Implementation of Linux Kernel Modules for Simulation and Provenance

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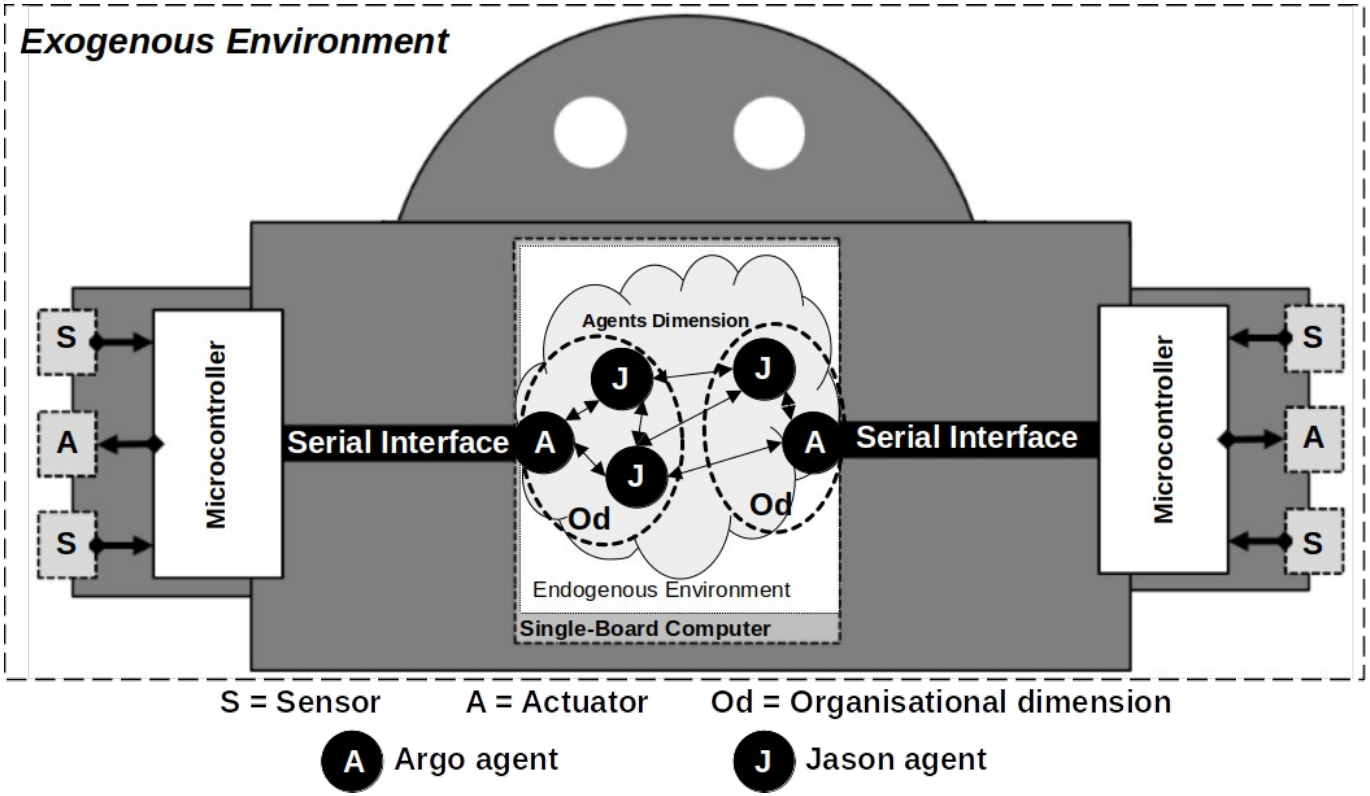
Introduction

- **An Embedded Multiagent System is system based on cognitive agents that act upon the real world [1]**
  - Input: data from sensors
  - Outputs: commands sent to the hardware

[1] Brandão, F. C., Lima, M. A. T., Pantoja, C. E., Zahn, J., and Viterbo, J. (2021). Engineering approaches for programming agent-based iot objects using the resource management architecture. Sensors, 21(23).

ARGO

- **For Embedded MAS, the ARGO architecture allows JASON agents to act directly on the real world (*exogenous environment*) [1]**



[1] Pantoja, C. E., Stabile, M. F., Lazarin, N. M., and Sichman, J. S. (2016). ARGO: An Extended Jason Architecture that Facilitates Embedded Robotic Agents Programming.In Baldoni, M., Müller, J. P., Nunes, I., and Zalila-Wenkstern, R., editors, Engineering Multi-Agent Systems, pages 136–155, Cham. Springer International Publishing.

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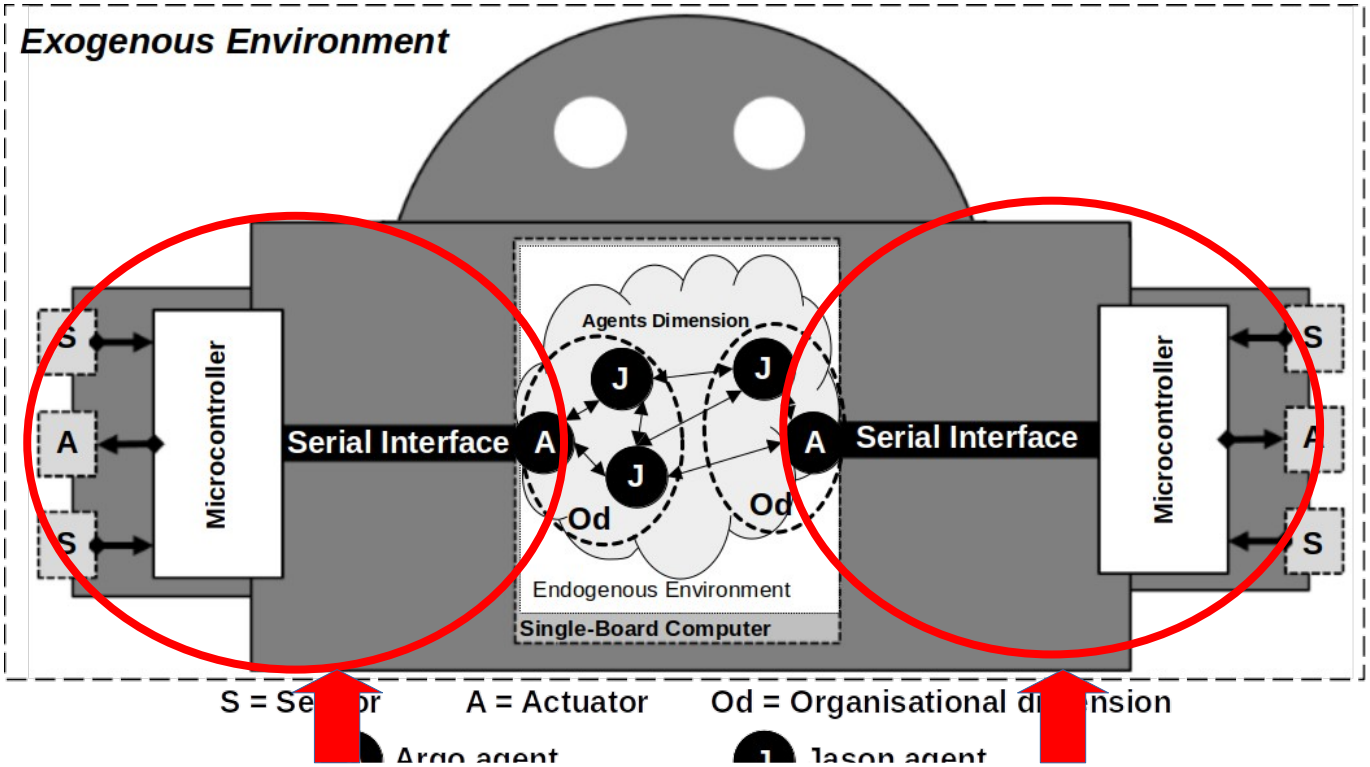


All communication is based on serial communication
Pior construction of hardware is needed before verification

Motivation

- **There are some challenges that arise when developing these systems:**
  - Verification of behaviour
  - Deploying a solution on the real world
  - Collecting data provenance of the deployed system

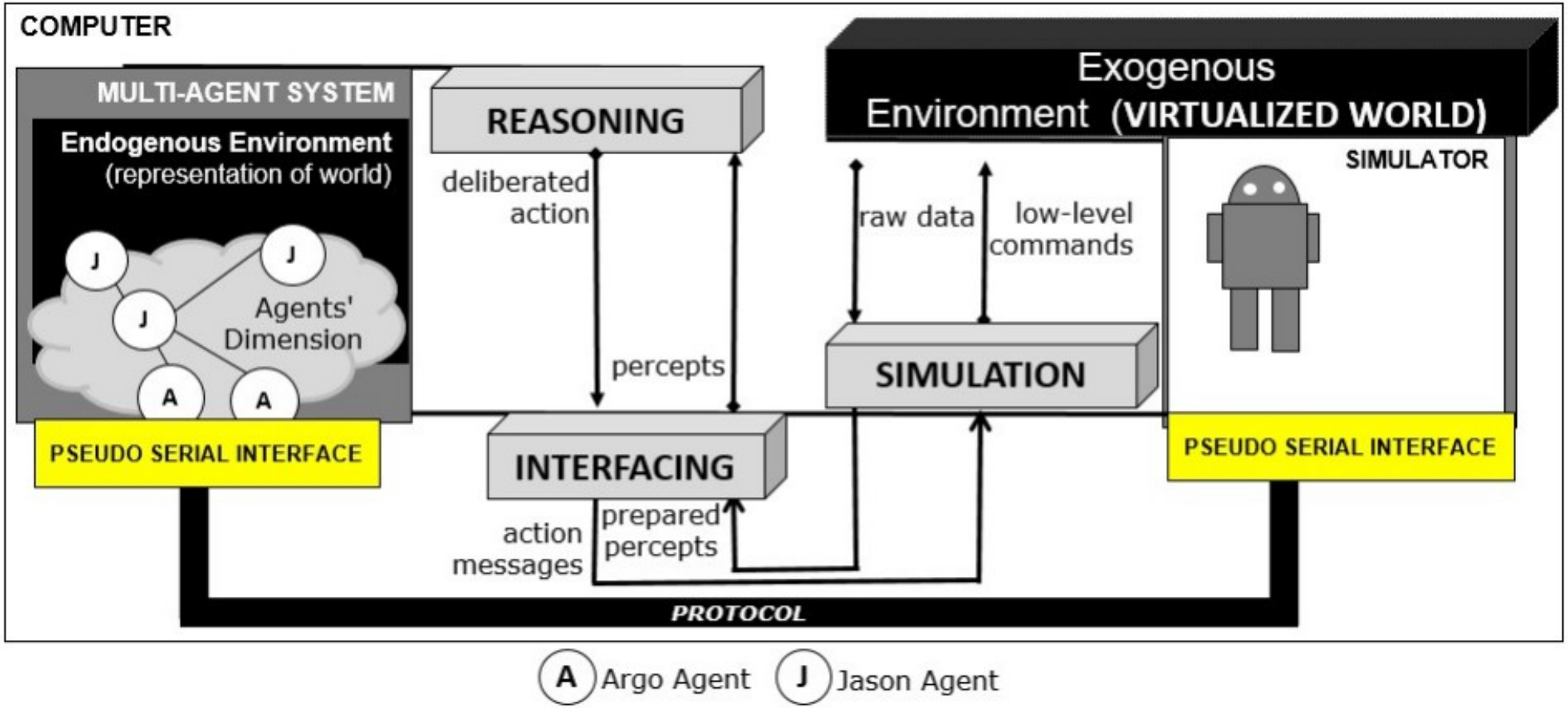
Problems

- **Embedded MAS lacks simulation tools for verification**
- **Data exchanged between an ARGO agent and a microntroller is lost unless the reasoning is heavily instrumented**

Proposal

- **This ongoing work aims to solve these issues by using kernel modules**
  - A module to transparently connect an ARGO agent to a simulator
  - A module to transparently capture *data provenance* on a serial channel

Serial channel emulation



A Argo Agent J Jason Agent

FREITAS, Bruno Policarpo Toledo; LAZARIN, Nilson Mori; PANTOJA, Carlos Eduardo. Uma Proposta de Emulador de Portas Seriais para Sistemas Multiagentes Embarcados. In: Workshop-Escola de Sistemas de Agentes, seus Ambientes e Aplicações (WESAAC), 17. , 2023, Pelotas/RS. Anais [...]. Pelotas: UFPel, 2023 . p. 55-66. URL: https://zenodo.org/record/8329081

Simulation tools

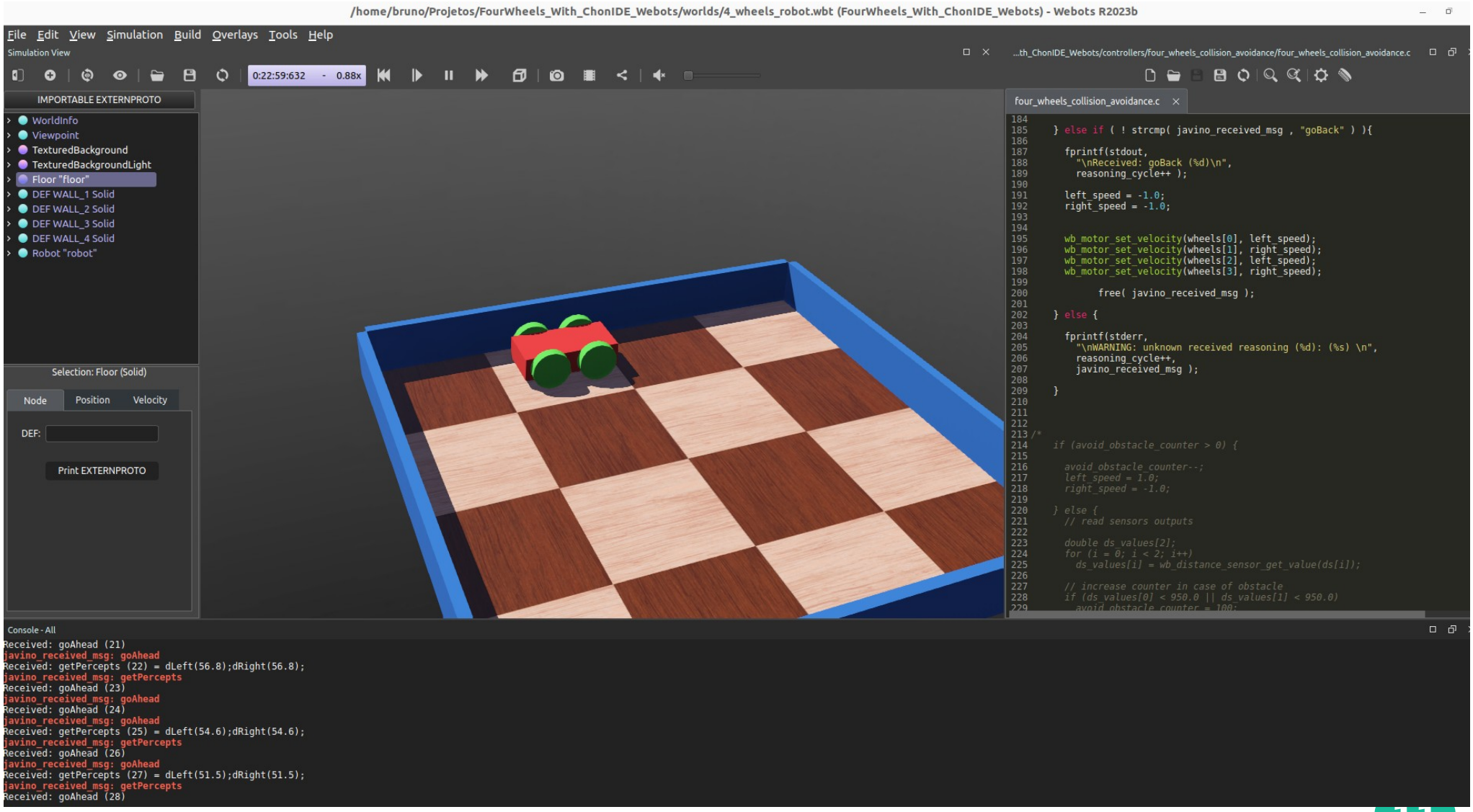
- **Previously we've developed a demonstration application of the communication[1]**
- **Since then, we have successfully completed integration with other simulators**

Simulation tools
Integration process

- **Steps:**
  - Understand the robot simulation programming
  - An implementation of the Javino protocol to the simulator’s development language
  - Mapping a *getPercepts* to return the robot simulation values
  - Programming the acts to robot’s simulation

Simulation tools

WeBOTS



Simulation tools
Integration process

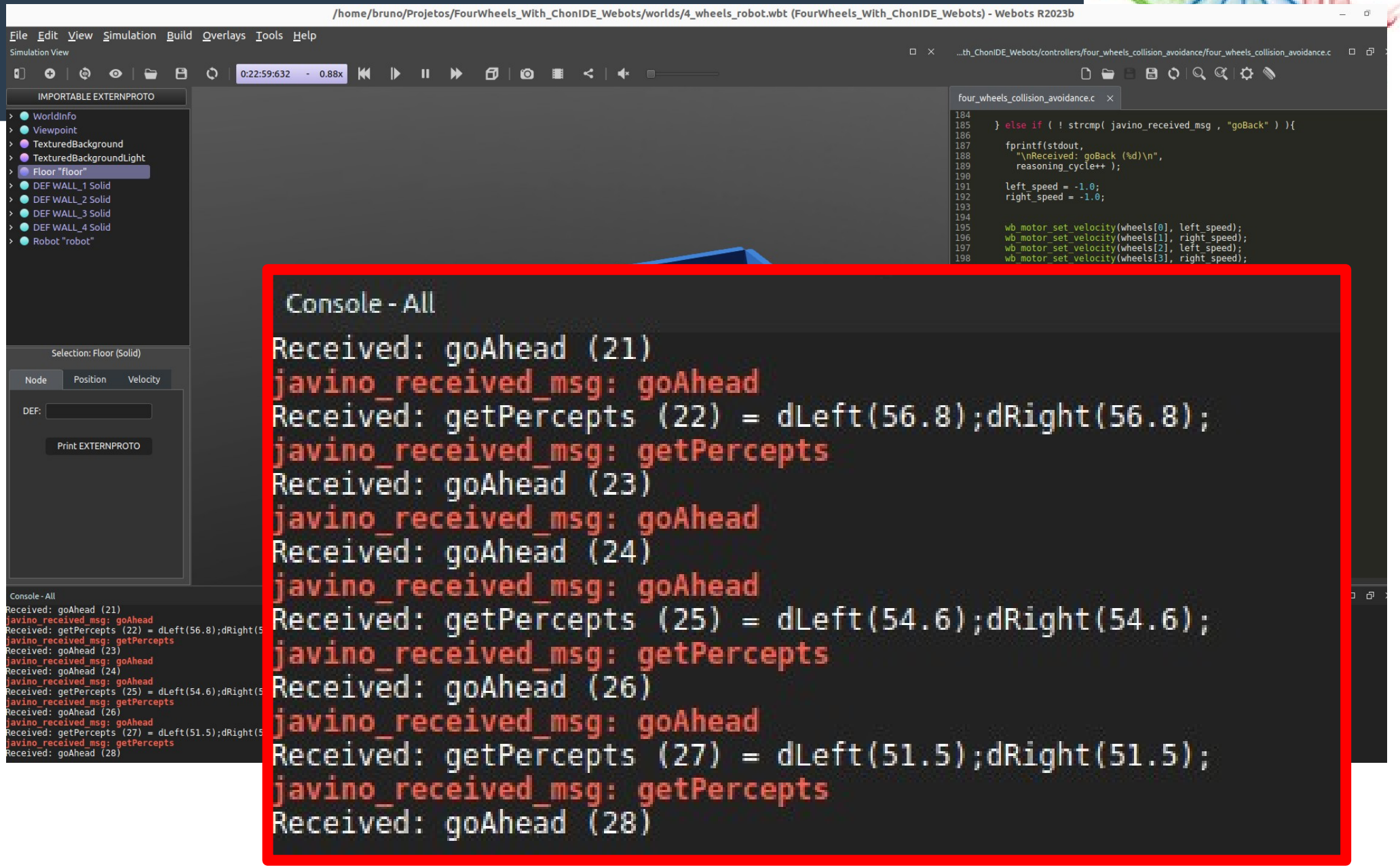
- **Mapping a *getPercepts* to a simulator structure**

```
javino_received_msg = javino_get_msg( );

if ( ! strcmp( javino_received_msg , "getPercepts" )  ){

   // left distance sensor value
   float d1 = wb_distance_sensor_get_value( ds[0] );

   // right distance sensor value
   float d2 = wb_distance_sensor_get_value( ds[1] );

   // Composing percepts message to send to Javino
   sprintf(percepts_msg, "dLeft(%.1f);dRight(%.1f);", d1,

   javino_send_msg( exogenous_port,  percepts_msg);

   free( javino_received_msg );
```

Simulation tools
Integration process

- **Mapping ARGO's acts to Simulator's API**

```
} else if ( ! strcmp( javino_received_msg , "goAhead" ) ){

  left_speed = 1.0;
  right_speed = 1.0;

} else if ( ! strcmp( javino_received_msg , "goRight" ) ){

  left_speed = 1.0;
  right_speed = 0.0;

} else if ( ! strcmp( javino_received_msg , "goBack" ) ){

  left_speed = -1.0;
  right_speed = -1.0;

}
```


/home/bruno/Projetos/FourWheels_With_ChonIDE_Webots/worlds/4_wheels_robot.wbt (FourWheels_With_ChonIDE_Webots) - Webots R2023b
File Edit View Simulation Build Overlays Tools Help
Simulation View
...th_ChonIDE_Webots/controllers/four_wheels_collision_avoidance/four_wheels_collision_avoidance.c
IMPORTABLE EXTERNPROTO
WorldInfo
Viewpoint
TexturedBackground
TexturedBackgroundLight
Floor "floor"
DEF WALL_1 Solid
DEF WALL_2 Solid
DEF WALL_3 Solid
DEF WALL_4 Solid
Robot "robot"
Selection: Floor (Solid)
Node
Position
Velocity
DEF:
Print EXTERNPROTO
four_wheels_collision_avoidance.c
} else if (! strcmp(javino_received_msg , "goBack")){
fprintf(stdout,
"\nReceived: goBack (%d)\n",
reasoning_cycle++);
left_speed = -1.0;
right_speed = -1.0;
wb_motor_set_velocity(wheels[0], left_speed);
wb_motor_set_velocity(wheels[1], right_speed);
wb_motor_set_velocity(wheels[2], left_speed);
wb_motor_set_velocity(wheels[3], right_speed);
Console - All
Received: goAhead (21)
javino_received_msg: goAhead
Received: getPercepts (22) = dLeft(56.8);dRight(56.8);
javino_received_msg: getPercepts
Received: goAhead (23)
javino_received_msg: goAhead
Received: goAhead (24)
javino_received_msg: goAhead
Received: getPercepts (25) = dLeft(54.6);dRight(54.6);
javino_received_msg: getPercepts
Received: goAhead (26)
javino_received_msg: goAhead
Received: getPercepts (27) = dLeft(51.5);dRight(51.5);
javino_received_msg: getPercepts
Received: goAhead (28)

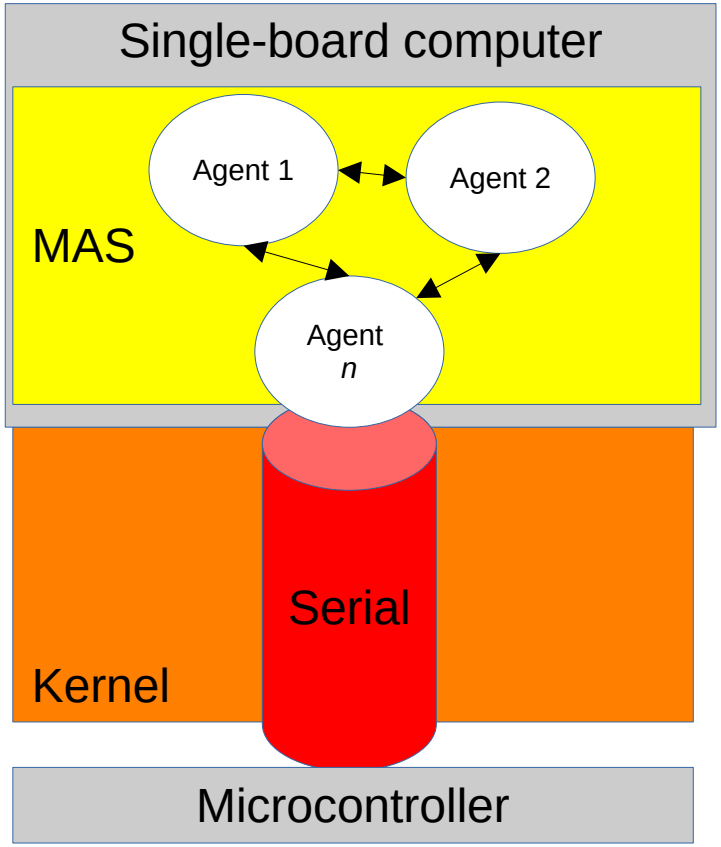
Real world execution

- **During real world execution, Embedded MAS applications data exchanged between an agent and the microcontroller will be lost unless heavily instrumented**

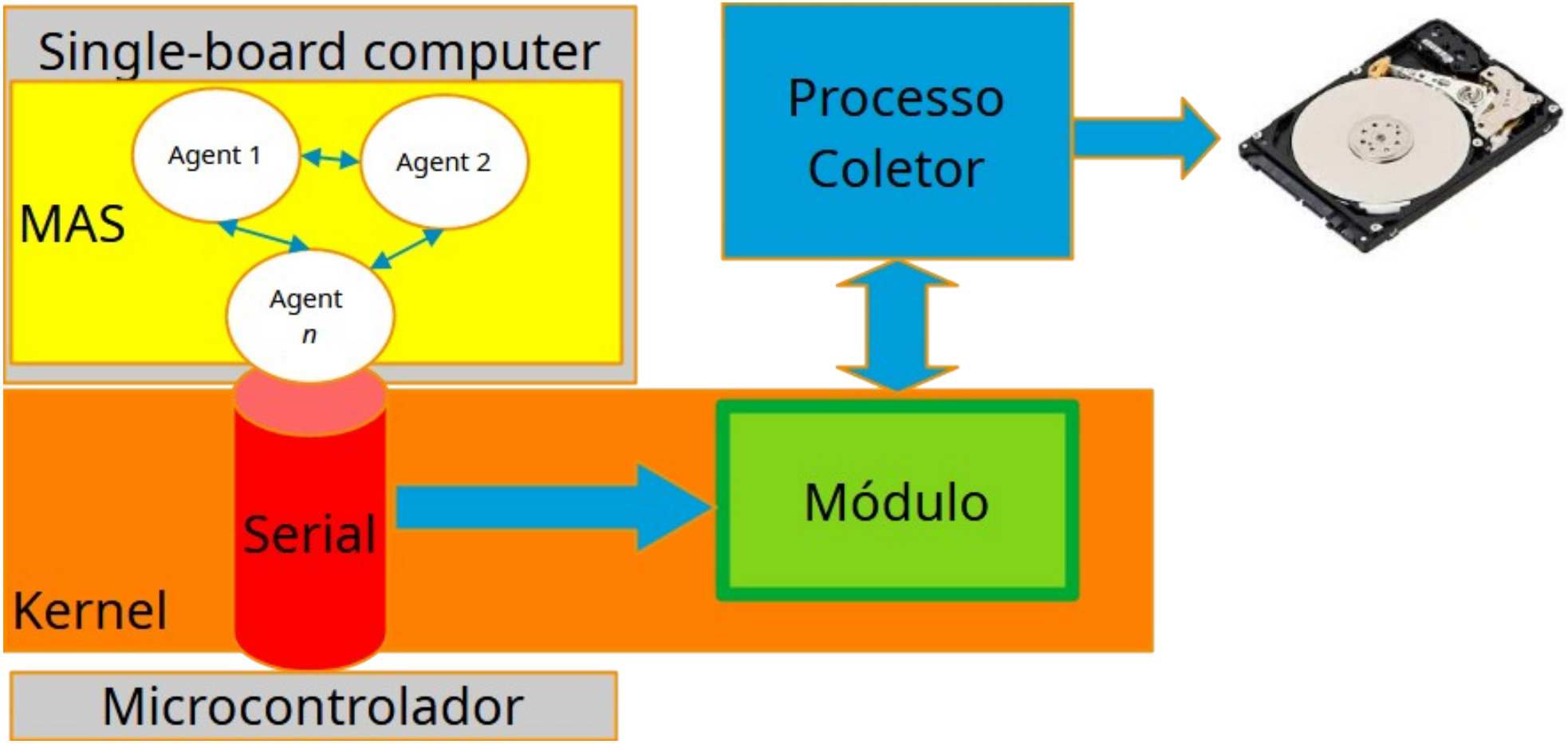
Data Provenance

- **Data provenance informs the processes and data used to generate it, allowing reproduction of scientific experiments**
- **For ARGO agents, this data is anything passing through the serial channel**

Data Provenance



Data Provenance



Conclusion

- **There is now enough infrastructure to simulate Embedded MAS**
  - More simulators could be integrated
- **For collecting data provenance on real systems, it is possible to transparently access and snoop the serial channel data**
  - Data sampling works but needs raw data processing
  - Automatic provenance hooks may be the best (but not easier) path

Obrigado!