# A Prolog Implementation of IndiGolog for Real Robots

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# Talk Overview: 3 parts

- Briefly go over P-IndiGolog, a Prolog implementation of the IndiGolog agent architecture
- Introduce EVOLUTION ER1 robot and explain how it can be controlled using P-IndiGolog
- Explain how to implement the simulated Wumpus World scenario using P-IndiGolog

# Reactive Robotics Architecture

## Headless!

Reactive robots:

given what is currently sensed and (a small amount of internal state), decide on commands to effectors

priority $\uparrow$

$$\begin{array}{l} \langle \text{sense outlet} \wedge \text{power low} \Rightarrow \text{recharge} \rangle \quad \| \\ \langle \text{sense trash} \Rightarrow \text{pickup trash} \rangle \quad \| \\ \langle (\textit{otherwise}) \Rightarrow \text{explore} \rangle \end{array}$$

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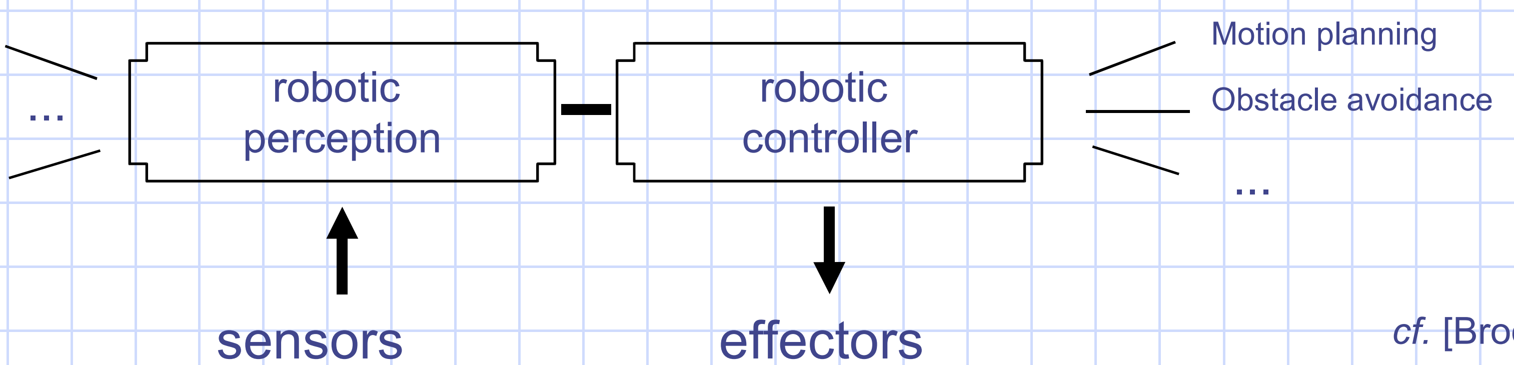
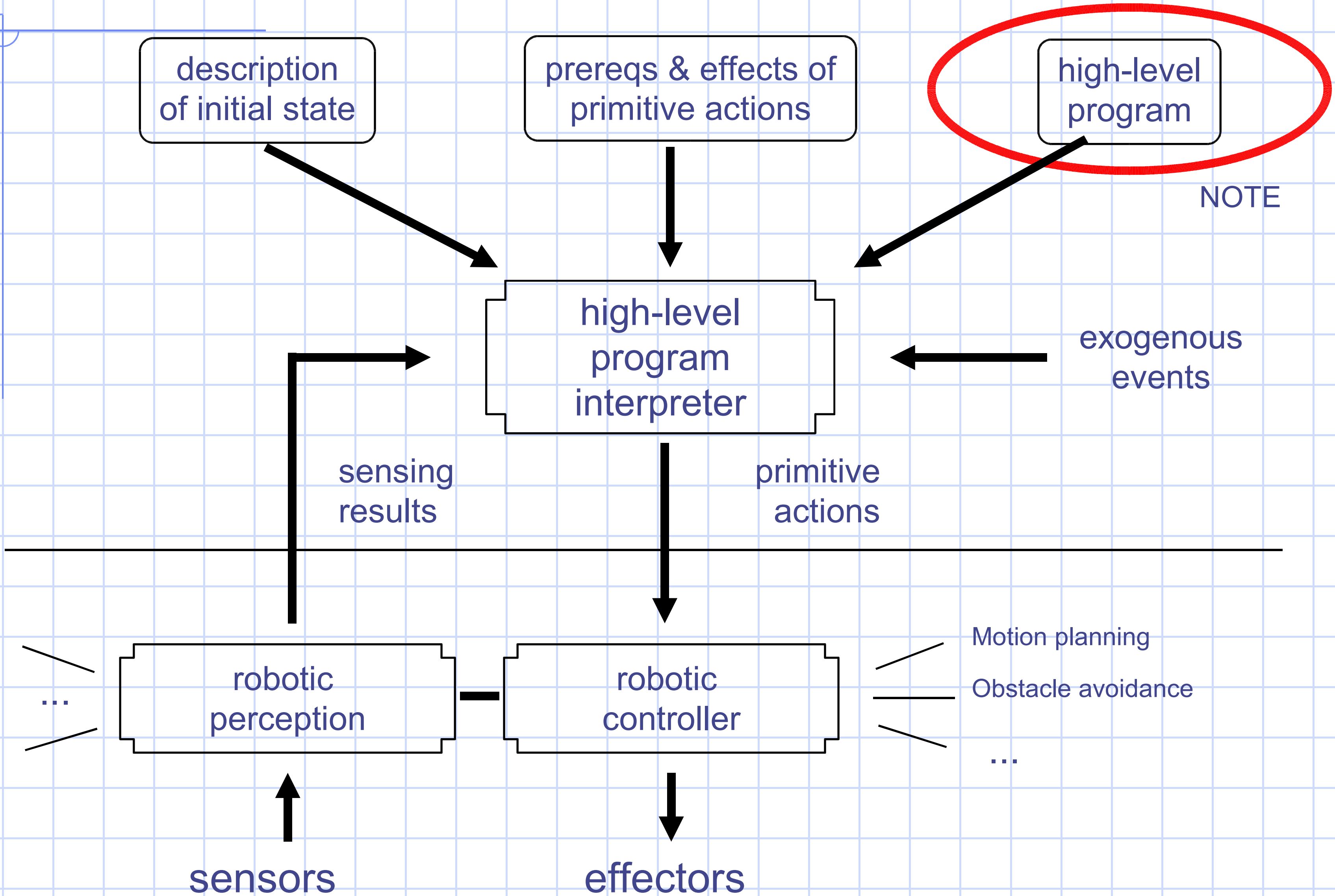



*cf.* [Brooks 86], ...

# Cognitive Robotics Architecture



# P-IndiGolog Overview

- Cognitive Robotics agent architecture implementation
  - Realization of IndiGolog (incremental Golog)
  - Based on LeGolog (LEGO® Mindstorm™ with IndiGolog: by Maurice Pagnucco & Hector Levesque)
  - Completely implemented in Prolog (SWI/ECLIPSE)
- So far, it provides an interleaved framework of
  - Execution
  - Sensing
  - Exogenous events
  - Local planning

# P-IndiGolog Design

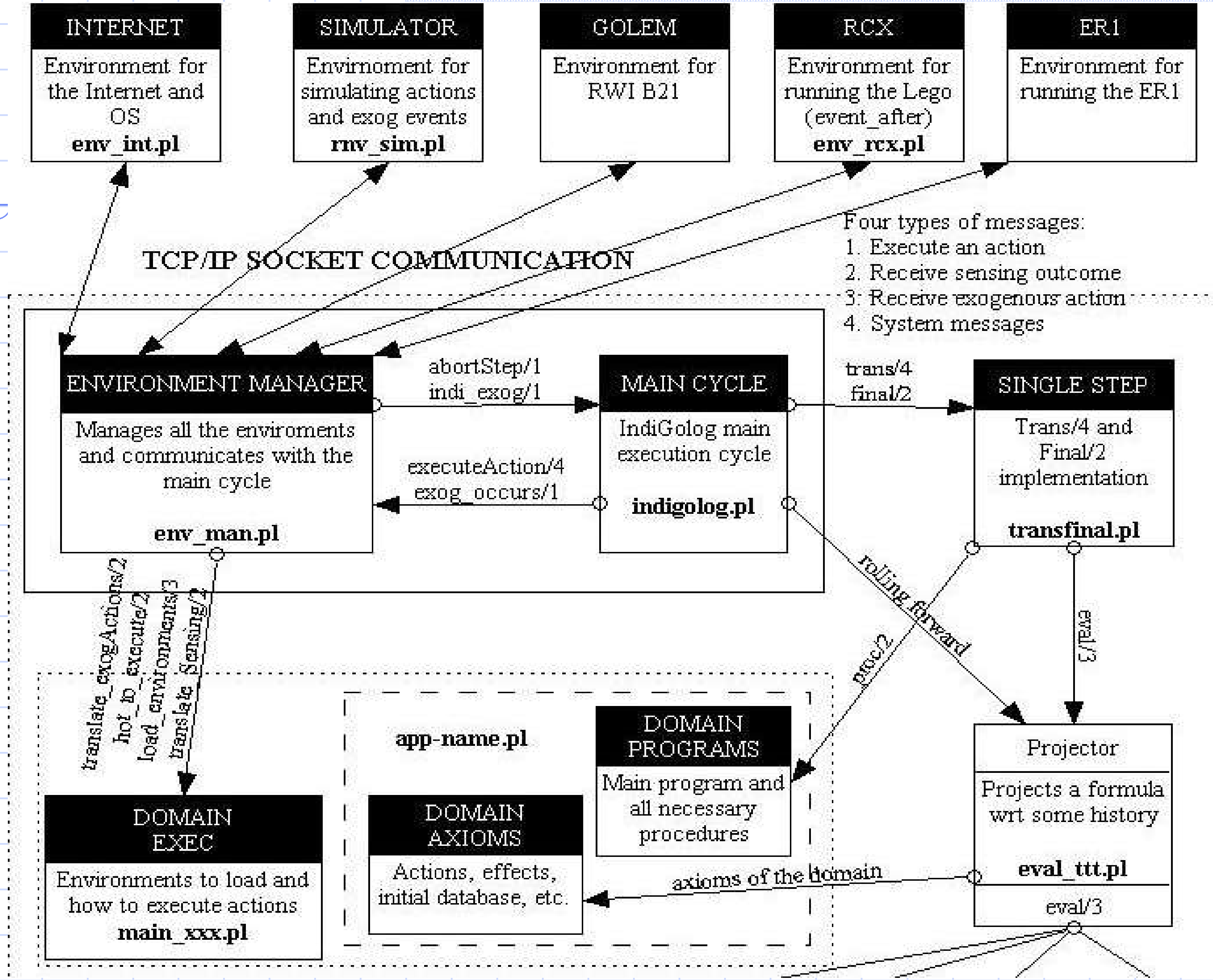
The user/programmer gets to choose:

- The agent programming language (e.g., ConGolog)
  - Define trans/4 and final/2
- The action theory and temporal projector
  - Define eval/3: eval(φ,H,B)
- The external devices/environments used
  - E.g.: specific robot (ER1), simulator, Internet?
- Some other options
  - E.g.: how to handle exogenous events: ignore/abort step?

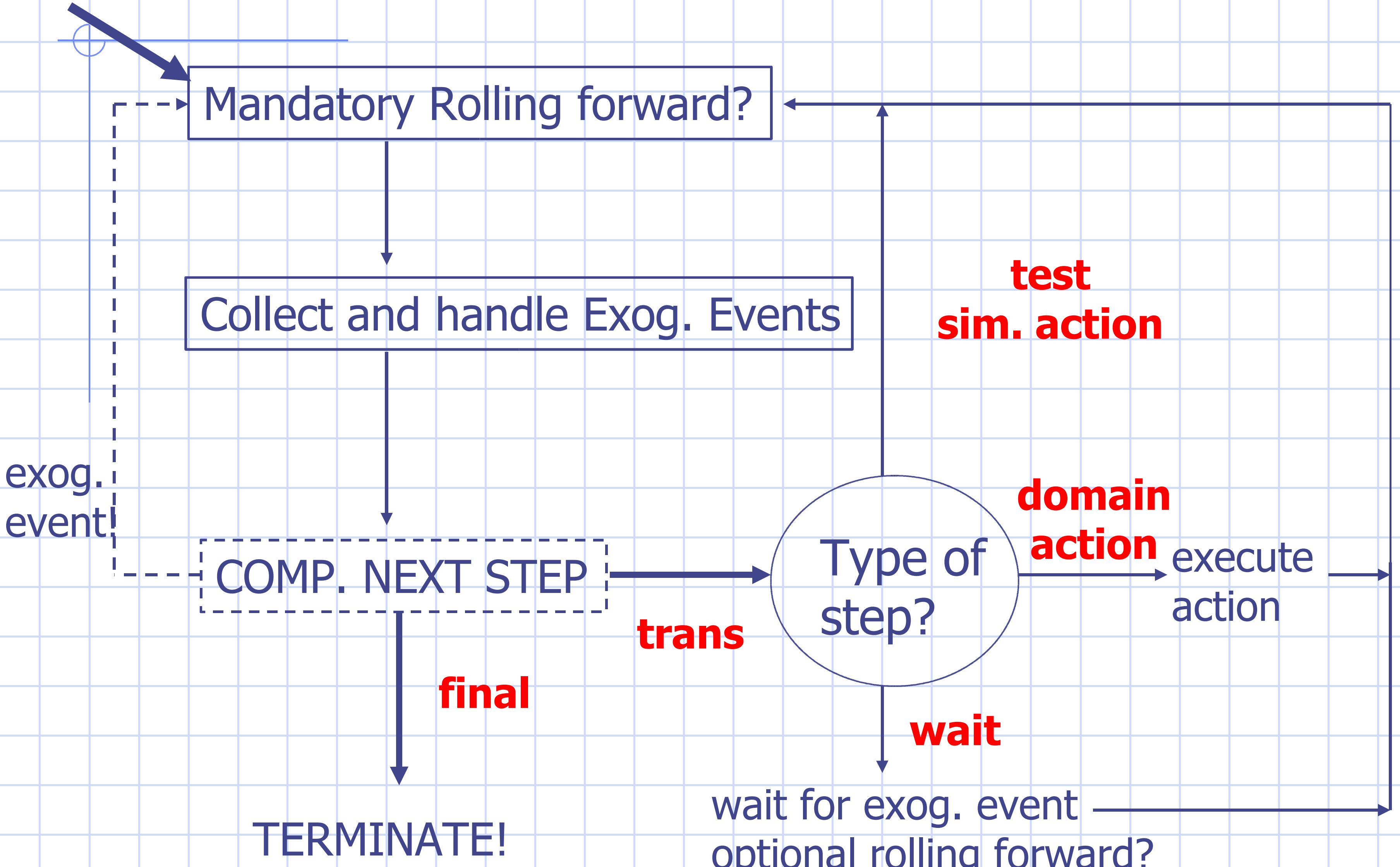
# P-IndiGolog Design (cont.)

It is divided in three main modules:

- Device managers (rcx, er1, web, simulator, etc.)
  - Understands each particular device or external environment
- Main module:
  - Main cycle
  - Environment manager
  - Transition system + temporal projector
- Domain application
  - Theory of action: states the dynamics of the world
  - High-level program: dictates the agent behaviour
  - Domain execution directives


INTERNET
Environment for the Internet and OS
env_int.pl
SIMULATOR
Envirnoment for simulating actions and exog events
rnv_sim.pl
GOLEM
Environment for RWI B21
RCX
Environment for running the Lego (event_after)
env_rcx.pl
ER1
Environment for running the ER1
TCP/IP SOCKET COMMUNICATION
Four types of messages:
1. Execute an action
2. Receive sensing outcome
3. Receive exogenous action
4. System messages
ENVIRONMENT MANAGER
Manages all the environments and communicates with the main cycle
env_man.pl
abortStep/1
indi_exog/1
executeAction/4
exog_occurs/1
MAIN CYCLE
IndiGolog main execution cycle
indigolog.pl
trans/4
final/2
SINGLE STEP
Trans/4 and Final/2 implementation
transfinal.pl
rolling forward
proc/2
eval/3
translate_exogActions/2
hot_to_execute/2
load_environments/3
translate_Sensing/2
app-name.pl
DOMAIN PROGRAMS
Main program and all necessary procedures
DOMAIN EXEC
Environments to load and how to execute actions
main_xxx.pl
DOMAIN AXIOMS
Actions, effects, initial database, etc.
axioms of the domain
Projector
Projects a formula wrt some history
eval_ttt.pl
eval/3

# The Main Cycle



# Main Cycle: first phase *indigo/2*

```
indigo(E,H) :-
    handle_rolling(H,H2), !,
    handle_exog(H2,H3),   !,
    mayEvolve(E,H3,E2,H4,S), !,                % Compute next step
    (S=trans     -> indigo2(H3,E2,H4) ;        % Second part of cycle
     S=final     -> report_message(program, 'Success') ;
     S=exog      -> report_message(program, 'Restart'), indigo(E,H3) ;
     S=failed    -> report_message(program, 'Program fails.')
    ).
```

# mayEvolve/5*: transition step...*

**% Vanilla Prolog (not aware of exog. events happening!)**

```
mayEvolve(E1,H1,E2,H2,S) :- mayEvolve2(E1,H1,E2,H2,S).

mayEvolve2(E1,H1,E2,H2,final) :- final(E1,H1).
mayEvolve2(E1,H1,E2,H2,trans) :-  trans(E1,H1,E2,H2).
mayEvolve2(E1,H1,E2,H2,failed).
```

**% SWI/ECLIPSE/SICSTUS Prolog (require events)**

```
mayEvolve(E1,H1,E2,H2,S) :-
     catch(bodyCatch(E1,H1,E2,H2,S)), exogAction, (retractall(flag),S=exog)).

bodyCatch(E1,H1,E2,H2,S) :-
     assert(flag),                % Assert flag
     mayEvolve2(E1,H1,E2,H2,S),
     retract(flag).               % Retract flag
```

# Main Cycle: second phase

```
indigo2(H,E,H)                 :- indigo(E,H).    % The case of Trans for tests
indigo2(H,E,[sim(_)|H])        :- !, indigo(E,H). % Drop simulated actions
indigo2(H,_,[abort|H])         :- !, indigo(?(false),H).
indigo2(H,E,[wait|H])          :- !, pause_or_roll(H,H1),  % Wait for events!
                                  doWaitForExog(H1,H2),  indigo(E,H2).
indigo2(H,E,[stop_interrupts|H]) :- !, indigo(E,[stop_interrupts|H]).
indigo2(H,E,[A|H])             :- indixeq(A, H, H1), indigo(E, H1).
```

**% Execute action Act at history H, with new history H2**

```
indixeq(Act, H, H2) :-
    type_action(Act, Type), !,                % Type=sensing / nonsensing
    execute_action(Act, H, Type, S), !,       % Environment manager!
    handle_sensing(Act, [Act|H], S, H2),
    update_now(H2).
```

# Environment Manager

Connects the main cycle with the external world:

- Communicates with every used device manager
  - Uses TCP/IP sockets
- Instructs the execution of actions in devices
  - User states how/where each HL-action is executed
  - Sensing outcome is collected for each action
- Collects exogenous actions from devices
  - Asyncrhonous
  - Signal main cycle if neccessary!

# Environment Manager (cont.)

How to implement the EM to run asynchronously?

1. *Multi-threads + Events*
   - *2 threads: main cycle + environment manager*
   - *Requires multi-threading support (e.g., SWI)*

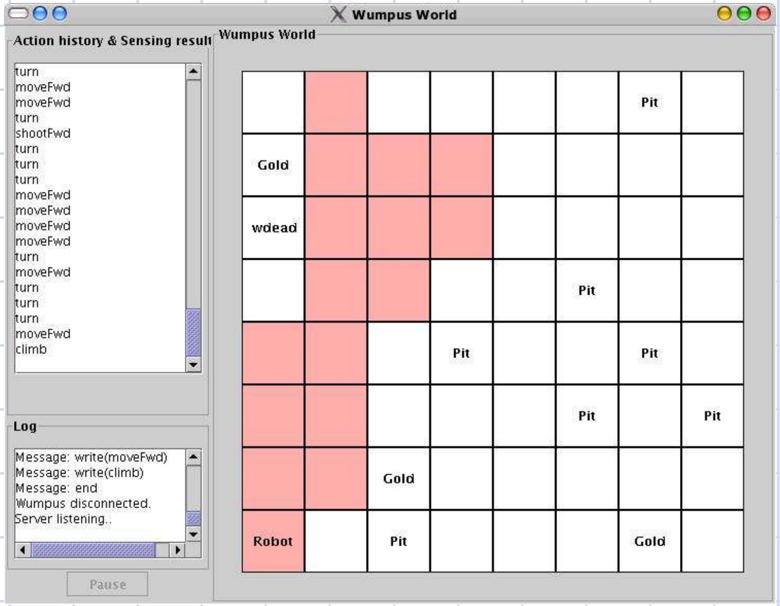
2. *Software signals / interrupts*
   - *Requires BSD, not too clean...*

3. *After-events*
   - *An event is triggered regularly*
   - *Requires event-after support (e.g., ECLIPSE)*

# Two Case Examples…

- ✔ Controlling the EVOLUTION ER1 robot

- ✔ Controlling an agent in the Wumpus World



# Evolution ER1 Robot Platform

- Promising as a research tool
  - Inexpensive ($1000 + Laptop)
  - Easy to set up (USB)
  - Easy to upgrade, modular
  - Sensors: camera, mic, IR
  - Actuators: motors, speech, gripper
  - Wireless connectivity
- Two control software tools:
  - RCC: simple, CAPI (Windows)
  - ERSP: sophisticated (Linux)

# P-IndiGolog on ER1

*P-IndiGolog*
Agent
Architecture

TCP/IP
Sockets

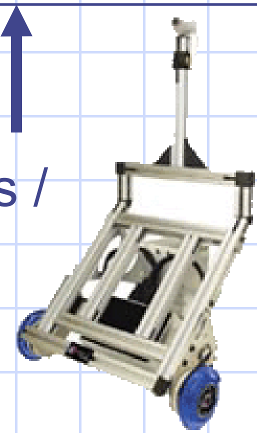
sensing / events

primitive actions

RCC or ERSP
low-level

```
events
gripper status
ir all
ir left/right/center
sense
position
etc…
```

sensors /
events

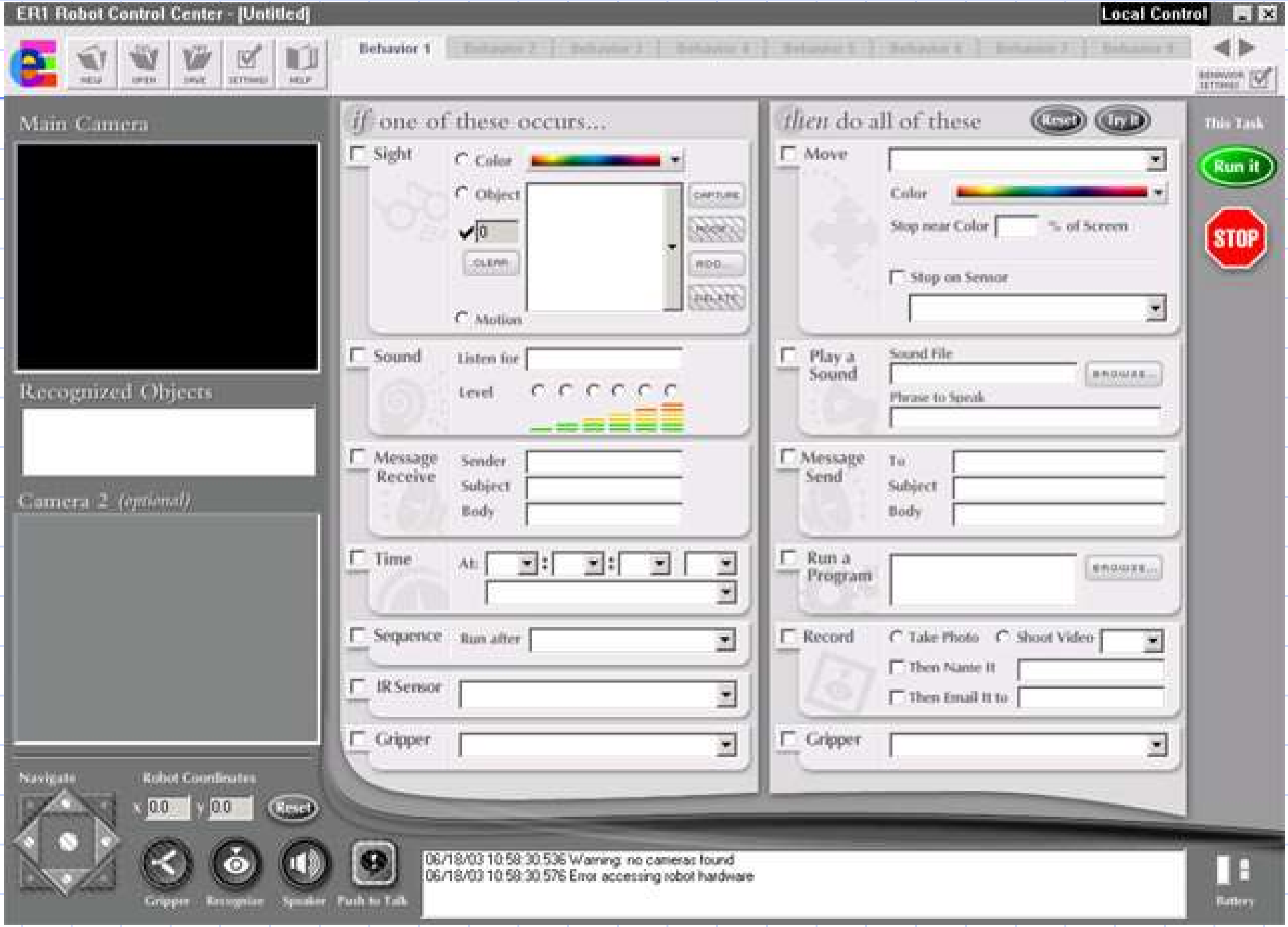


effectors

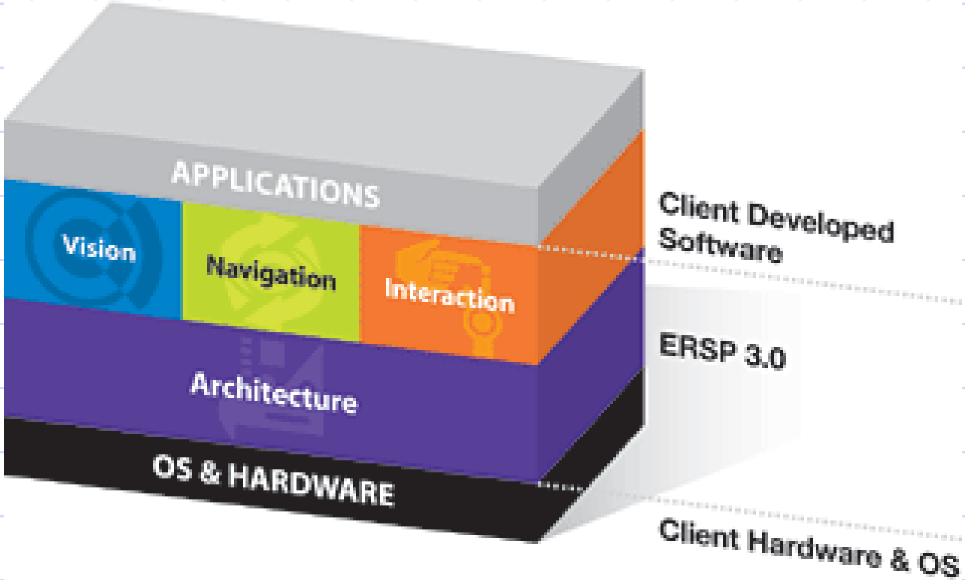
```
move
move rotate
move towards
talk
send email
gripper
open/close
etc…
```

Built-in obstacle and collision avoidance

# RCC Screenshot



# ERSP 3.0

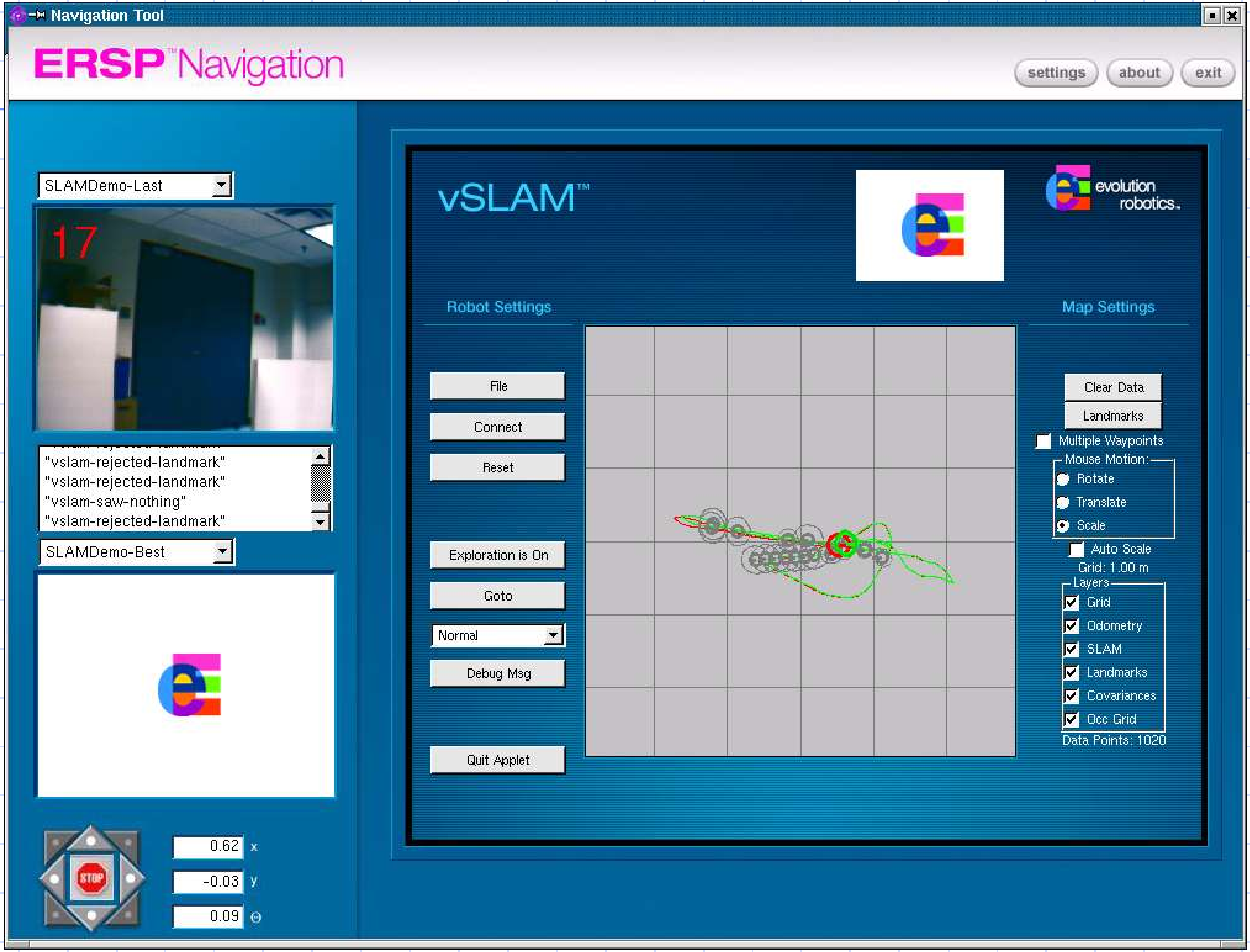



The Evolution Robotics Software Platform 3.0 (ERSP™) is a comprehensive development platform with four primary areas of functionality: **vision, obstacle avoidance, interaction, and architecture**. ERSP 3.0 includes **library APIs**, developer tools, and applications to aid you in the robot development process and allow you to move to higher-level programming quickly.

# ERSP 3.0: Four Modules

- ER Vision
  - Object recognition, motion analysis, and colour segmentation
- ER Navigation: SLAM
  - Mapping, localization, and path-planning, obstacle and cliff detection and avoidance with webcams
- ER Interaction
  - Software for robot-human interaction (e.g., person detection and tracking, robot emotions)
- ER Architecture
  - Infrastructure for Rapid Robot Development & Control

# SLAM on ERSP 3.0



# Running ER1 with IndiGolog

- Fluent "state":

```
causes_val(moveFwd(_),          state, moving, true).
causes_val(turnLeft,            state, moving, true).
causes_val(turnRight,           state, moving, true).
causes_val(arrive,              state, stopped, true).
causes_val(getStuck,            state, stopped, true).
causes_val(stop_abnormally,     state, suspended, true).
```

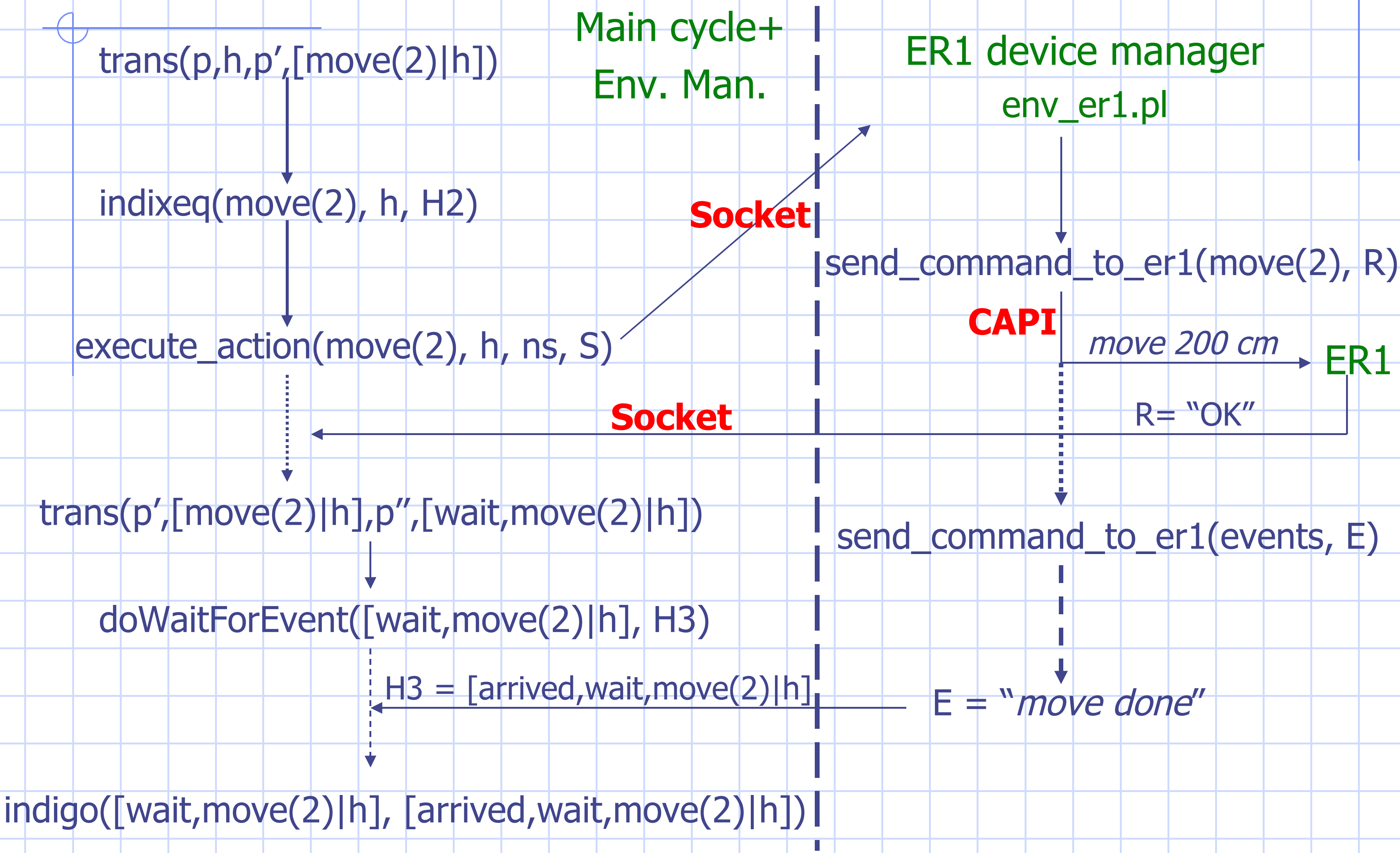
- Action Preconditions:

```
poss(moveFwd(_),        neg(state=moving)).
poss(turnRight,         neg(state=moving)).
poss(freeze,            true).
poss(forgetObject(O),   or(sawObject(O), objectLost(O))).
poss(say(_),            and(neg(talking),neg(silent))).
```

# An IndiGolog Controller for ER1

```
proc(mainControl(3),
     [talk('ER1 controller initiated successfully!'),
      setObjectConfidence(20), senseOn(objects), setPower(moving, 40),
      prioritized_interrupts(
        [interrupt(talking, wait),
         interrupt(o, sawObject(o),
                   [talk(['Hey!, I have just seen ', o]), forgetObject(o)]),
         interrupt(o, objectLost(o),
                   [talk(['I have just lost the object ', o]), forgetObject(o)]),
         interrupt(state=moving, wait),
         interrupt(true, [talk('Starting a new round'),
                          pi(n,[getNumber(10,30,n), setLinearVelocity(n)]),
                          rndet(goSquare(right, 200),
                                [turnRight, goSquare(left,200), turnLeft]),
                          talk('Another round finished')]),
         ])  % END OF INTERRUPTS     ]).
```

# IndiGolog on ER1: A trace



# Why ER1 is useful for us?

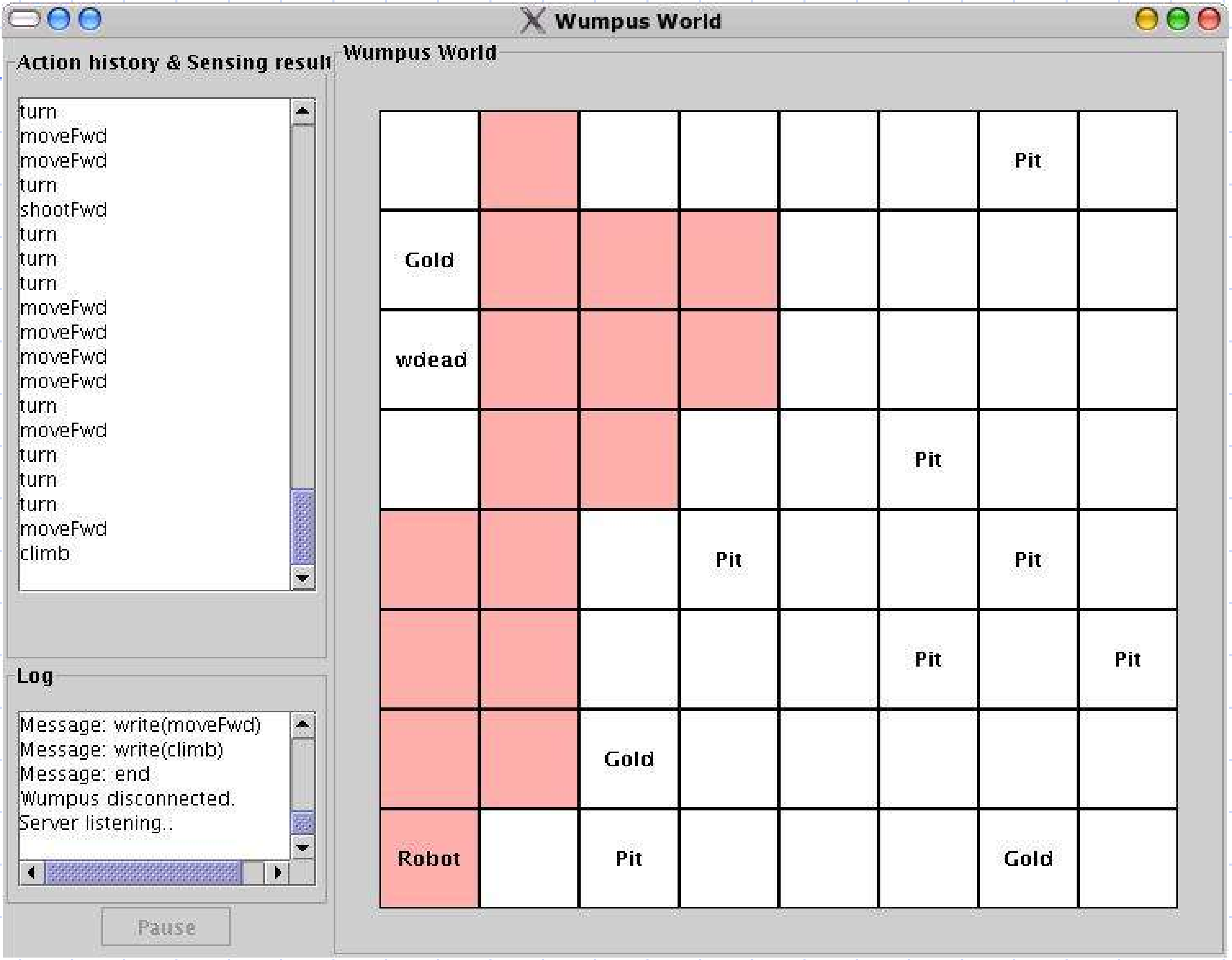
- It’s simple to deal with (laptop + USB devices)
- Low-level control is already done!
  - Good interface for primitive actions
  - Events management
- Good communication via TCP/IP
  - Not the case with Lego RCX!
- Complex tasks are already implemented
  - Object/colour recognition
  - Obstacle avoidance via IR and camera
  - Object/colour tracking (*move towards ….*)
  - Sound/voice recognition and speech

# Wumpus World in IndiGolog

- Fluents: `locA, dirA, locW, isPit(L), aliveW, noGold, inDungeon, ...`
- Agent actions: `moveFwd, turn, smell, exit, pickGold, shoot,senseBreeze, senseGold`
- Exog. actions: `scream`

$$
\begin{array}{l}
\textbf{proc}\ mainControl \\
\langle d, l : \ \mathtt{locW} = l \wedge \mathtt{aliveW} = \mathtt{true} \wedge \\
\qquad \mathtt{aligned}(\mathtt{locA}, dir, \mathtt{locW}) \longrightarrow shoot(d) \rangle\ \rangle\!\rangle \\
\langle \mathtt{isGold(locA)} = \mathtt{true} \longrightarrow \mathtt{pickGold} \rangle\ \rangle\!\rangle \\
\langle \mathtt{inDungeon} = \mathtt{true} \longrightarrow \\
\qquad \{\mathtt{smell}; \mathtt{senseBreeze}; \mathtt{senseGold} \\
\qquad \{?(\mathtt{noGold} = 0); explore\} \mid \{goto(\mathtt{g(1,1)}); \mathtt{climb}\}\}\rangle \\
\textbf{endProc}
\end{array}
$$

# The Wumpus World



# Conclusions

- ER1 is a promising tool for research: simple, cheap, and powerful.
- ERSP toolkit can provide an excellent starting point for our Cognitive Robotics applications
- IndiGolog can be already successfully used to control ER1.

We welcome everybody interested in working with ER1 and IndiGolog !
:-)

# Interesting Problems with ER1

- Discover ERSP (it's already installed and working!)
- Take full advantage of SLAM and vision capabilities

- Implement a real-world Wumpus World!
- Find known signs/objects in a room, approach them, and read them (e.g., numbers and directions)
  - First look for object color (long range)
  - Can use two behaviors in priorities
  - If nothing can be found, move around the room