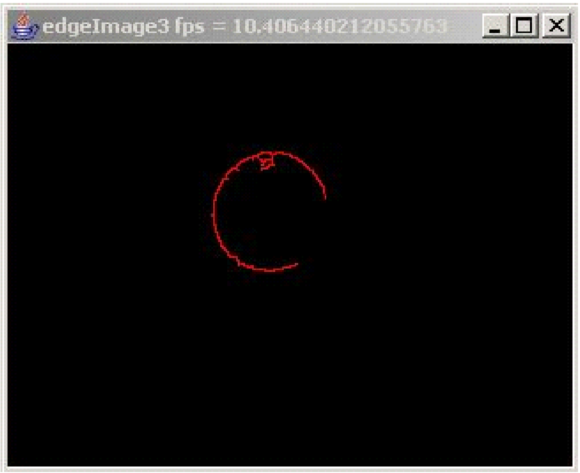
A mobile robot following a ping-pong ball

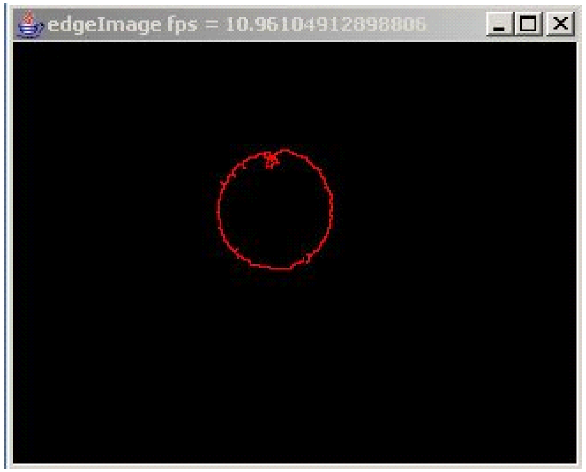
Traditional pipeline

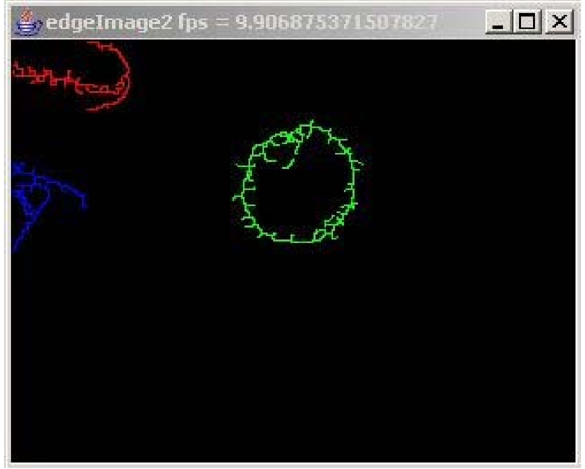




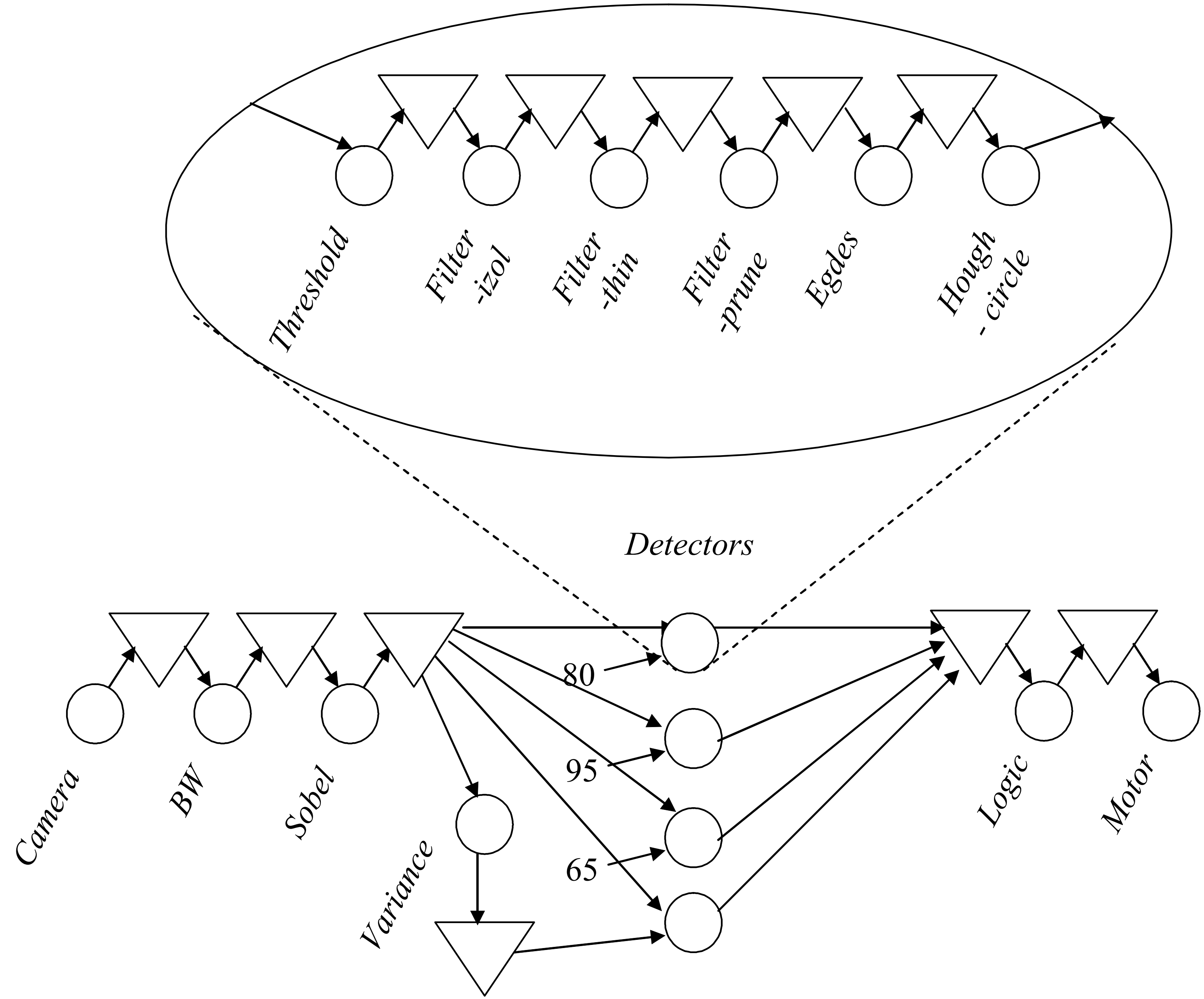
Competition among more thresholds



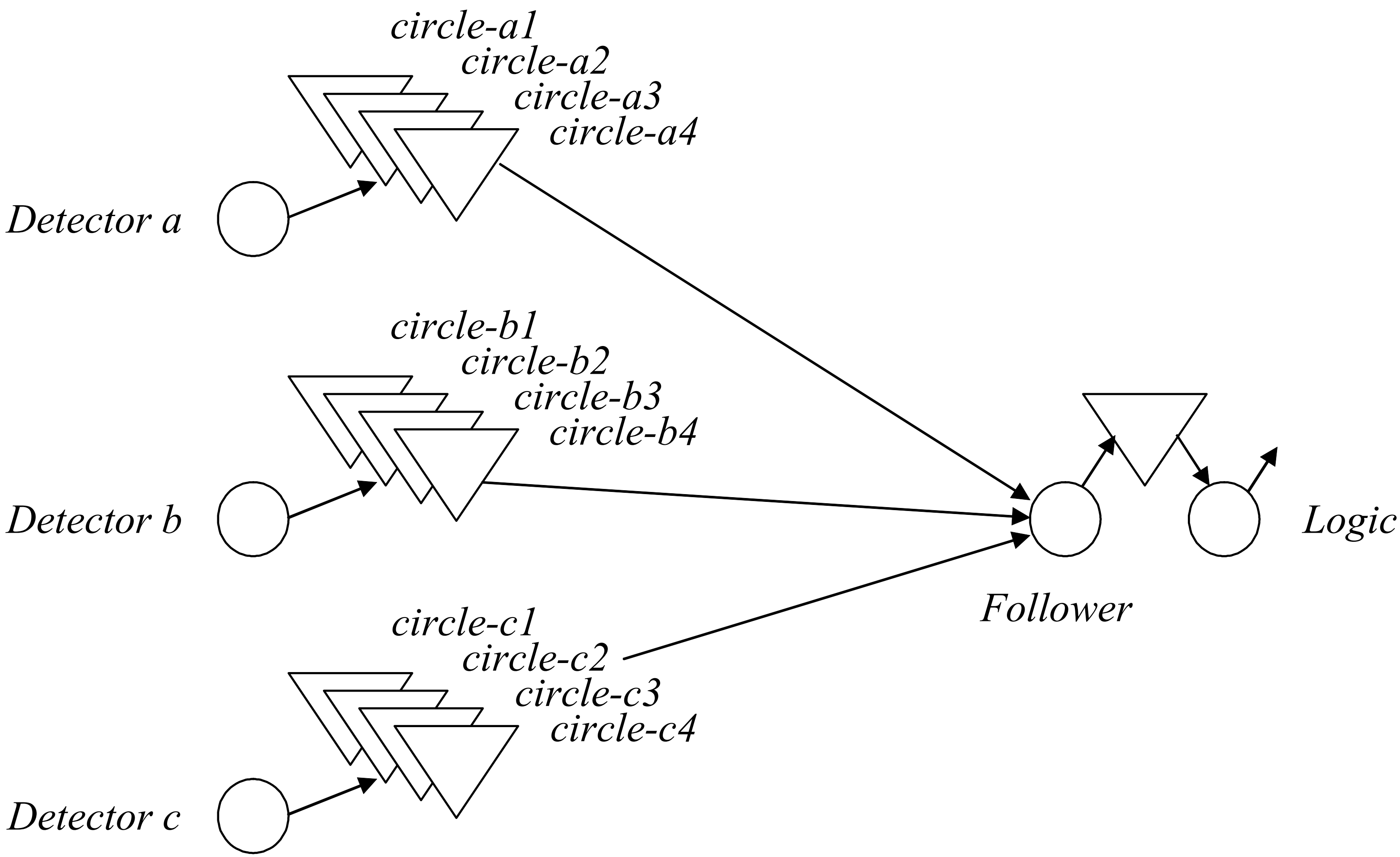




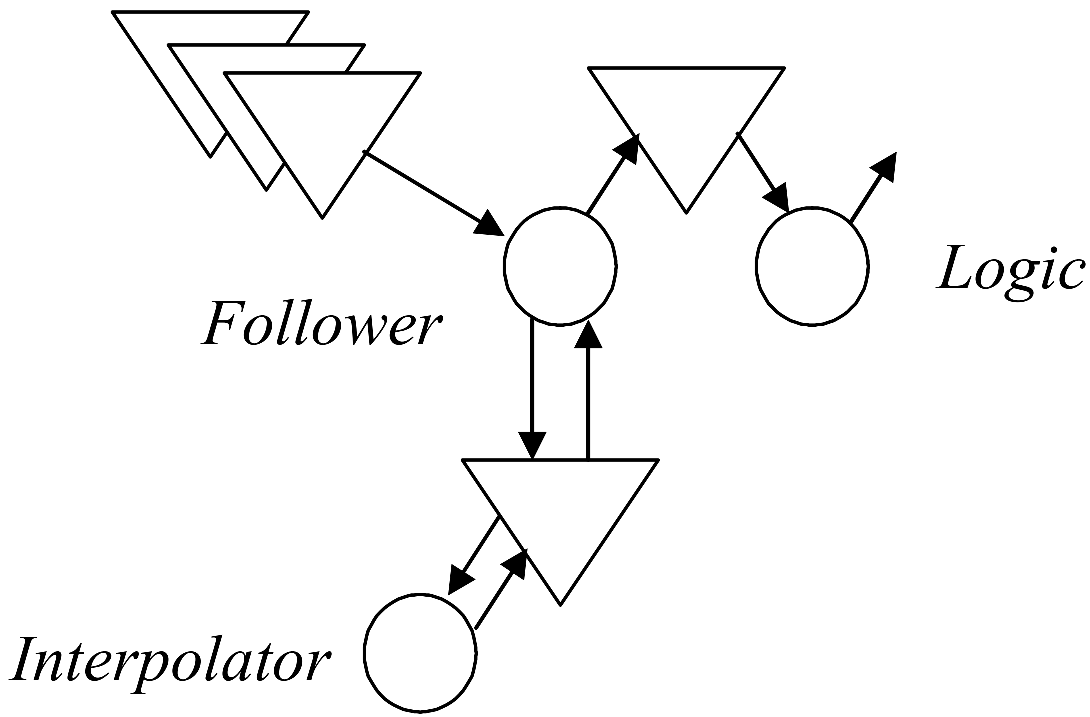
pseudo-optimal threshold calculation



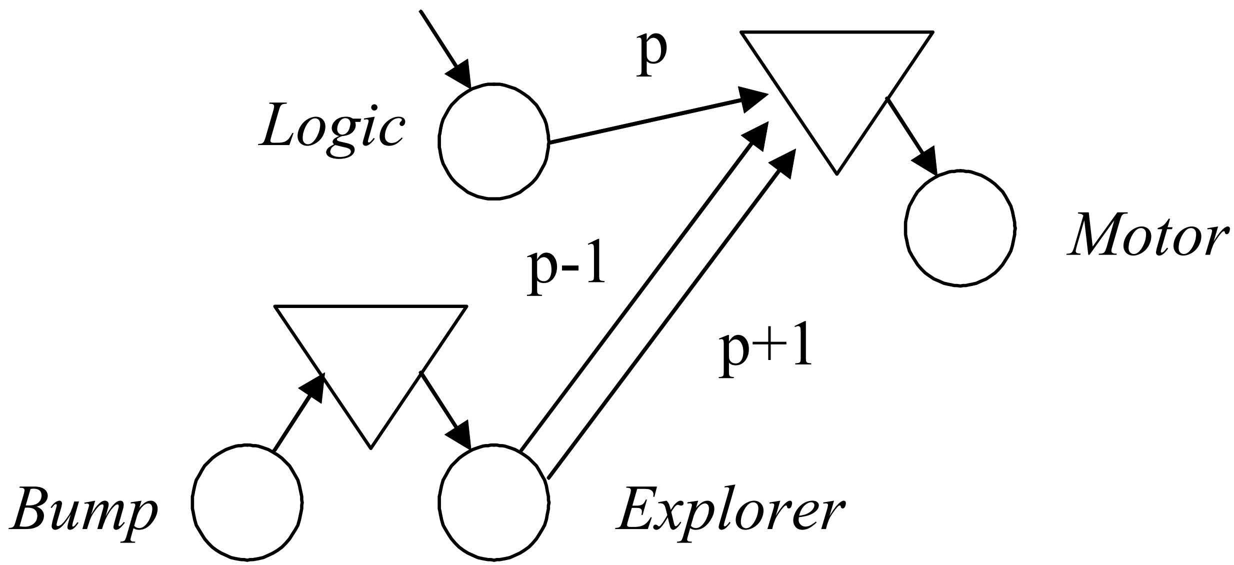
more balls in scene



concentration on particular ball protected to occlusion



combining ball following with obstacle avoidance (looking for a ball when no ball is present)



Thank you for attention!

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