Tuple Centre Spread over the Network (TuCSoN)

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Outline

Coordination Meta-model [Ciancarini, 1996]

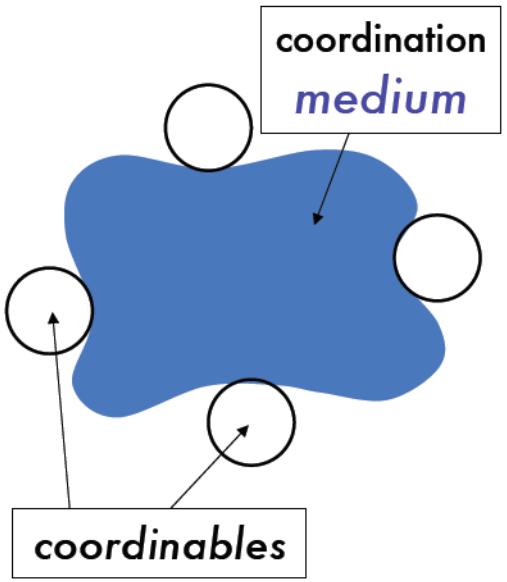
- Interaction is one of the main sources of complexity in the software system engineering

→ Coordination is the activity of managing/costraining the interactions occurring dynamically among software components

→ Coordination models and languages are a set of approaches for the engineering of a system interaction space based on the following abstractions:

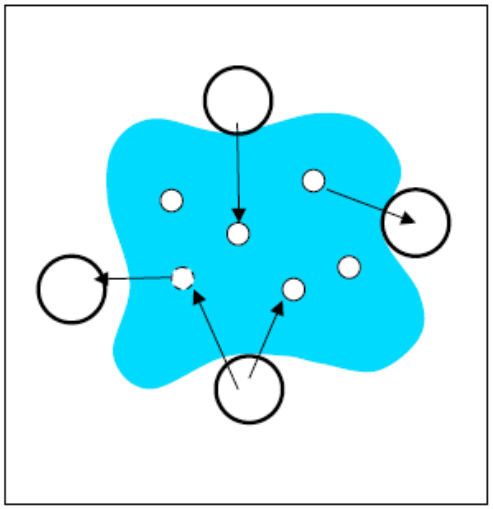
  - Coordination media enabling interaction among
  - coordinables – system components to be coordinated – by means of suitable
  - coordination laws

and on communication languages – syntax used to express and exchange data structures – and coordination languages—linguistic embodiements of the coordination model

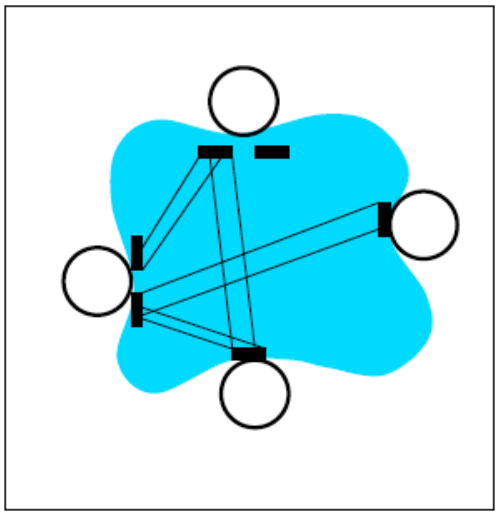


Data vs. Control Driven [Papadopoulos and Arbab, 1998]

- Data/information-driven models
  - Coordinables synchronise, cooperate, compete by accessing, consuming and producing information available in the *shared data spaces*



- Control-driven models
  - Coordinables synchronise, cooperate, compete by generating and reacting to signals/events in ports connected by *channels*



Data-driven Models [Papadopoulos and Arbab, 1998]

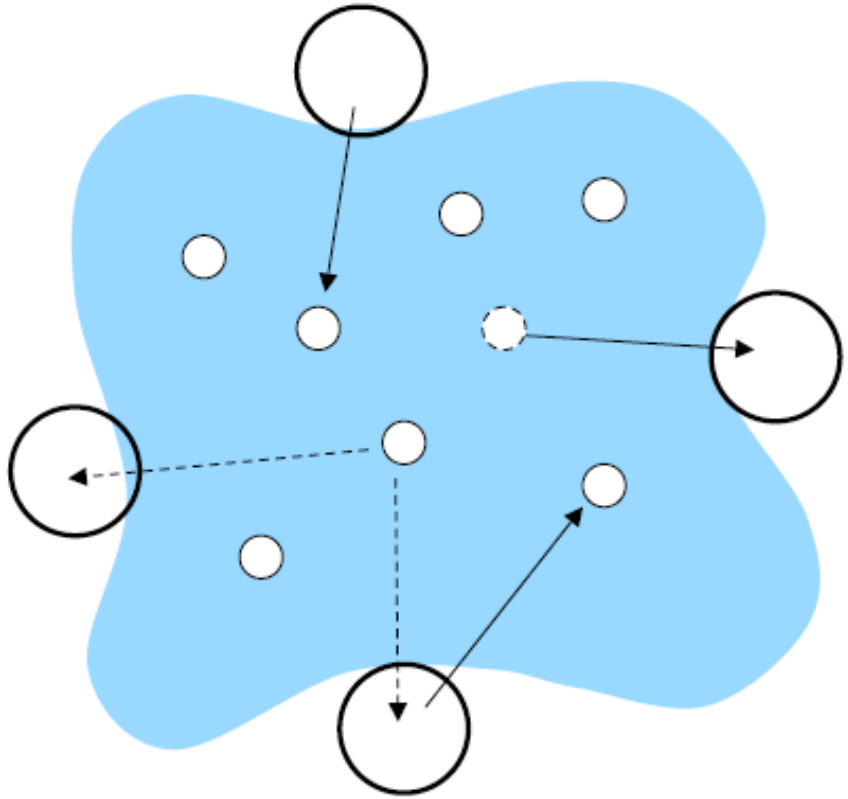
- Almost all coordination models belonging to this category have evolved around the notion of a shared data-space [Roman and Cunningham, 1990]
- A shared data-space is a common, content-addressable data structure. All processes involved in some computation can communicate among themselves only indirectly via this medium

$\Rightarrow$ Data-driven models seems to be suitable for open applications, where a number of possibly a-priori unknown and autonomous entities have to cooperate

$\Rightarrow$ Data-driven models better fit our application scenario than control-driven ones

A Notable Example: The Tuple Space Model

- Coordination medium: Tuple Space
  - Multiset/bag of data objects/structures called tuples
- Communication Language: Tuples
  - Tuple = ordered collection of (possibly heterogeneous) information items
- Coordination Language: set of operations to put and retrieve associatively tuples to/from the space



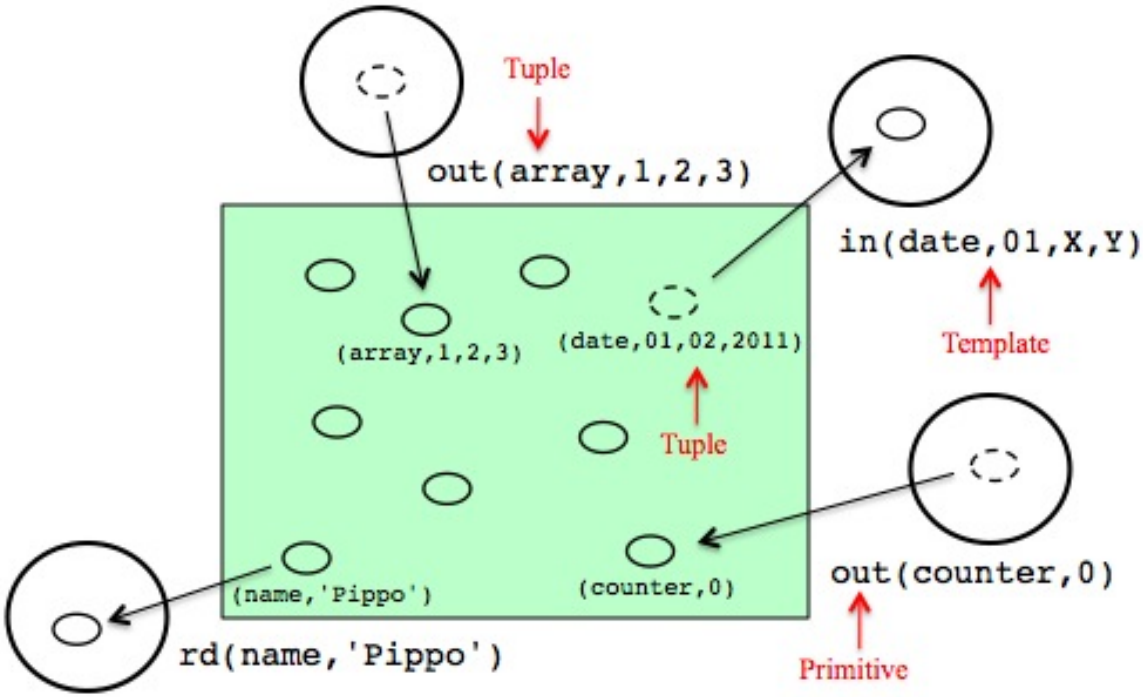
Linda Coordiantion Language [Gelernter, 1985a]

- A coordination language is the materialisation or the linguistic embodiment of a coordination model [Gelernter and Carriero, 1992]
  - ⇒ It offers syntactical means with which a coordination model can be used for implementing an application
- Linda is a coordination language for shared tuple space coordination model
- Communication Language
  - Tuple, Templates (anti-tuples), and Tuple Matching
- Coordination Primitives
  - `out(T)`
    - ⇒ Puts in the space the tuple `T`
  - `in(TT)`
    - ⇒ Removes from the space a tuple matching the template `TT`
  - `rd(TT)`
    - ⇒ Reads (without removing) from the space a tuple matching the template `TT`

Linda Features

- Generative communication [Gelernter, 1985b]: tuples are permanently written in a tuple space
  - * Promotes communication uncoupling—name, space and time uncoupling
  - → Supports openness in distributed systems
- Associative access: in order to read/consume a tuple, a tuple set description has to be specified
  - * Promotes knowledge-based coordination
  - → Fits well with knowledge-intensive systems

Example


Tuple
out(array,1,2,3)
in(date,01,X,Y)
Template
(array,1,2,3)
(date,01,02,2011)
Tuple
(name,'Pippo')
(counter,0)
out(counter,0)
rd(name,'Pippo')
Primitive

Outline

Tuple Centre Spread over the Network (TuCSoN) [Omicini and Zambonelli, 1999]

- Infrastructure providing services enabling the communication and coordination of distributed/cuncurrent independent software components (agents)
- It is based on programmable tuple spaces called tuples centres [Omicini and Denti, 2001]
- Each tuple centre provides the following primitives:

out to put the specified tuple in the specified tuple centre

in to remove a tuple matching with the specified template from the specified tuple centre

rd to read a tuple matching with the specified template from the specified tuple centre

inp to remove, if present, a tuple matching with the specified template from the specified tuple centre (if not present, the operation fails)

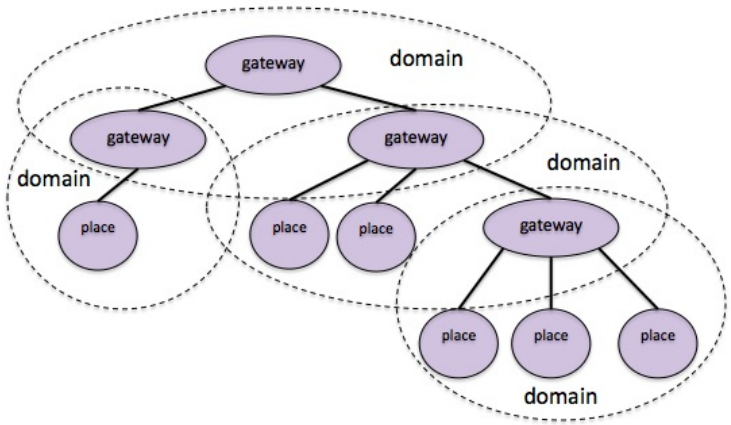
rdp to read, if present, a tuple matching with the specified template from the specified tuple centre (if not present, the operation fails)

Tuple Centres Features

- Programmable
  - Tuple centre behaviour can be programmed to enact the desired coordination policies
  - $\Rightarrow$ Tuple centres as a general purpose coordination media customisabled
- Locality/encapsulation
  - Tuple centres embed coordination laws
  - $\Rightarrow$ A tuple centre can be a full-fledged coordination abstraction
- Inspectable at runtime
  - Tuple centre behaviour can be inspected dinamically, at runtime
- Adatable at runtime
  - Tuple centre behaviour can be changed/adapted dynamically, at runtime, by reprogramming the coordination media
- Uniformity of languages
  - Same structure/primitives for communication and coordination

The TuCSoN Topology [Cremonini et al., 1999]

- Tuple centres are distributed over the network hosted in nodes and organised into articulated domains
- A domain is characterised by
  - a gateway node that is meant to host tuple centres used for domain administration, keeping information on the places ($ORG tuple centre)
  - a set of nodes called places, where a place is meant to host tuple centres for the specific applications/systems



- TuCSoN is an infrastructure for Internet environment
  - It is possible to access to remote tuple centres identifying them by means of their complete identifier:

    <Tuple Centre Name> @ *<Tuple Centre IP Address>*

    Examples:

    temperature@'137.204.192.175'

    temperature@'deis.unibo.it'

    temperature@localhost

The TuCSoN Organisations

- Tuple centres are structured and ruled in organisations mapped in domains
- Agents can be thought as a sort of society (permanent or temporal) with a specific objectives
- An organisation can be conceived as a static as well as dynamic set of societies
- Such societies are composed by agents playing some roles
- Organisations modelled through the RBAC model [Omicini et al., 2005]

The TuCSoN Context

- We call context *the physical/virtual and social situation in which an agent is situated* [Moran and Dourish, 2001]

  ⇒ In open world agents need some form of context awareness in order to interact with a system (other agents and resources) [Mamei and Zambonelli, 2006]

- When an agent enters in a new context, the system should provide it with a sort of control room that provides agents with context awareness [Omicini, 2002]
  - Is the only way in which the agent can perceive the system as well as ...
  - ... the only way in which the agent can interact

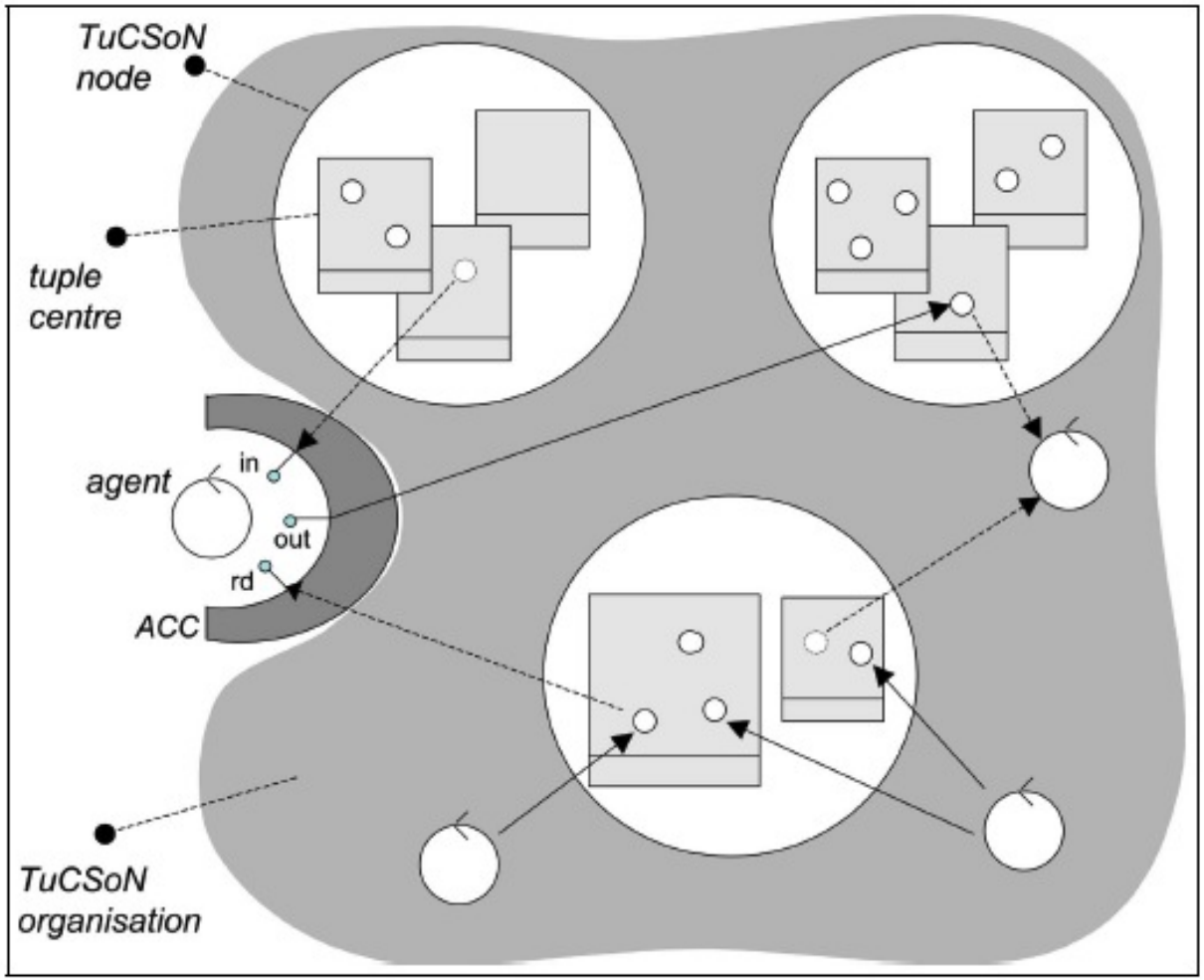
⇒ While the system manages social coordination, the control room manage coordination of the particular agent

⇒ It is possible to scale with openness of modern software systems

The Agent Coordination Context (ACC) [Omicini, 2001]

- Each TuCSoN organisation defines a coordination context, providing an open/dynamic set of tuple centres as coordination media
- Each agent has its own view of the context that is called Agent Coordination Context (ACC)
  - Works as a model for the agent system, by describing the system where an agent can interact
  - Enables and rules the interactions between the agent and the system by defining the space of the admissible agent interactions
- In order to access and use the tuple centres of a domain, an agent must
  - negotiate the ACC in order to start a working session inside an organisation, specifying which roles to activate
  - use the ACC to interact with the system by exploiting the actions enabled by the ACC

The TuCSoN Coordination Model



Outline

TuCSoN Technology

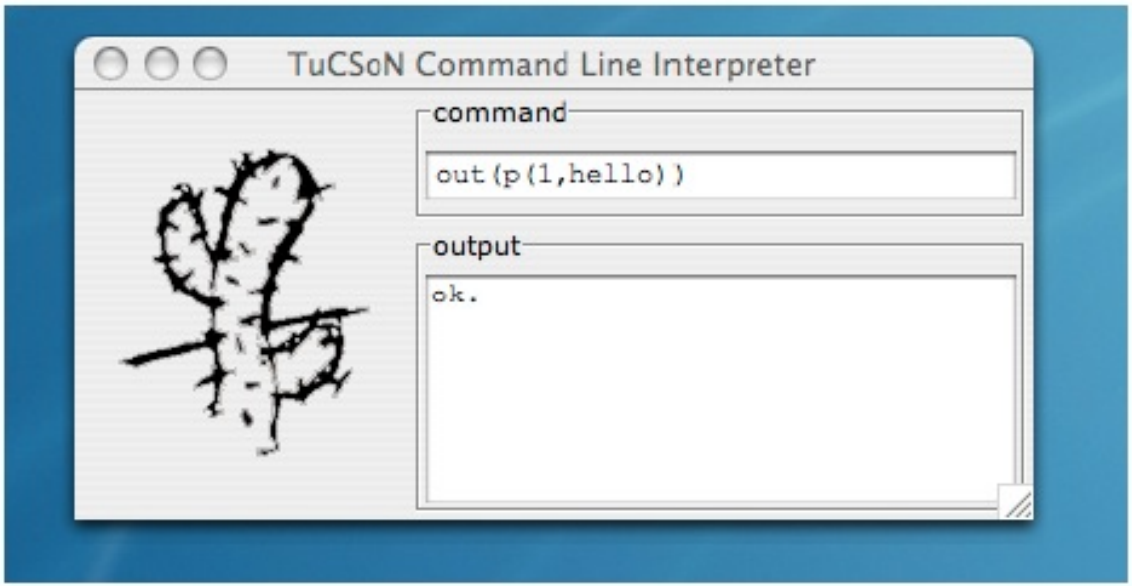
- TuCSoN API
  - Virtually any hosting language, currently Java and Prolog
    - $\Rightarrow$ Support for Java and Prolog agents
  - Heterogeneous hardware support
- TuCSoN Service
  - Booting the TuCSoN Service daemon
    - ★ The host becomes a TuCSoN node
    - ★ With current version (1.9.1) run: `alice.tucson.service.Node`

TuCSoN Tools

- TuCSoN Tools
  - Inspector
    - ★ Fundamental tool to monitor tuple centre communication and coordination state, and to debug tuple centre behaviour
    - ★ With current version (1.9.1) run: `alice.tucson.tools.Inspector`
  - TuCSoN Shell
    - ★ Shell interface for human agents
    - ★ With current version (1.9.1): `alice.tucson.tools.CLIAgent`
- TuCSoN technology is freely available in `http://alice.unibo.it/xwiki/bin/view/TuCSoN/`

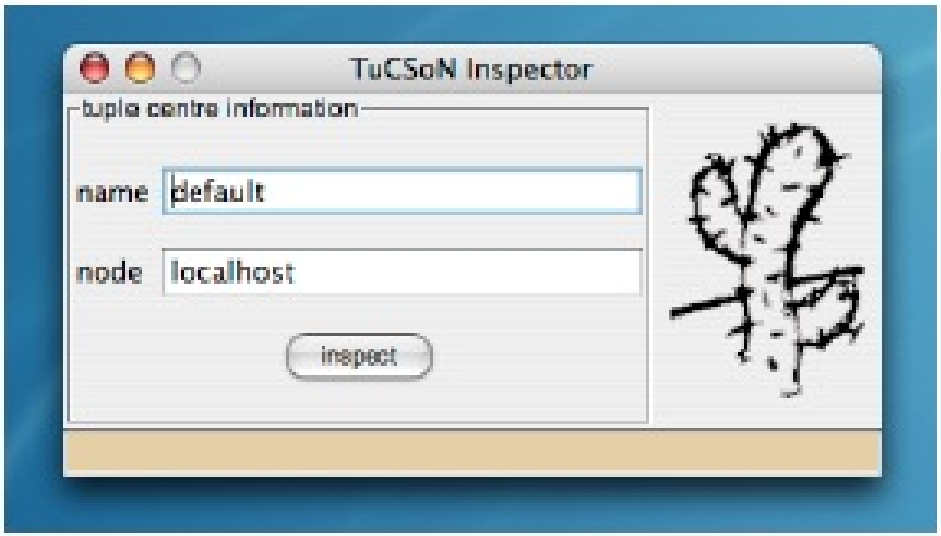
TuCSoN on the Fly: CLI Agent

- Booting a TuCSoN node
- Using the CLIAgent (as a human agent) by exploiting TuCSoN tuple centre default



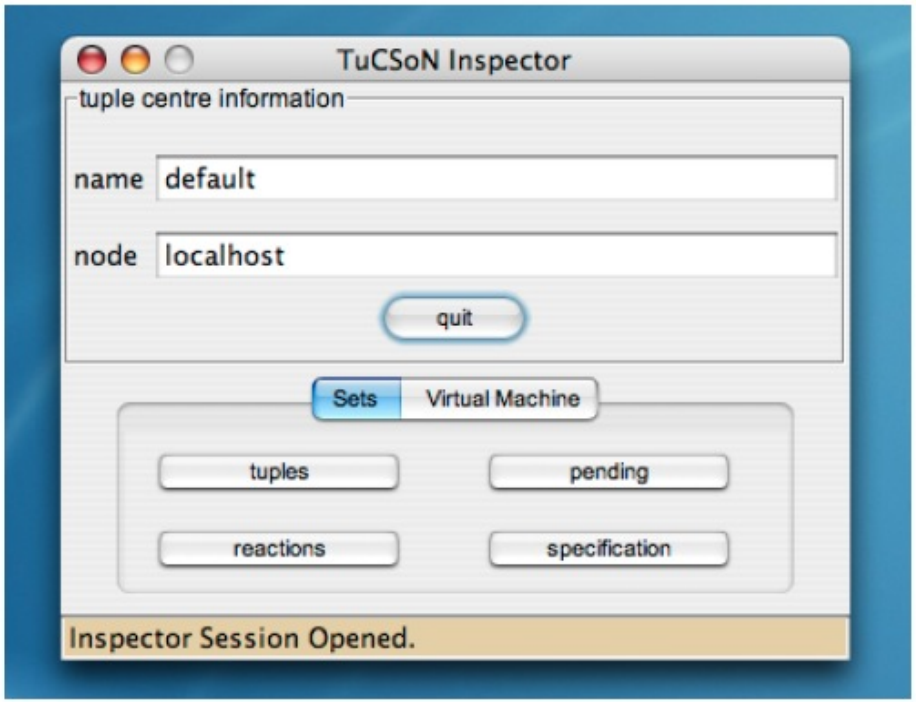
TuCSoN on the Fly: Inspector (1)

- Inspecting and debugging tuple centres by exploiting TuCSoN Inspector



TuCSoN on the Fly: Inspector (2)

- Inspecting and debugging tuple centres by exploiting TuCSoN Inspector



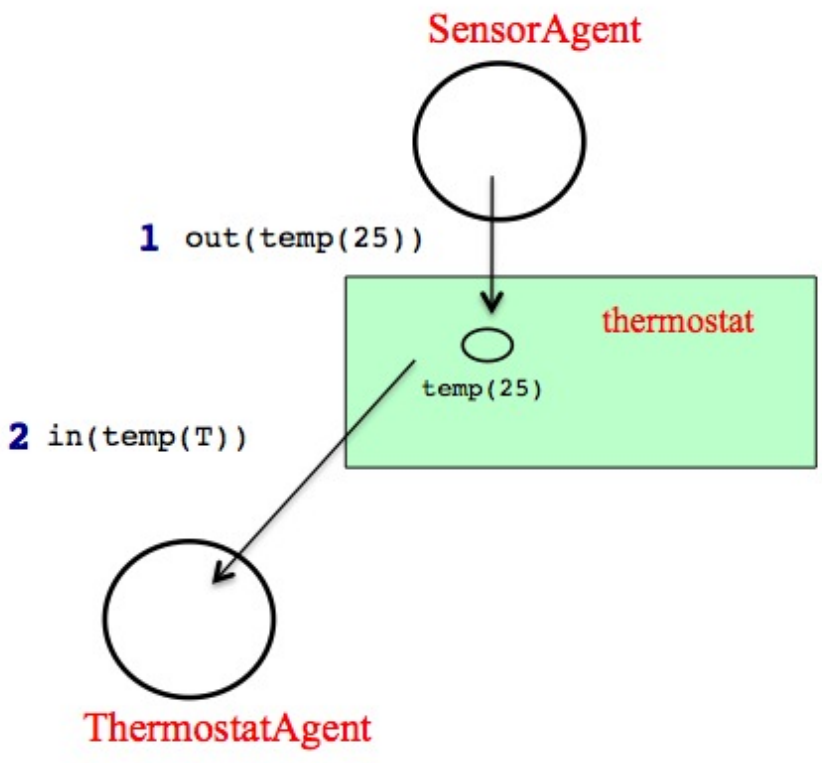
Outline

Exercise 1: 'Hello World' Example

```
package alice.tucson.examples.basic;

import alice.logictuple.LogicTuple;

public class HelloWorld
{
    public static void main(String[] args) throws Exception
    {
        TucsonAgentLanguageManager.useLanguage(TucsonLanguageManager.DEFLANGUAGE);

        TucsonTupleCentreId tid = null;

        if (args.length == 0)
            tid = new TucsonTupleCentreId("default");
            tid = new TucsonTupleCentreId(args[0]);

        TucsonContext cnt = Tucson.getContext(new TucsonAgentId("agent"),
                TucsonAgentLanguageManager.getCurLanguage());

        long now = System.currentTimeMillis();
        LogicTuple tuple = new LogicTuple("msg", new Value("Hello world!"),
                new Value("time", new Value(now)));

        cnt.out(tid, tuple, (Long) null);
        System.out.println("Tuple inserted: " + tuple);

        LogicTuple template = new LogicTuple("msg", new Var("Msg"), new Var("Time"));
        LogicTuple msg = cnt.in(tid, template, (Long) null);

        System.out.println("Tuple retrieved name: " + msg.getName());
        System.out.println("Msg argument: " + msg.getArg(0));
        System.out.println("Time argument: " + msg.getArg(1).getArg(0));
    }
}
```

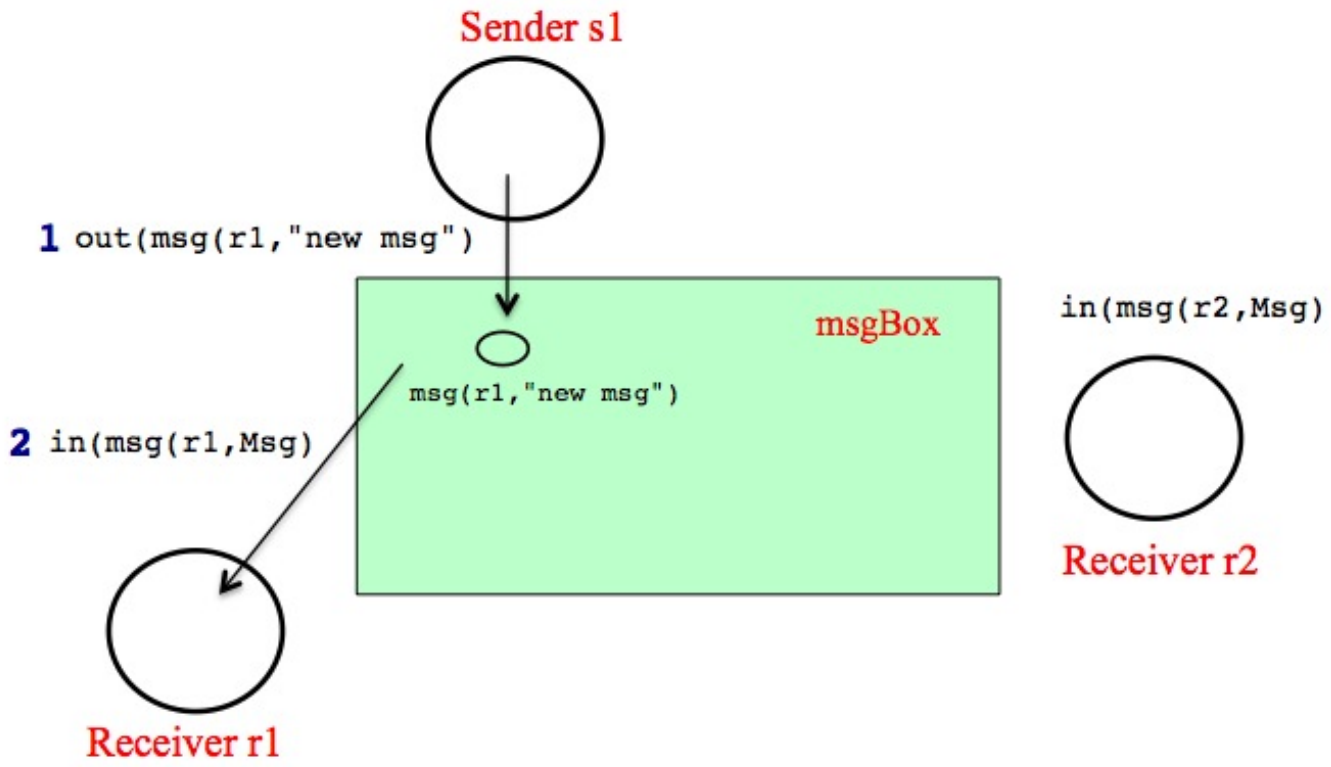
Exercise 2: The Thermostat

- Create the tuple centre thermostat
- Create the agent sensorAgent writing in the tuple centre the sensed external-temperature
- Create the agent thermostatAgent reading the sensed temperature.
  The temperature has to be ≥ 23 and ≤ 26.
  The agent's task is to adapt the external temperature in order to respect the constraint



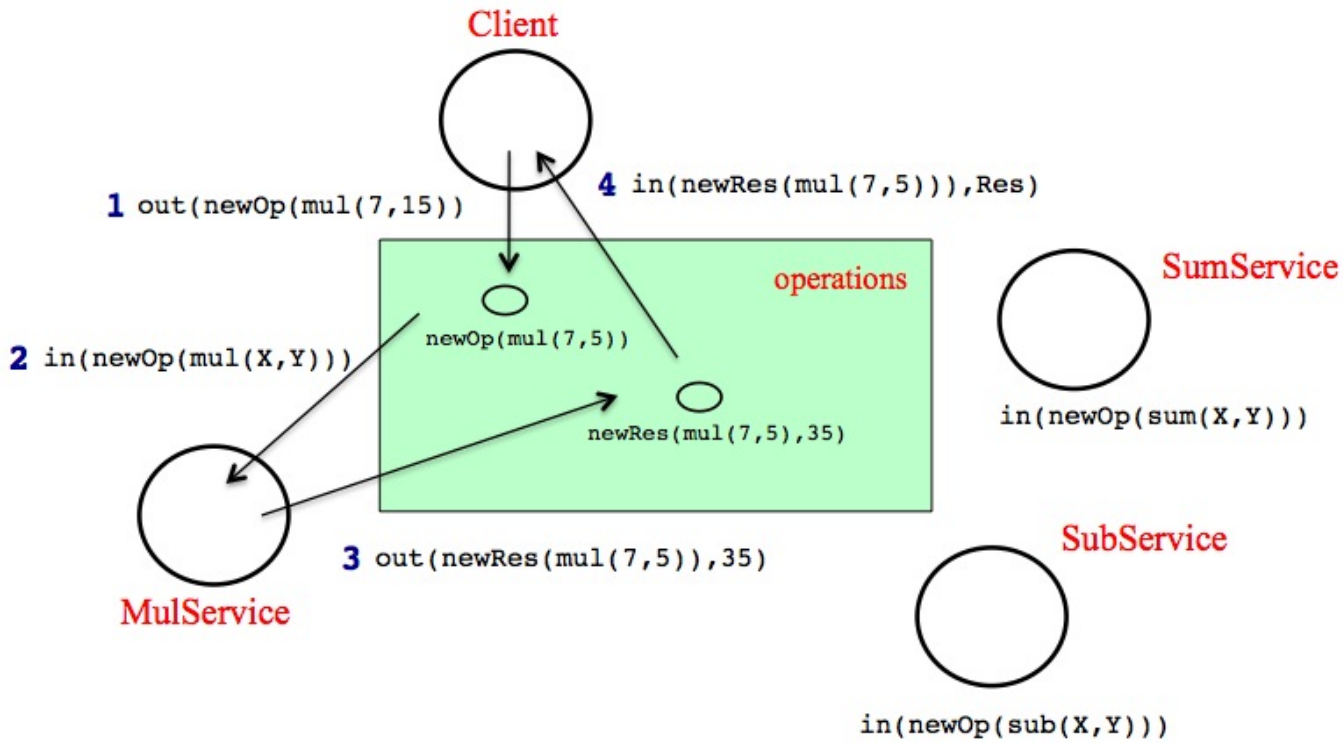
Exercise 3: Message-oriented Communication

- Create the tuple centre msgBox
- Create sender agents
- Create receiver agents



Exercise 4: Remote Procedure Calls and Services

- Create the tuple centre operations
- Create a client agent
- Create a service agent for each kind of operation (sum, mul and sub)



Exercise 5: Exploiting TucsonAgent

- Try to use the alice.tucson.apiTucsonAgent class

Outline

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