Inteligência Artificial das Coisas com Sistemas Multiagente Distribuídos e Embarcados

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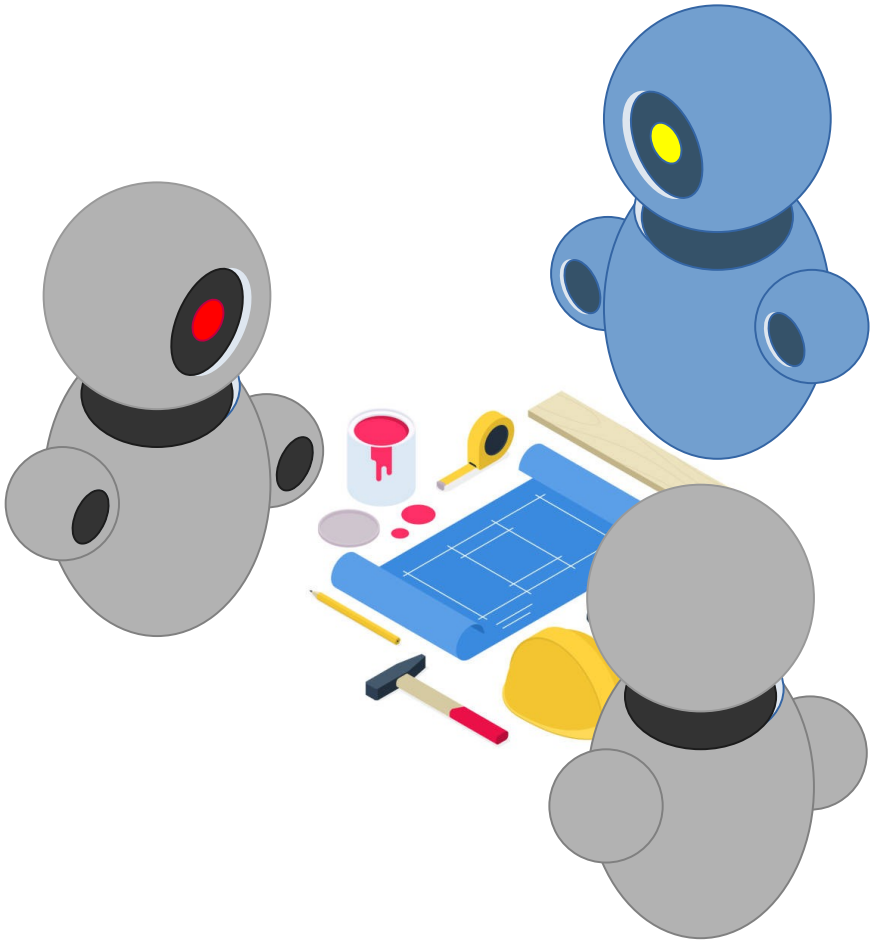
INTRODUCTION



Who we are?

Cognitive Hardware on Networks (Chon)

Research Group

https://chon.group

Where we have been?

This workshop is part of:

- **Undergratuate course**
  - CEFET/RJ Maria da Graça and Nova Friburgo
- **Graduate course**
  - M.Sc. and Ph.D. at UFF
-

It was **presented at:**

IFSP, IFC, UFPel, UFRJ, UFSC, UnB, UTFPR, UDESC and Estácio;

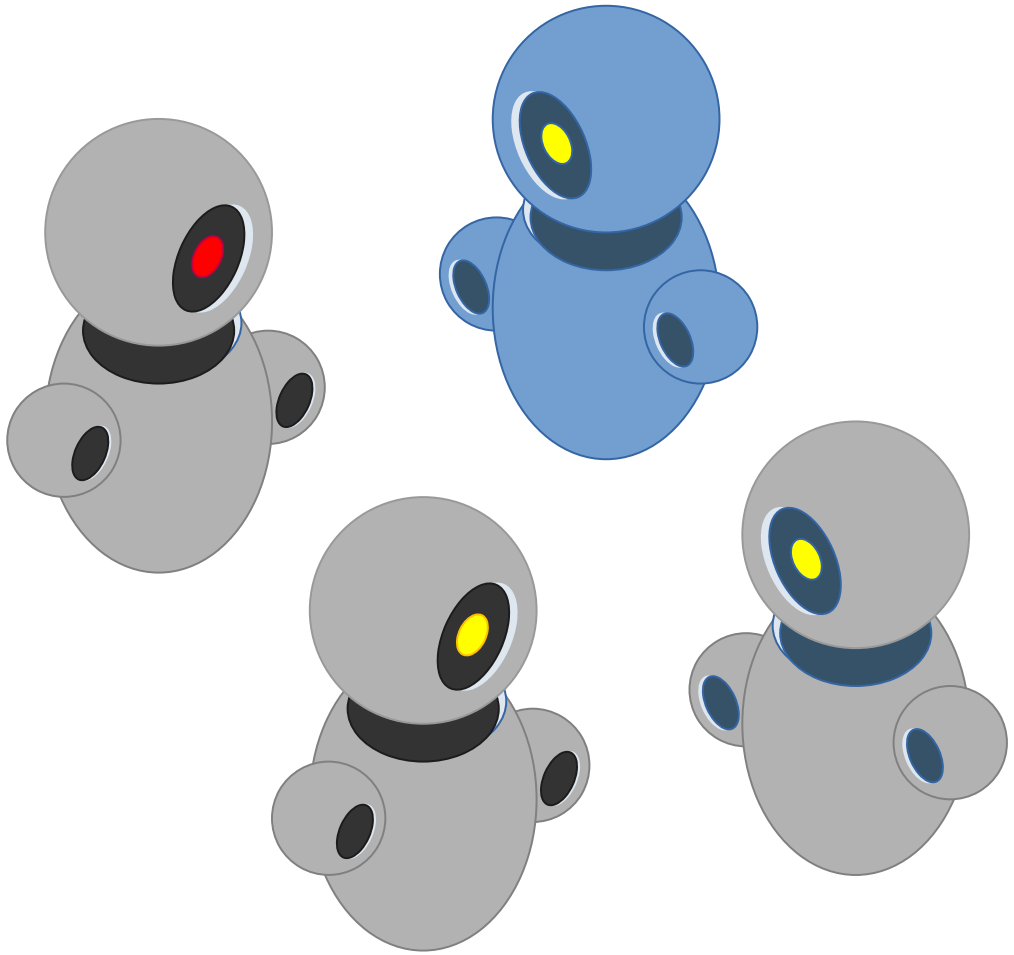
https://workshops.chon.group

Goals

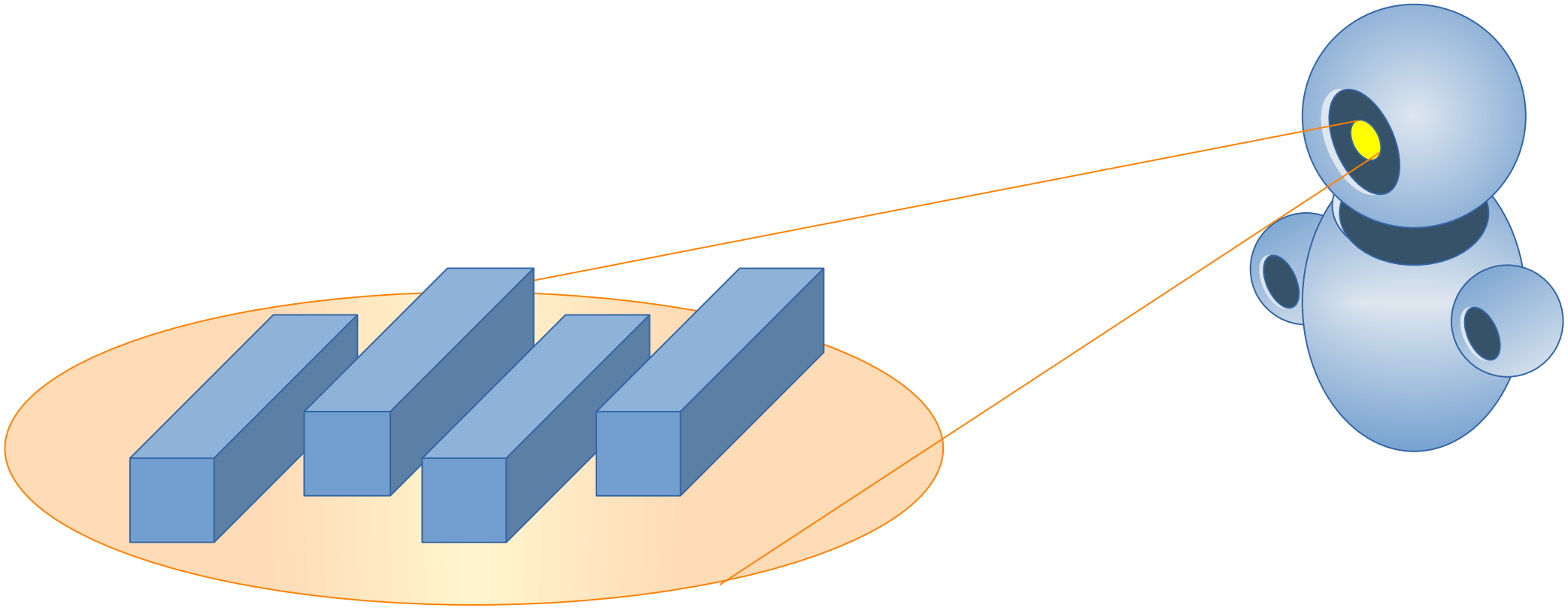
This workshop goals are:

- **To experience** the development process of **Embedded MAS** using BDI-agents and Jason.
- to learn how to **collaborate** using IoT in **distributed** scenarios.
-

THE AGENT ORIENTED APPROACH



Agent



WOOLDRIDGE, Michael. Intelligent Agents. Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence. Cambridge, MA, USA: MIT Press, 1999. p. 27–77
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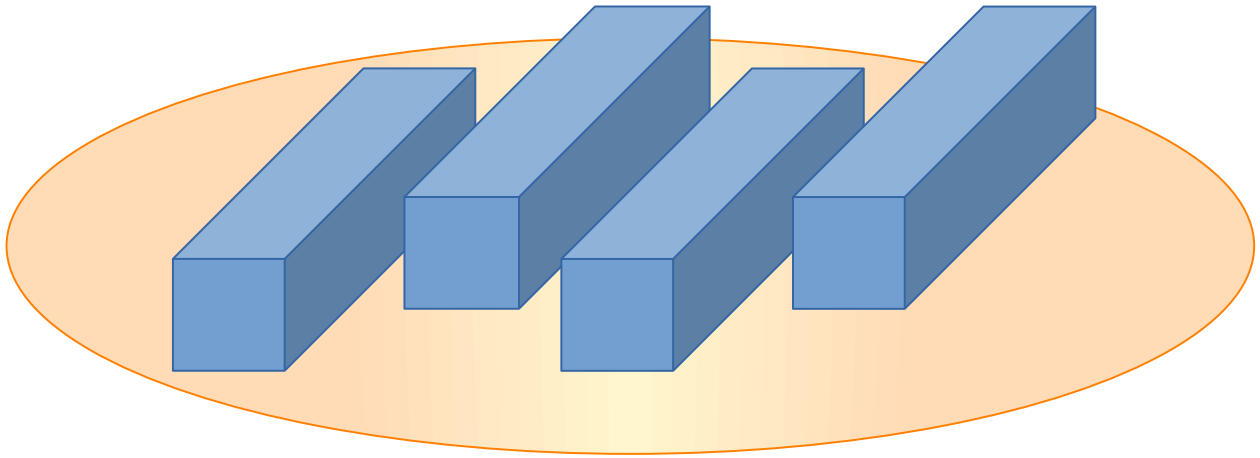
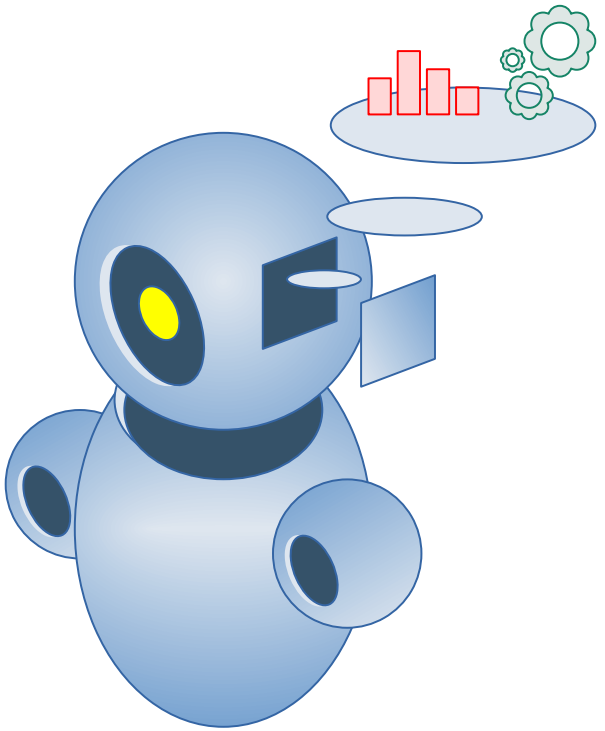
Agent





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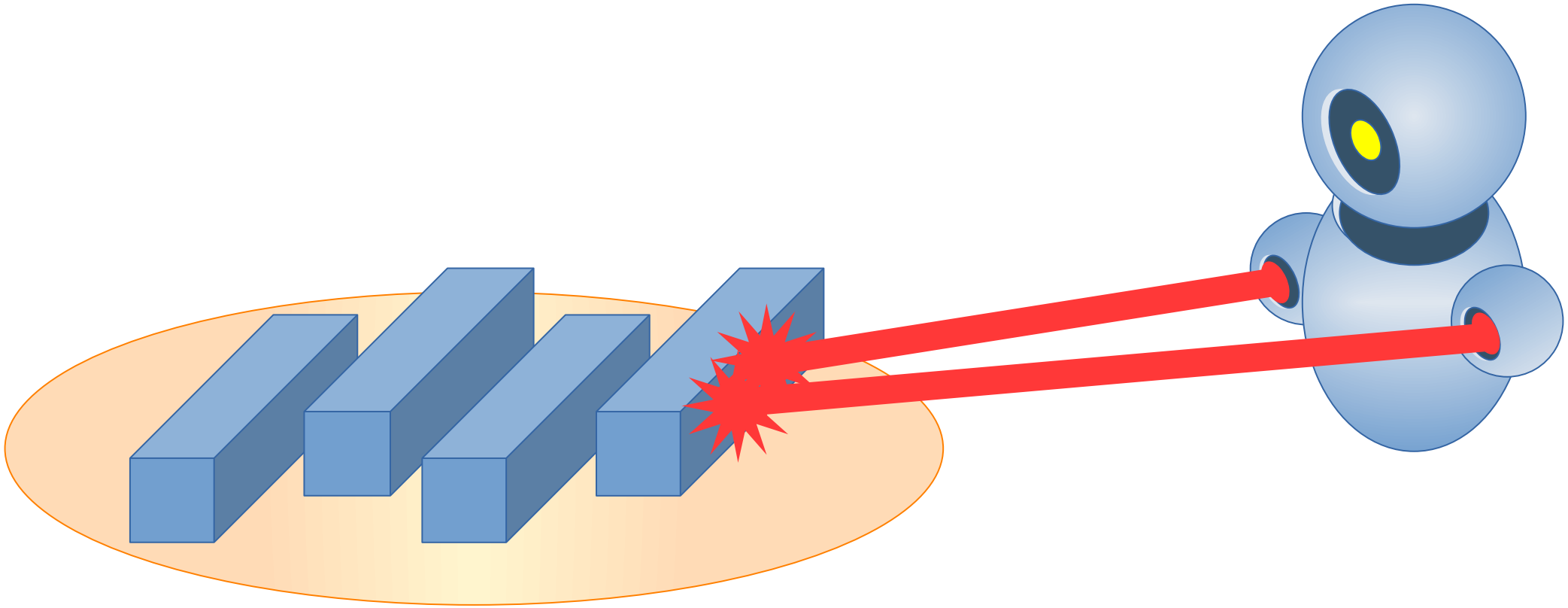
Agent



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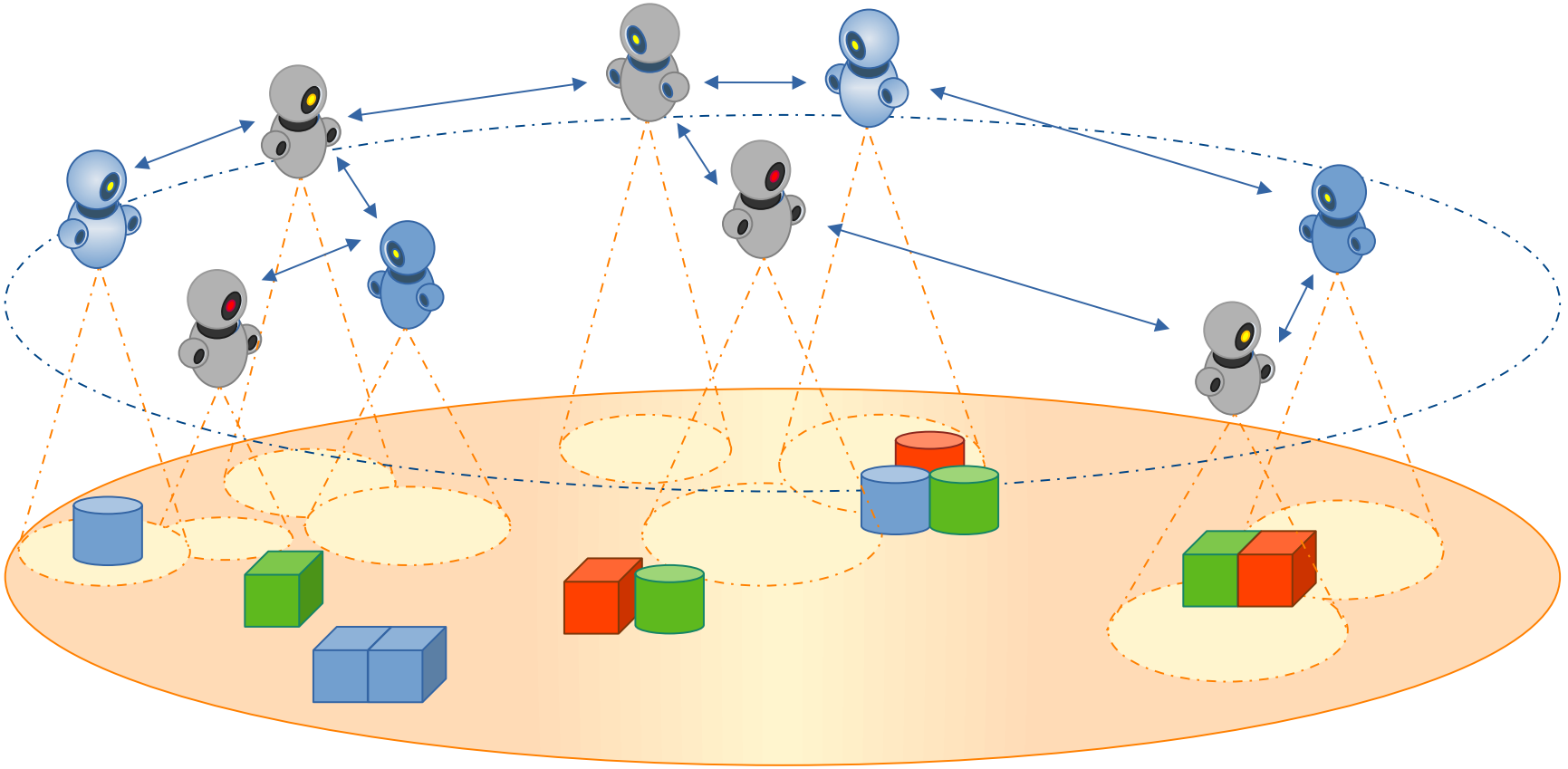
Multi-agent System



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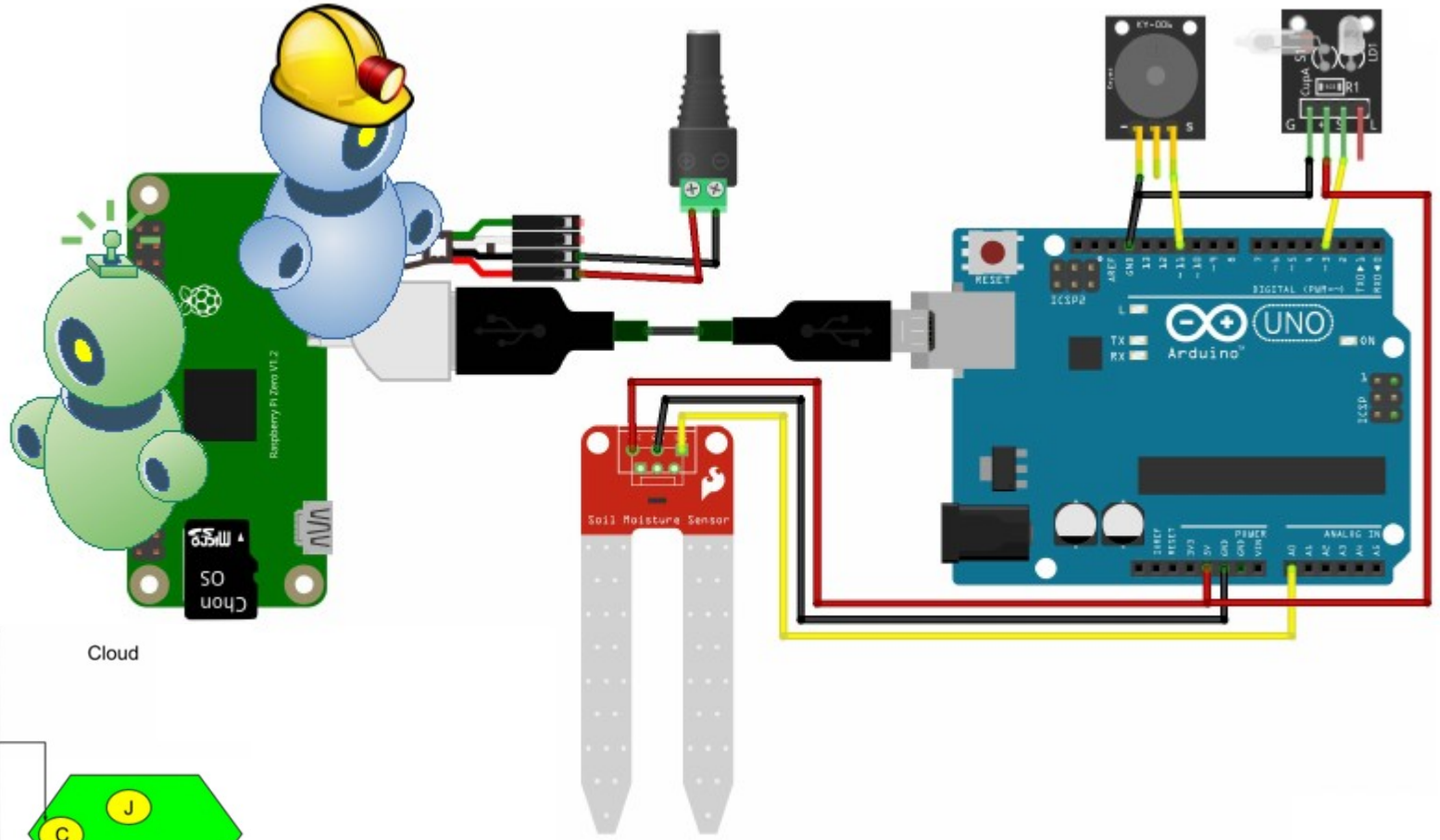
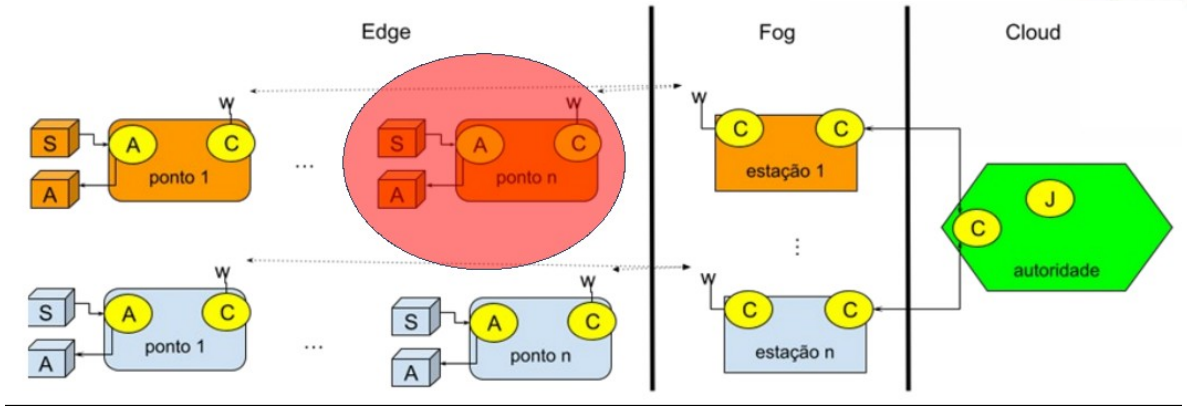
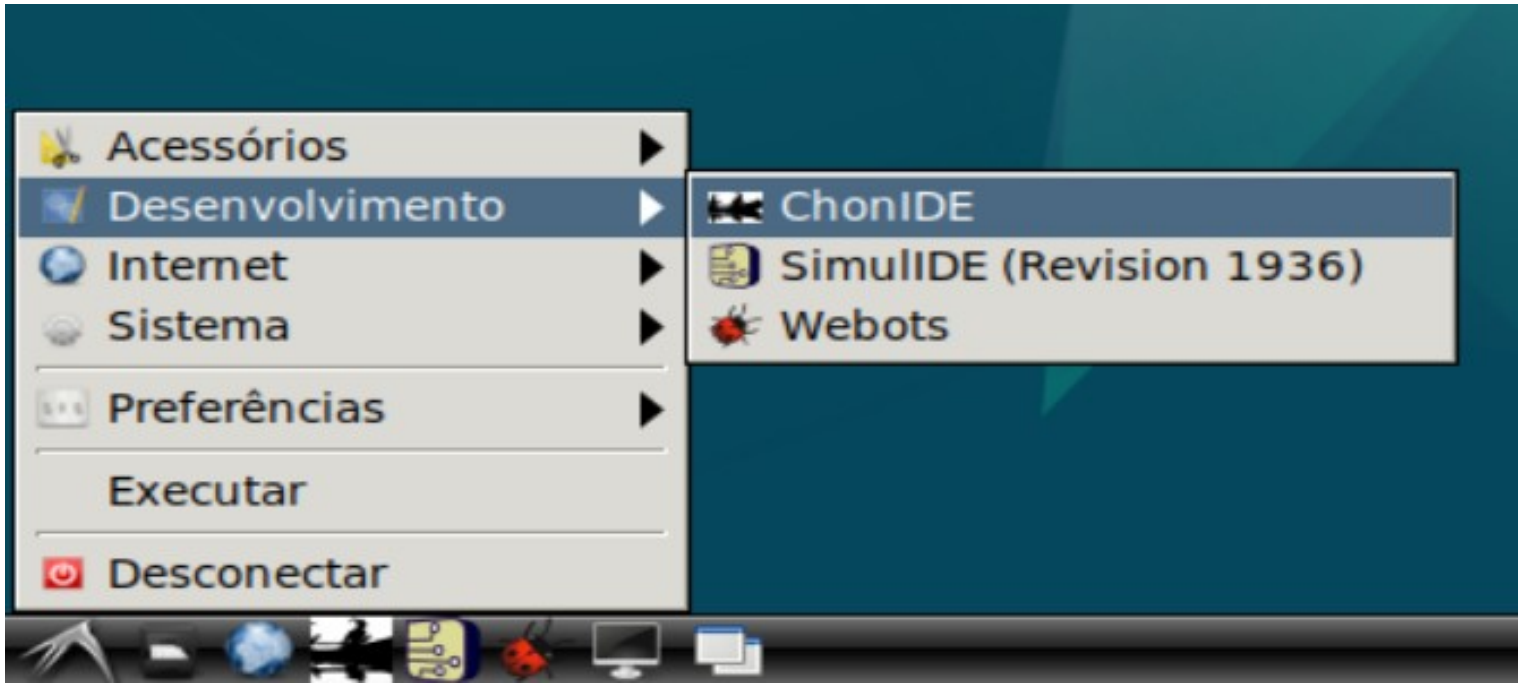
Embedded Multi-agent System



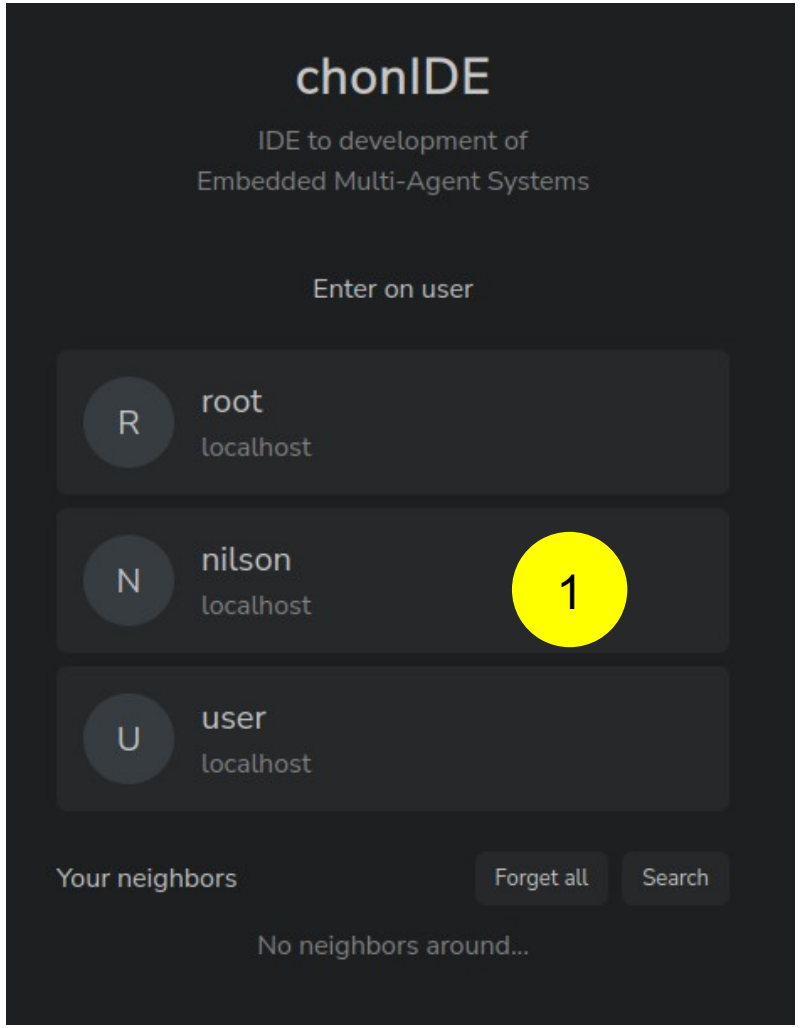


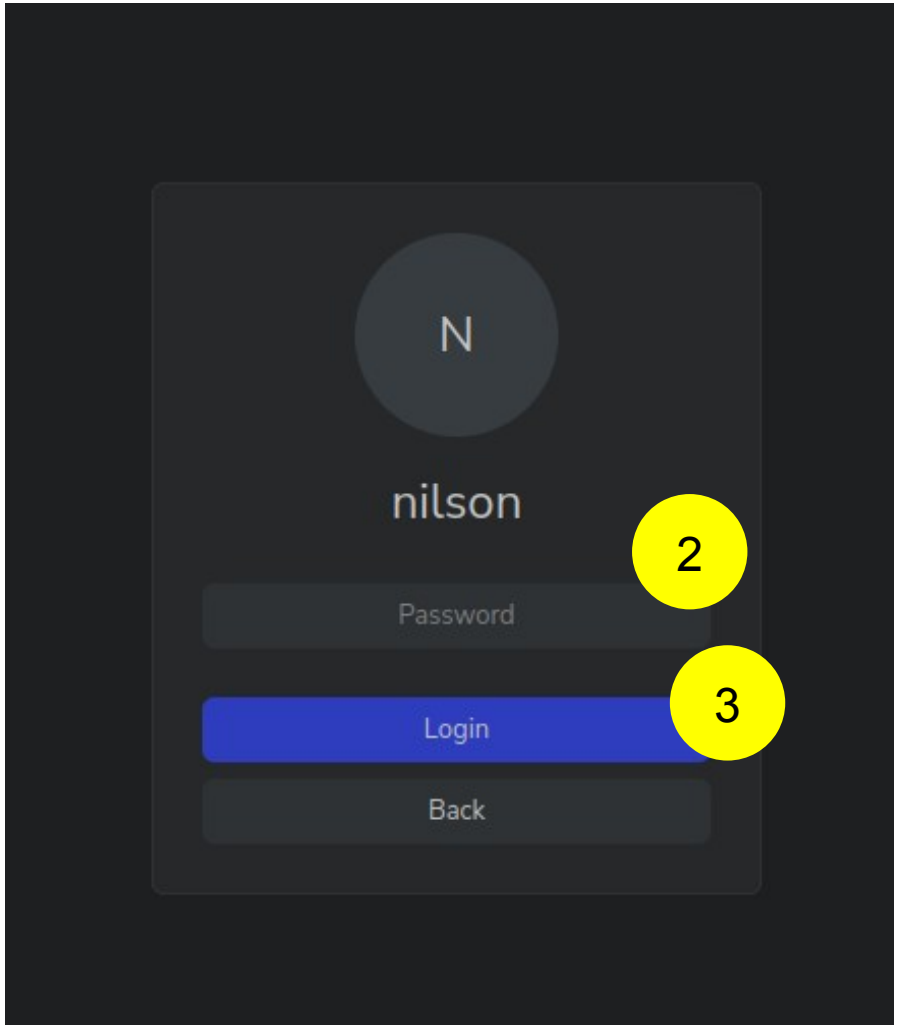
THE DEVELOPMENT TOOLS



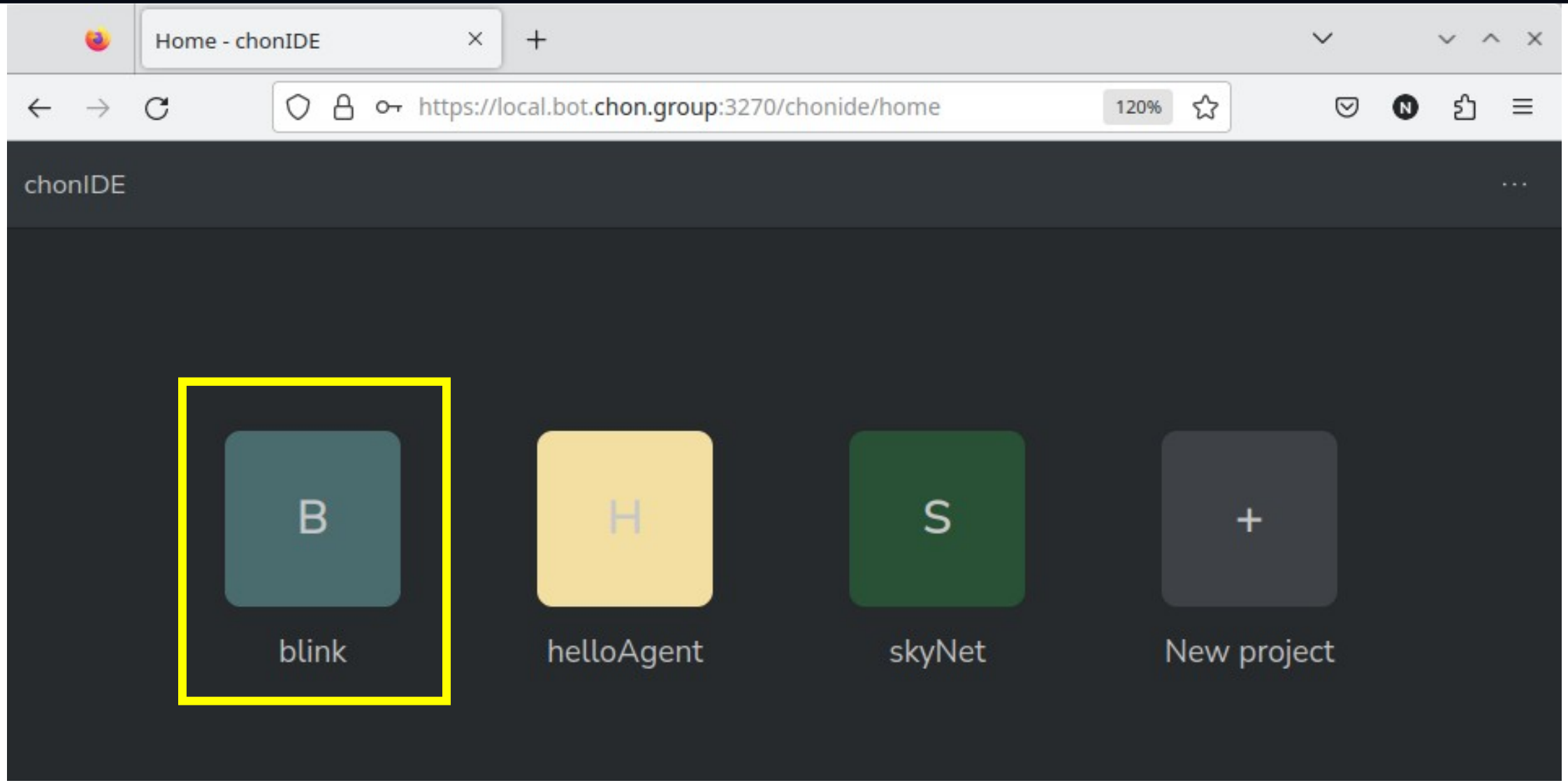
How to install?
https://github.com/chon-group/chonIDE/wiki

ChonIDE: login





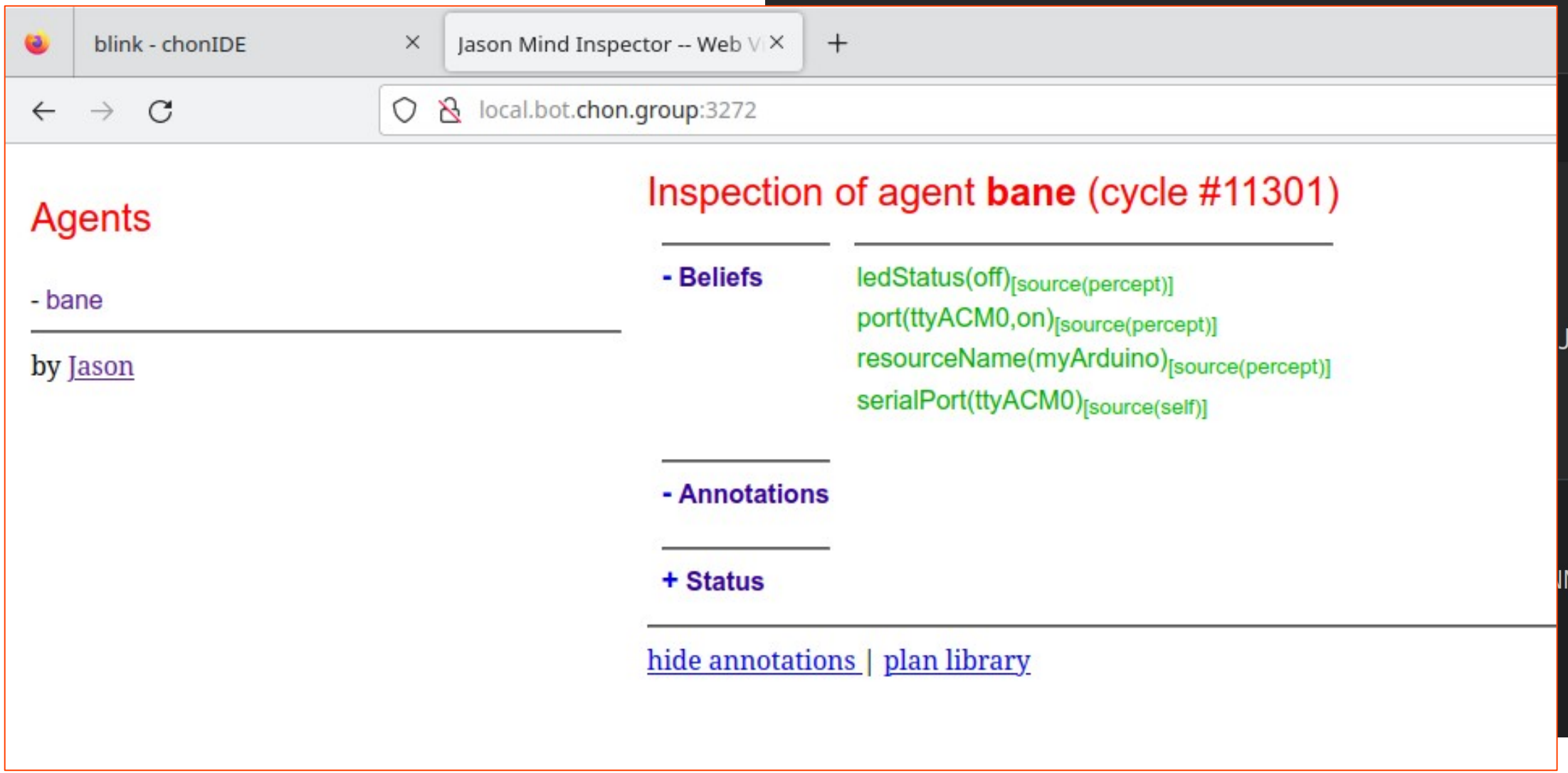
ChonIDE: blink



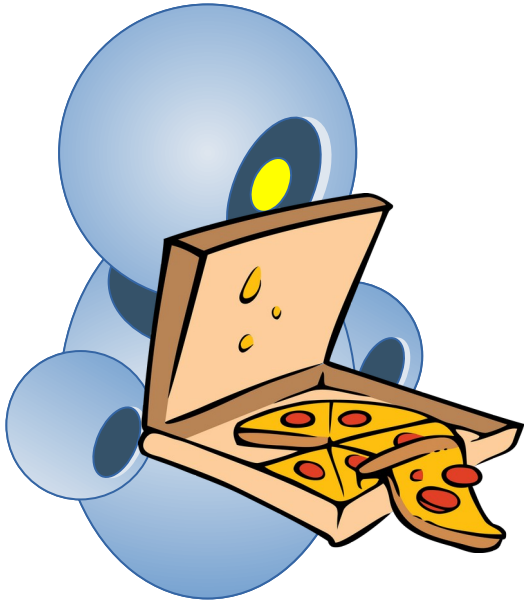
ChonIDE: blink

ChonIDE: blink

ChonIDE: mindInspector



MY FIRST SINGLE AGENT



Arquitetura BDI

O BDI possibilita a implementação de atitudes mentais em agentes cognitivos:

- **Crença** é uma informação, ou seja, aquilo que o agente sabe sobre o ambiente, si mesmo ou outros agentes.
- **Desejo** é um propósito que o agente busca tornar realidade.
- **Intenção** é uma ação que o agente faz para alcançar um desejo.

HÜBNER, Jomi Fred; BORDINI, Rafael Heitor; VIEIRA, Renata. Introdução ao desenvolvimento de sistemas multiagentes com Jason. **XII Escola de Informática da SBC**, v. 2, p. 51–89, 2004.

AgentSpeak(L)

Um agente AgentSpeak(L) possui minimamente:

- Uma base de **crenças**;
- Uma lista de **objetivos**;
- Uma biblioteca de **planos**.

HÜBNER, Jomi Fred; BORDINI, Rafael Heitor; VIEIRA, Renata. Introdução ao desenvolvimento de sistemas multiagentes com Jason. **XII Escola de Informática da SBC**, v. 2, p. 51–89, 2004.

Jason Framework: Crenças

Em Jason, um agente armazena as **informações** percebidas do ambiente; as informações internas; e informações de comunicação através de crenças.

As **crenças** são armazenadas em uma **Base de Crenças** (Belief Base).

As crenças são representadas como predicados da **lógica tradicional**. Os **predicados** representam propriedades particulares.

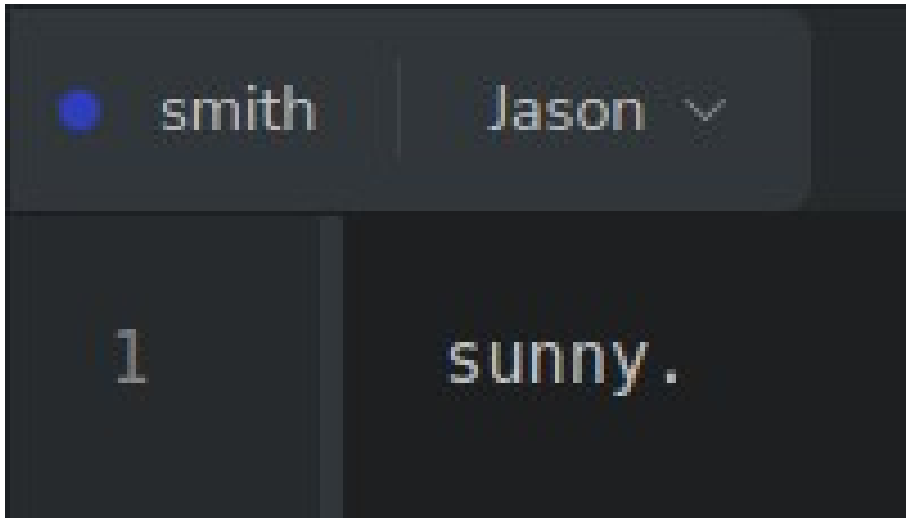
Jason Framework: Beliefs Types

1. **Mental Notes (self)**
   - Informações adicionadas na base de crenças pelo próprio agente.

2. **Communication (agent)**
   - Informações obtidas pelo agente através da interação com outros agentes.

3. **Environmental Perceptions (percepts)**
   - Informações coletadas pelo agente que são relativas ao sensoriamento constante do ambiente.

Initial Beliefs: Mental Notes



Inspection of agent **smith**

- **Beliefs** sunny[source(self)].

- **Annotations**

Initial Beliefs: Mental Notes

smith | Jason

```
1  myName(smith).
2  salary(1000).
```

Inspection of agent **smith**

- **Beliefs**

myName(smith)[source(self)].
salary(*1000*)[source(self)].

- **Annotations**

Initial Beliefs: Mental Notes

smith Jason

```
1   myName("Smith").
2   salary(1500.80).
```

Inspection of agent **smith**

- **Beliefs**

myName("Smith")[source(self)].
salary(*1500.8*)[source(self)].

- **Annotations**

Rules: Predicate and Variable

rule | Jason

```
1  day :- (sky(blue) | sky(grey)) & time(Hour) & Hour <= 17.
2
3  sky(blue).
4  time(14).
```

The verified conditions.

Jason Framework: Plans Format

triggering_event : context <- body.

1. **triggering Event**
   - Um agente pode ter diversos objetivos. Os planos são ativados baseados nos eventos que podem ser ativados em determinado momento.

2. **context**
   - São as condições para a ativação de um plano dentro vários eventos.

3. **body**.
   - É o corpo do plano. Uma sequência de ações a ser executada pelo agente.

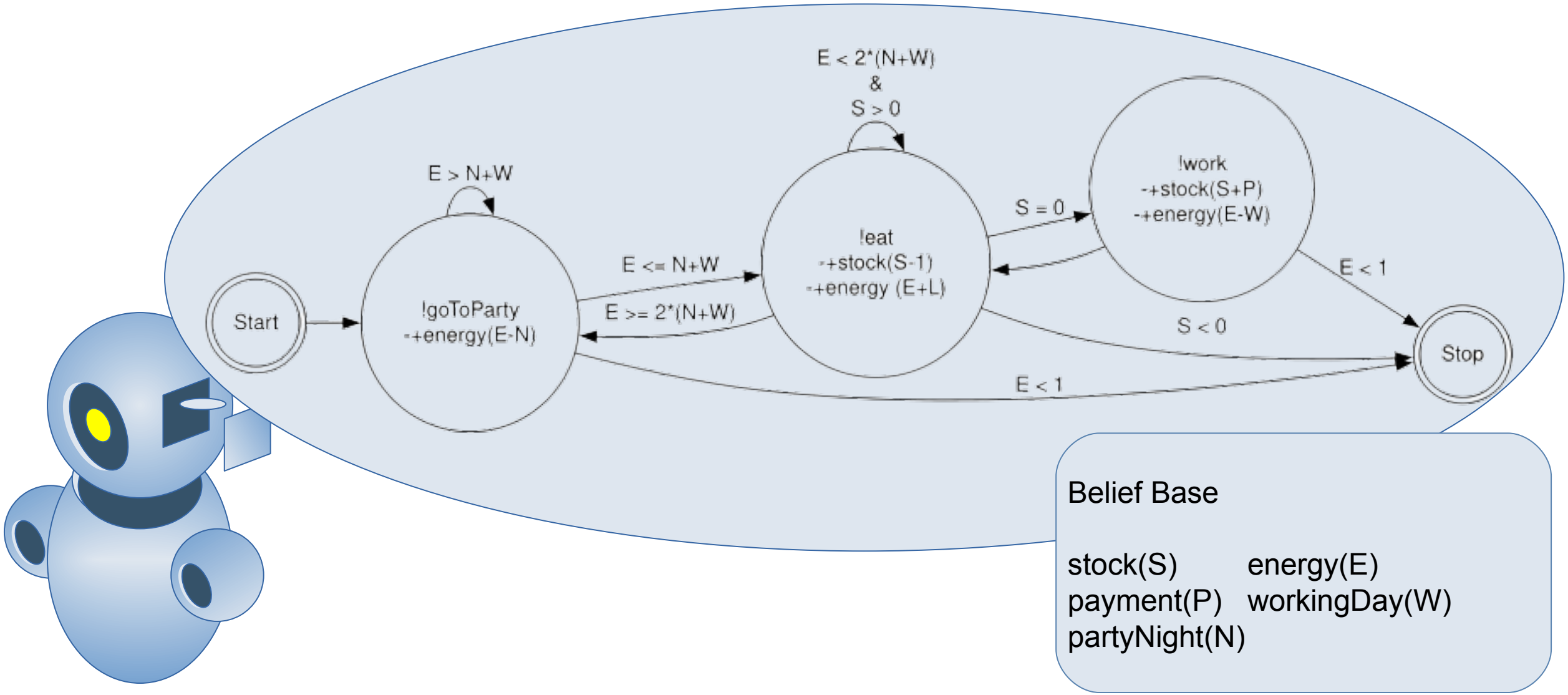
Plan: Hello World

bob Jason

```
1   !start.
2
3   +!start <-
4           .print("I'm Alive!").
```

```
[ChonOS EmbeddedMAS] Starting the Multi-Agent System.
NOTE: Picked up JDK_JAVA_OPTIONS:  --add-opens=java.base
rmi/sun.rmi.transport=ALL-UNNAMED
Jason Http Server running on http://127.0.1.1:3272
[bob] I'm Alive!
```

My First Agent



Belief Base

stock(S) energy(E)
payment(P) workingDay(W)
partyNight(N)

My First Agent: Code

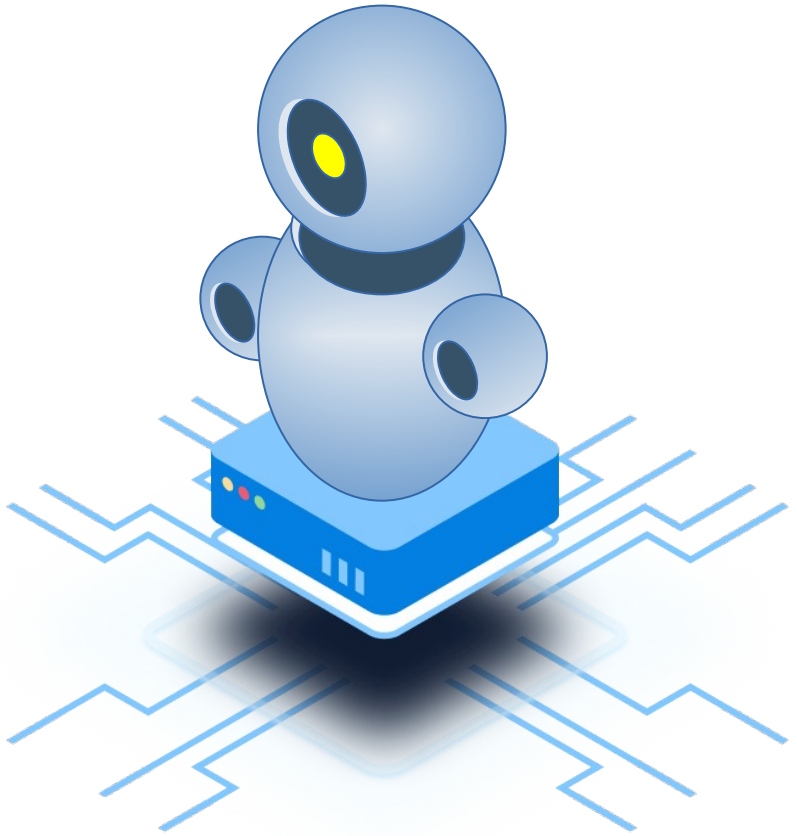
```
/* Initial beliefs and rules */
stock(0).       // This is a Belief that represents the pizza stock.
payment(+2).    // ... represents how many pizzas does Giacomo get by a working day?
energy(5).      // ... represents the Giacomo life energy.
workingDay(-1). // ... represents how much energy does Giacomo lose in a working day?
partyNight(-2). // ... represents how much energy does Giacomo lose on a party night?
lifeParameters(S,E,P,W,N) :- stock(S) &  energy(E) & payment(P) & workingDay(W) & partyNight(N). //this is a RULE!

/* Initial goals */
!startGiacomoLife.

/* Plans */
+!startGiacomoLife <- !startClock; !goToParty.
+!goToParty: lifeParameters(S,E,P,W,N) & (E+(N+W)>1) <- -+lastParty(0); -+energy(E+N); .wait(1000); !goToParty.
+!goToParty: lifeParameters(S,E,P,W,N) & (E+(N+W)<=1)<- !eat.
+!eat: lifeParameters(S,E,P,W,N) & (E<2*(-1*(N+W))) & S>0  <- -+stock(S-1); -+energy(E+1); .wait(1000); !eat.
+!eat: lifeParameters(S,E,P,W,N) & (E>=2*(-1*(N+W))) <- !goToParty.
+!eat: lifeParameters(S,E,P,W,N) & S=0  <- !work.
+!work: lifeParameters(S,E,P,W,N) <- -+stock(S+P); -+energy(E+W); !eat.
+!startClock <- +lastParty(0); !!tickingClock.
+!tickingClock <- .wait(100); ?lastParty(Time); -+lastParty(Time+100); !tickingClock.

+energy(E): E < 1 <- .print("Giacomo died of hunger!"); .stopMAS.
+stock(S): S < 0 <- .print("Without food!"); .stopMAS.
+lastParty(Time): Time > 10000 <- .print("Giacomo died of sadness!"); .stopMAS.
```

https://github.com/chon-group/distributedAndEmbeddedAI/blob/main/workshops/sepex/2024/projects/giacomoAgent.chon

JASON stdlib → https://jason-lang.github.io/api/jason/stdlib/package-summary.html

Introdução ao Jason → https://www.researchgate.net/publication/228828757_Introducao_ao_desenvolvimento_de_sistemas_multiagentes_com_Jason

EMBEDDED MAS



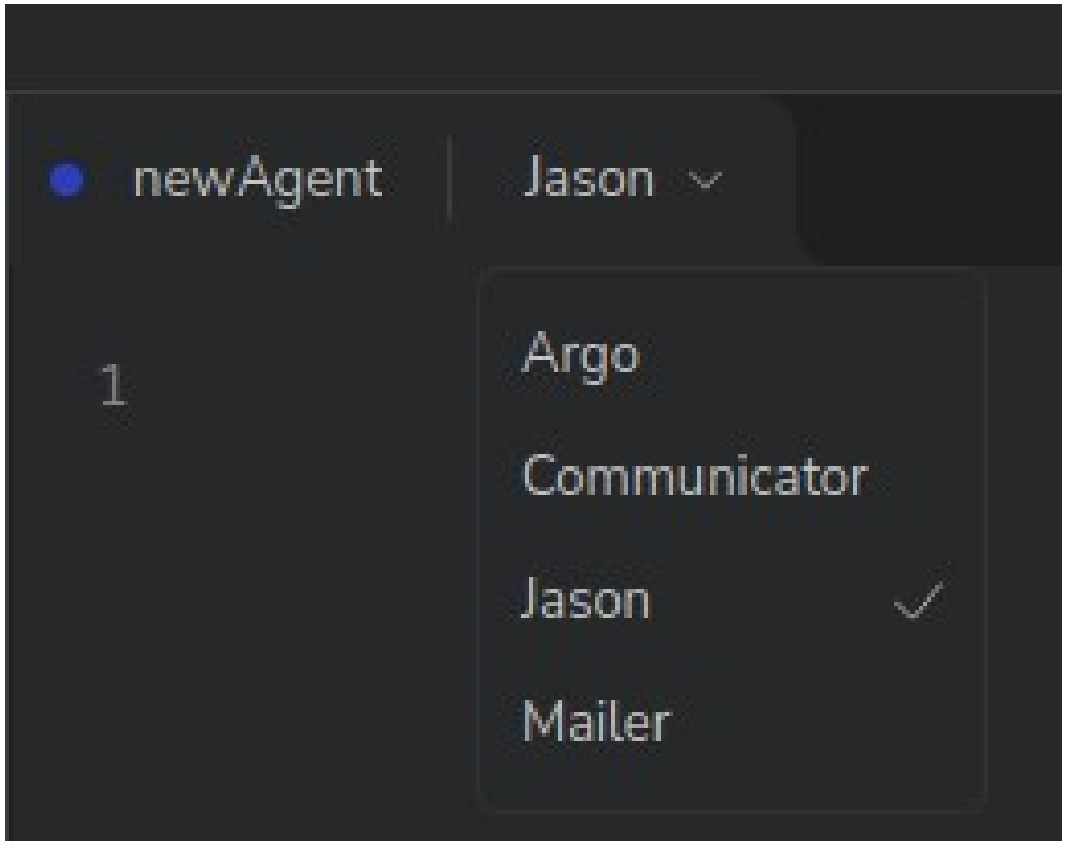
Jason Embedded

Jason Embedded is a spin-off Version of Jason for IoT and Embedded MAS:

- **Autonomy** as a characteristic an Embedded MAS provides to a device that does not need external architectures to control and manage it.
- **Communicability** is the agent's ability to communicate with other agents in its MAS or another MAS.
- **Mobility** as the agents' ability to move from one MAS to another.
- **Fault Tolerance and Adaptability** are defined as the ability of an agent to identify if a physical resource is absent or not answering commands and to overcome this situation by modifying its goals.
- **Distributed Ledger Technologies** technologies to facilitate the agreement between agents.

Jason Embedded

- **Jason Embedded** also provides **new types of agents** to control hardware devices and to communicate with agents hosted in other MAS.



Jason Embedded

- **Jason Embedded** also provides **new types of agents** to control hardware devices and to communicate with agents hosted in other MAS.

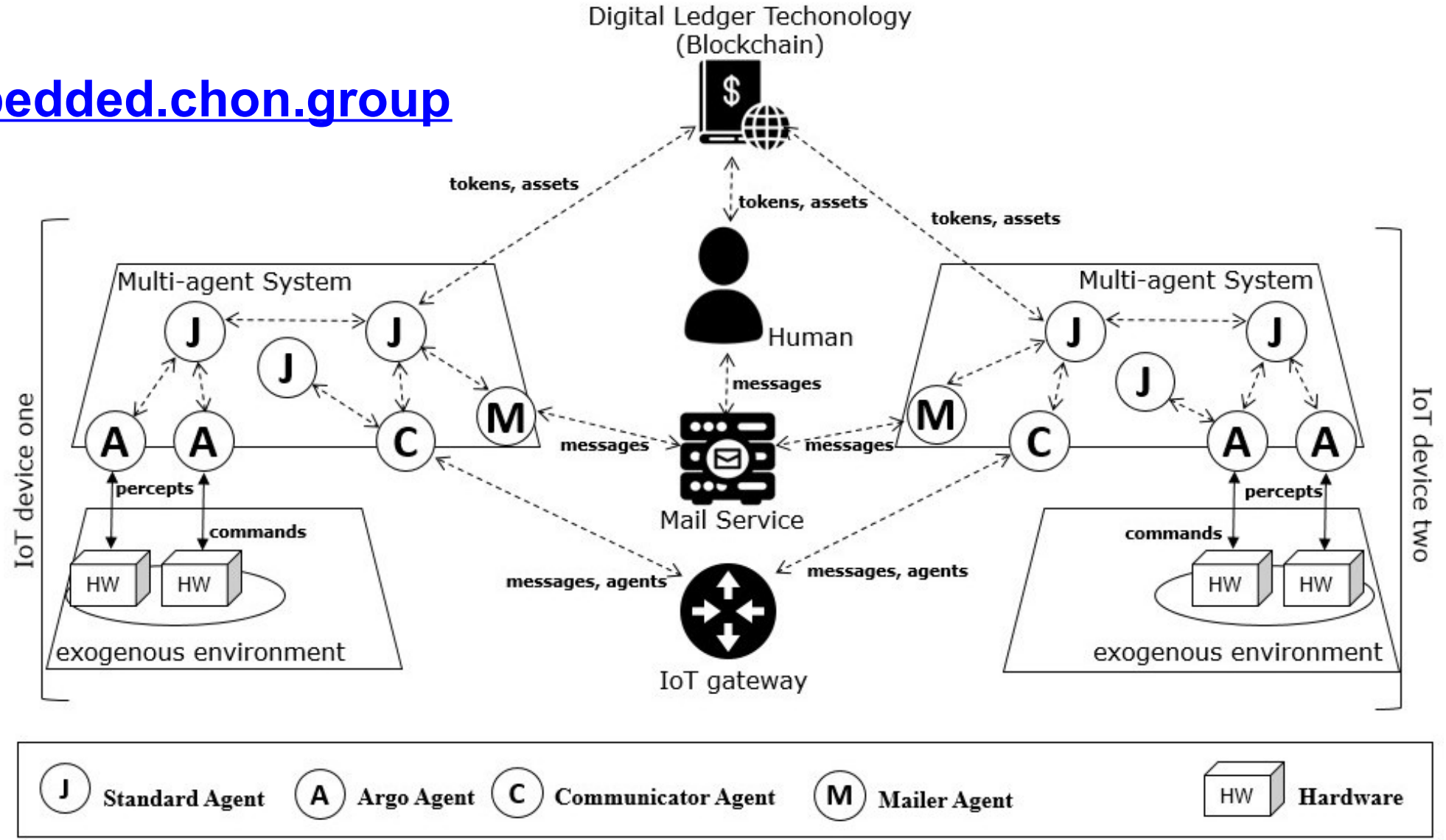
  - **ARGO**: is a customized agent architecture built on the Jason framework that extends Jason's standard agents by adding the **ability to control microcontrollers** [Pantoja et al., 2016].
  - **Hermes (Communicator)** : is another customized agent architecture built on Jason's Standard agent by adding the **ability to communicate** with agents from **other MAS**, which also have Communicator agents [Pantoja et al., 2018].
  - **Mailer** : agent architecture based on the Jason framework to enable secure and simplified **human-agent interaction** [Lazarin et al., 2024].

Jason Embedded

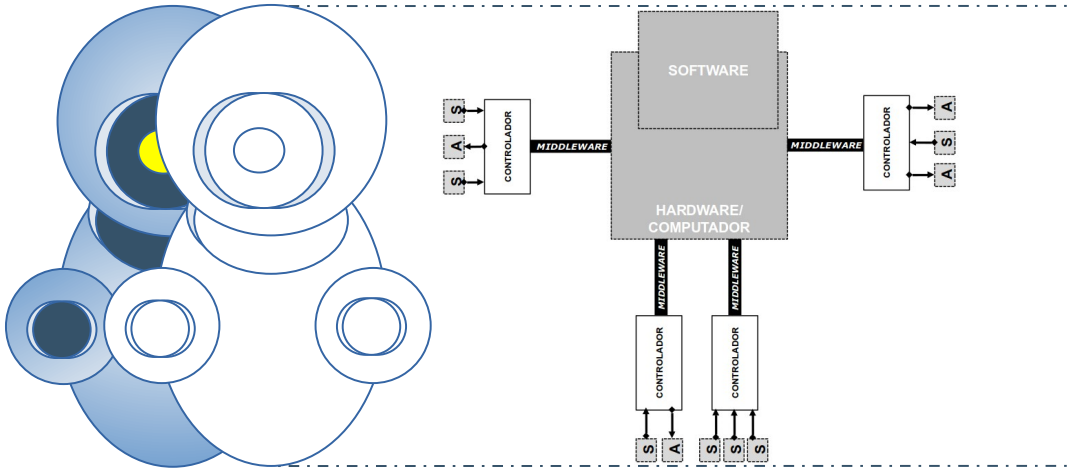
- **Mobility** is based on **bio-inspired protocols** [Jesus et al., 2021].
  - The protocols simulate natural behaviors that could be explored in collaborative tasks using IoT devices.
  - One or more agents or even the whole MAS could move from one device to another to take control of the destination device (**Predation**) or to use it as a temporary non-hazardous relationship (**Mutualism** and **Inquilinism**) if both parties accept the protocol.
- **Middleware** that allows cognitive agents to manipulate Tokens and NFT in blockchain network [Lazarin et al., 2023].

Jason Embedded

https://jasonembedded.chon.group



ARGO AGENT

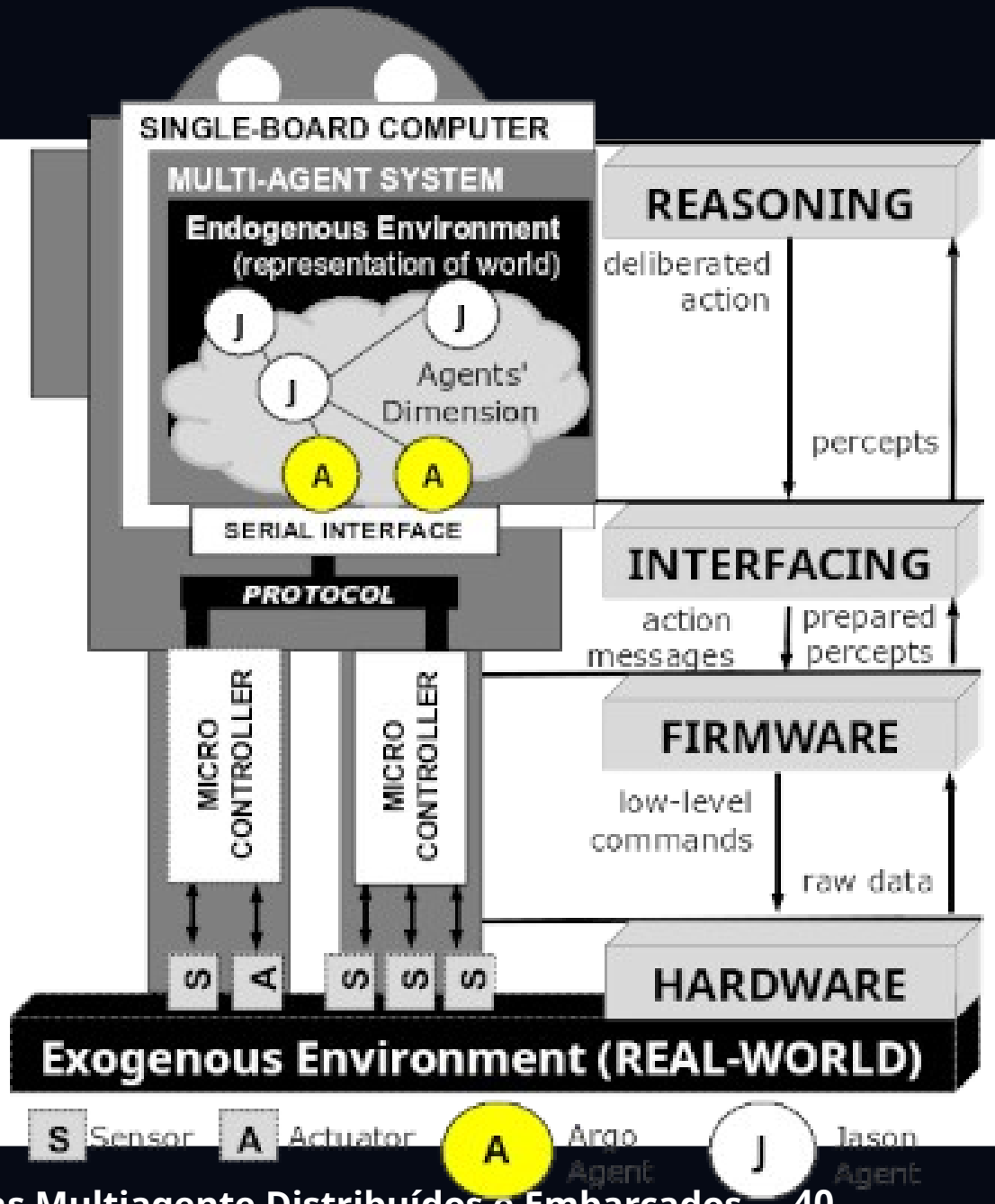


https://argo.chon.group

Argo for Jason

ARGO is a customized agent architecture that **interfaces** sensors and hardware actuators.

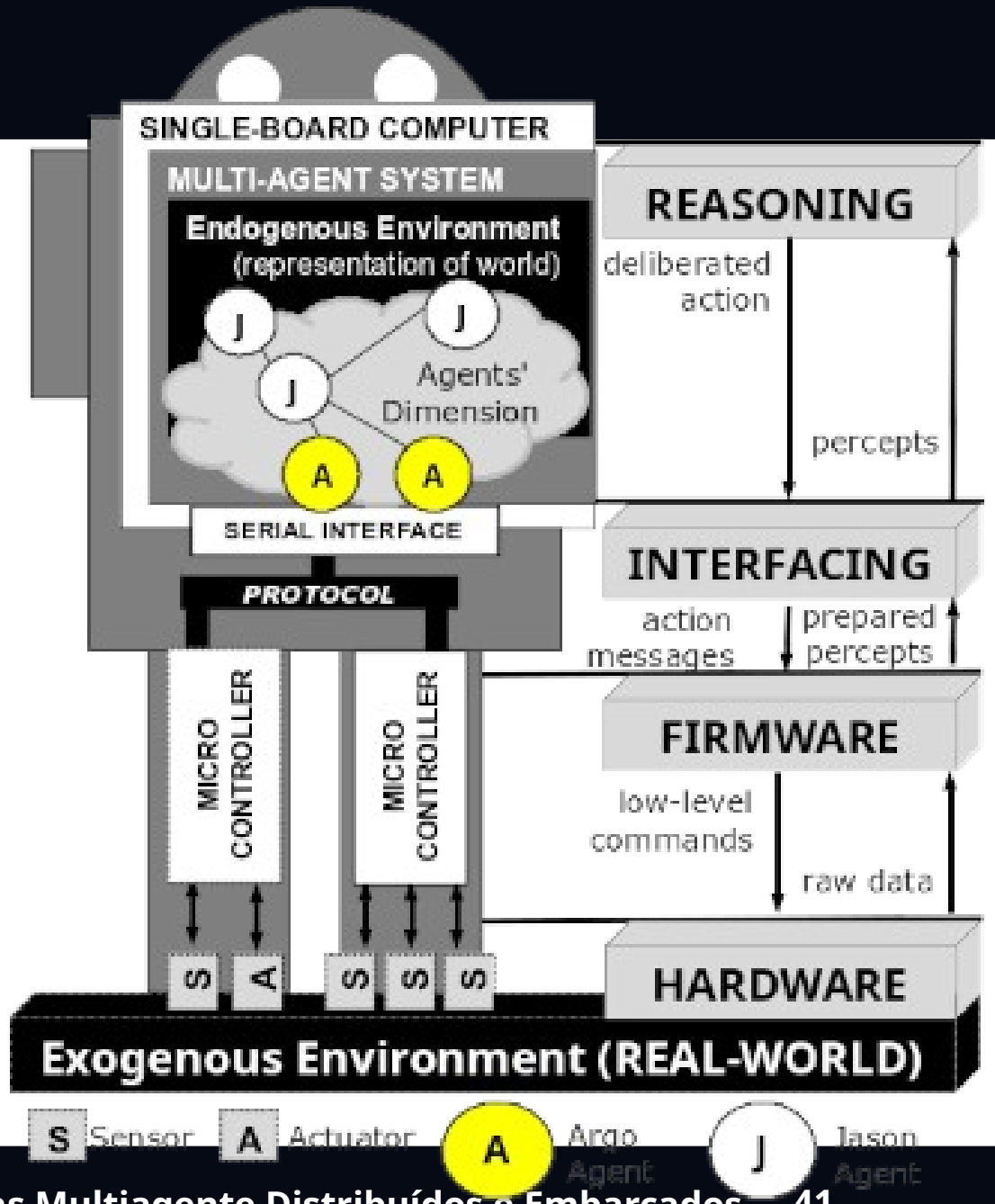
ARGO aims to be a practical architecture for **programming embedded BDI agents** using **Jason** and microcontroller boards.



Argo for Jason

The **ARGO** allows to:

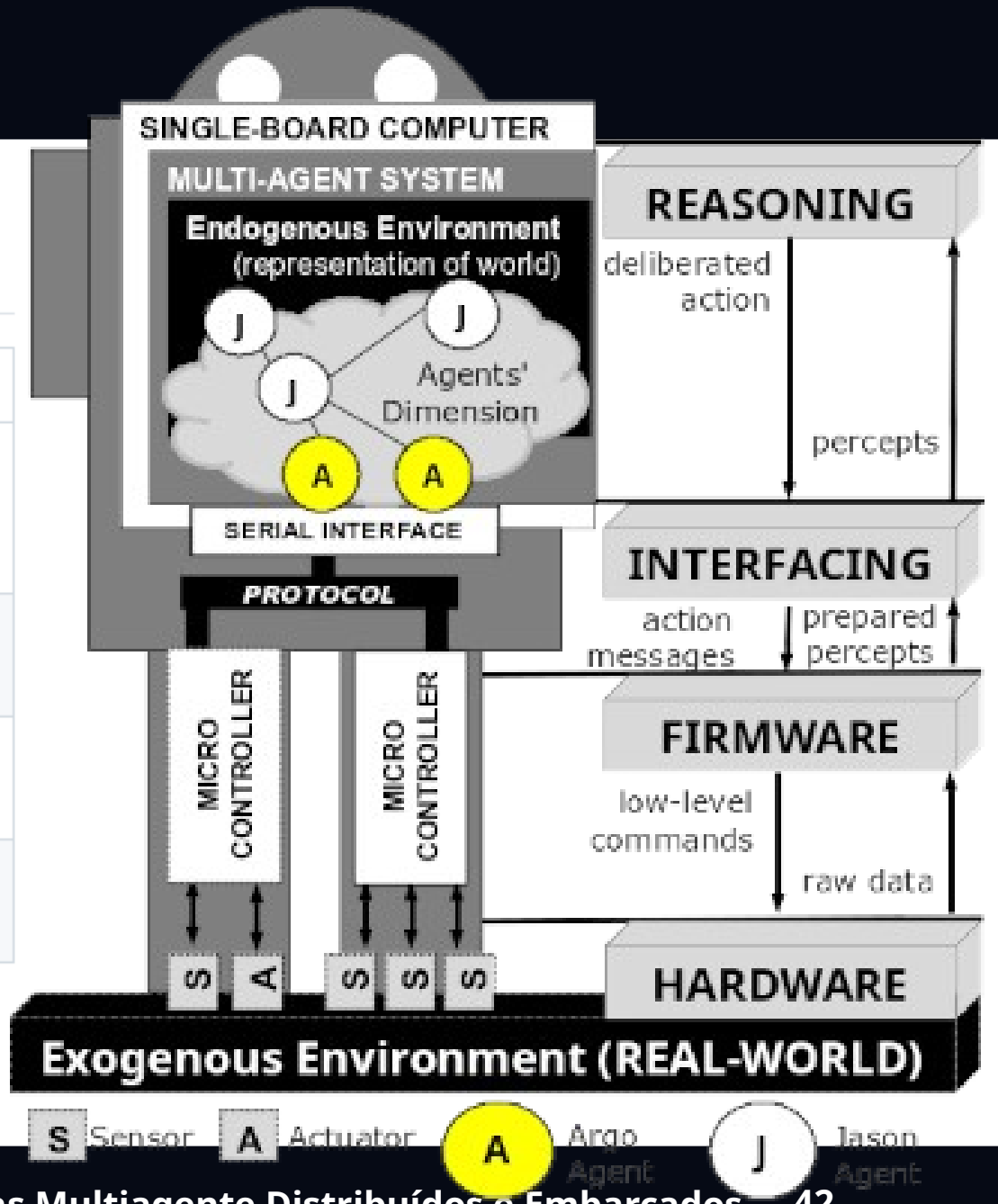
1. to direct control actuators at runtime;
2. to receive sensor perceptions within a predefined period automatically;
3. to change which devices are being accessed at runtime;
4. to communicate with other agents in Jason;
5. whether or not to perceive the real world at runtime;
6. to change perception filters at runtime.



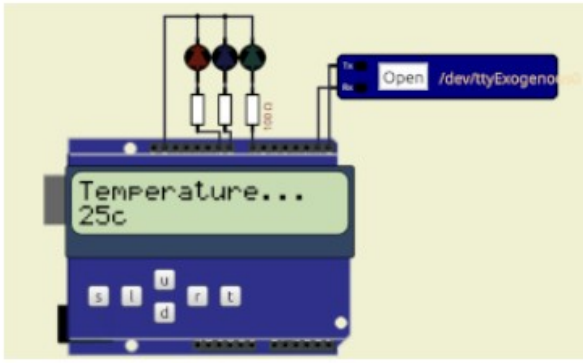
Argo for Jason

ARGO Internal Actions

Action	Description
.argo.port(*P*)	defines which serial port should be used by the agent, where *P* is a literal representing the port identification(e.g., COM8, ttyUSB0).
.argo.limit(*M*)	defines the sensing interval, where *M* is a value in milliseconds.
.argo.percepts(*open*|*close*)	decides whether or not to perceive the exogenous environment (physical world).
.argo.act(*A*)	sends to the hardware an action, represented by literal *A*, to be executed by a microcontroller;



Exercise: LCD KeyPad



Percepts:

```
device(arduinoWithLCDKeypadShield)[source(percept)].    // the device name
humidity(H)[source(percept)].                           // H is a Integer
rainLast24hrs(R)[source(percept)].                      // R is a Integer
temperature(T)[source(percept)].                        // T is a Integer
```

Actions:

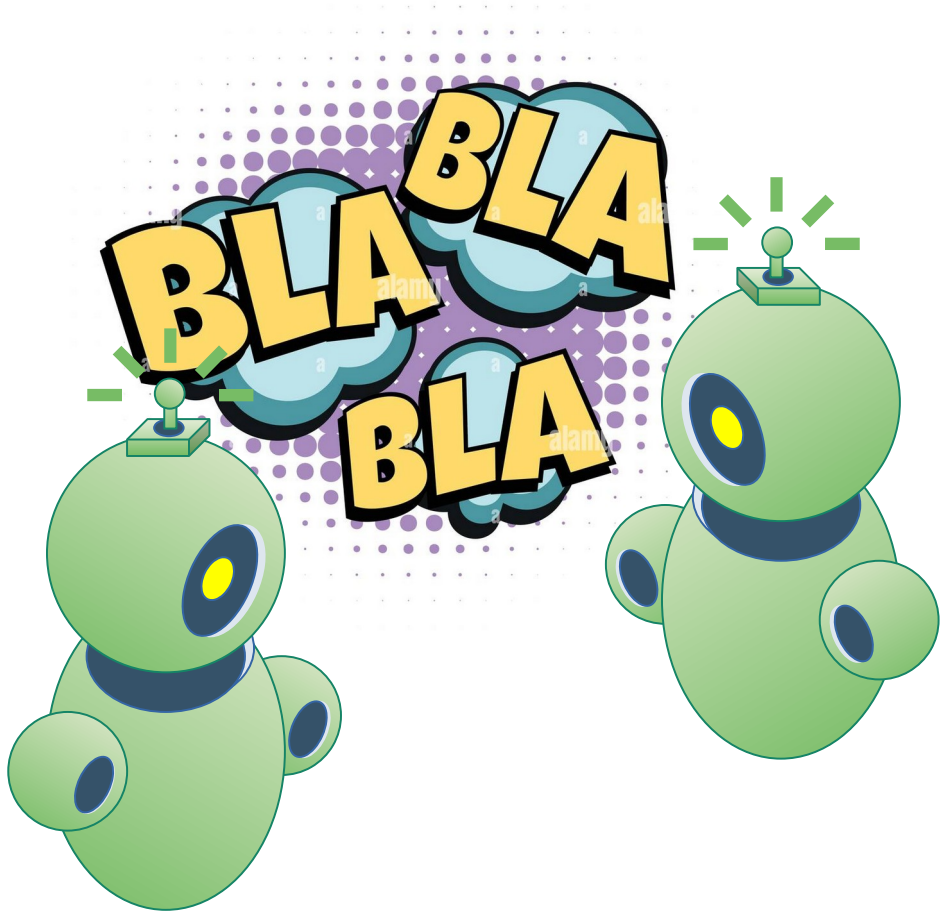
```
.argo.act(redAlert)             // turn on the RED LED
.argo.act(yellowAlert)          // turn on the YELLOW LED
.argo.act(greenAlert)           // turn on the GREEN LED
.argo.act(alertOff)             // turn off all LED
.argo.act(M)                    // print the String M in the LCD Display
```

Adjust the ARGO agent to:

- turn on the **green LED** if the rain intensity less than 50mm;
- turn on the **yellow LED** if the rain intensity exceeds 50mm;
- turn on the **red LED** if the the rain intensity exceeds 80mm;

https://github.com/chon-group/distributedAndEmbeddedAI/blob/main/workshops/sepex/2024/projects/lcdKeyPad.chon

COMMUNICABILITY



Jason Framework: Communication

Based on the theory of Speech Acts [1] and KQML [2] (Knowledge Query and Manipulation Language), a communication protocol for knowledge-based systems.

[1] M. Bierwisch, “Semantic Structure and Illocutionary Force”, em Speech Act Theory and Pragmatics, J. R. Searle, F. Kiefer, e M. Bierwisch, Orgs., Dordrecht: Springer Netherlands, 1980, p. 1–35. doi: 10.1007/978-94-009-8964-1_1.
[2] T. Finin, R. Fritzson, D. McKay, e R. McEntire, “KQML as an agent communication language”, em Proceedings of the third international conference on Information and knowledge management - CIKM ’94, Gaithersburg, Maryland, United States: ACM Press, 1994, p. 456–463. doi: 10.1145/191246.191322.

Jason Framework: Performatives

The performatives that are currently available for agent communication in Jason are largely inspired by KQML. We also include some new performatives, related to plan exchange rather than communication about propositions. The available performatives are briefly described below, where s denotes the agent that sends the message, and r denotes the agent that receives the message [1].

PERFORMATIVE	DESCRIPTION
tell	s intends r to believe (that s believes) the sentence in the message's content to be true;
untell	s intends r not to believe (that s believes) the sentence in the message's content to be true;
achieve	s requests that r try to achieve a state of the world where the message content is true;
unachieve	s requests that r try to drop the intention of achieving a state of the world where the message content is true;
tellHow	s informs r of a plan;
untellHow	s requests that r disregard a certain plan (i.e., delete that plan from its plan library);
askIf	s wants to know if the content of the message is true for r;
askAll	s wants all of r's answers to a question;
askHow	s wants all of r's plans for a triggering event;

[1] R. H. Bordini e J. F. Hübner, "BDI Agent Programming in AgentSpeak Using Jason", em Computational Logic in Multi-Agent Systems, F. Toni e P. Torroni, Orgs., em Lecture Notes in Computer Science, vol. 3900. Berlin, Heidelberg: Springer Berlin Heidelberg, 2006, p. 143–164. doi: 10.1007/11750734_9.

Jason Framework: Message Structure

.send(receiver, ilf, message, answer, timeout)
.broadcast(ilf, message)

receiver : Name of the agent receiving the message (or list of recipients)
ilf : Illocutionary force of the speech act (KQML)
message : Message content
asnwer : A term that will store the response (optional field)
timeout : Timeout in milliseconds to receive a response (optional field)

Illocutionary Forces: tell

kate Jason

```
1   !hi.
2
3   +!hi <-
4           .print("Hi, I'm Kate'!");
5           .send(bob, tell, name(kate)).
```

Inspection of agent **bob**

- Beliefs	name(kate)[source(kate)].

Illocutionary Forces: achieve

kate — Jason

```
1
2
3
4
5
6
```

```
!turnOn(lights).

+!turnOn(light) <-
        .print("Please Bob, turn on the lights.");
        .send(bob, achieve, turnOn(lights)).
```

bob — Jason

```
1
2
3
```

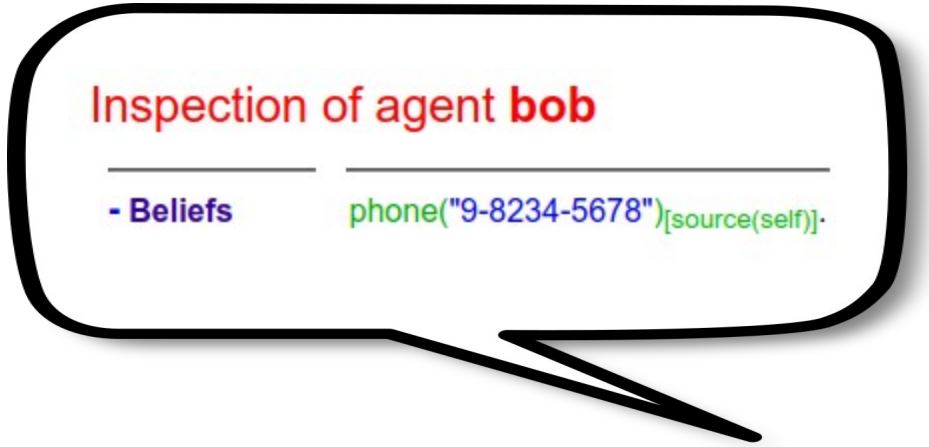
```
+!turnOn(light) <-
        .print("Lights On!").
```

Illocutionary Forces: askOne

kate | Jason

```
1   !hi.
2
3   +!hi <-
4           .print("What's your phone number?");
5           .send(bob, askOne, phone(Number)).
```

Illocutionary Forces: askOne



Illocutionary Forces: askOne

Example: Chief and Glutton

https://github.com/chon-group/distributedAndEmbeddedAI/blob/main/workshops/sepex/2024/projects/chiefGlutton.chon

Image credits:
https://smurfs.fandom.com/wiki/Chef_Smurf
https://smurfs.fandom.com/pt/wiki/Fominha

TRANSACTIONS

https://github.com/chon-group/Velluscinum/wiki

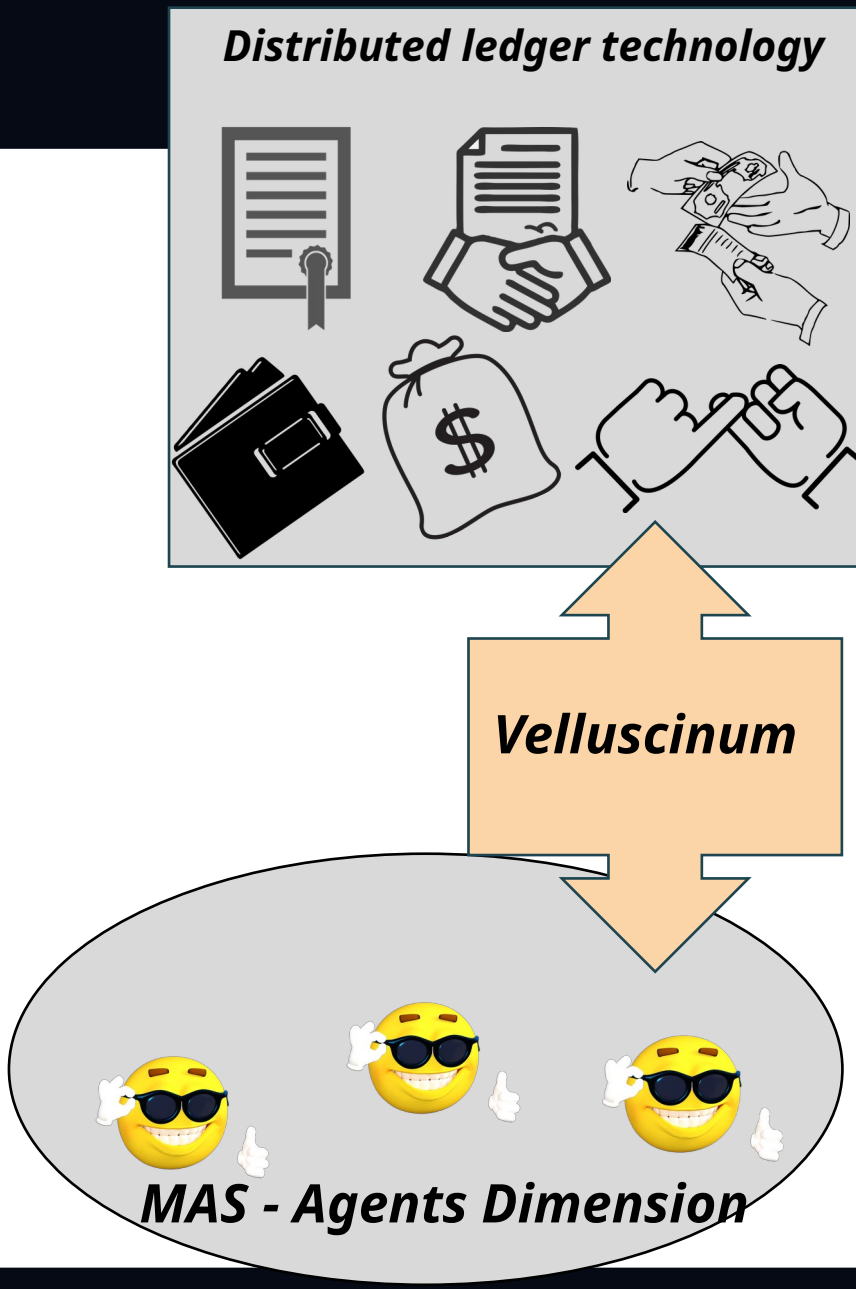
Using digital assets in the relationships between cognitive agents:

the transfer of funds;

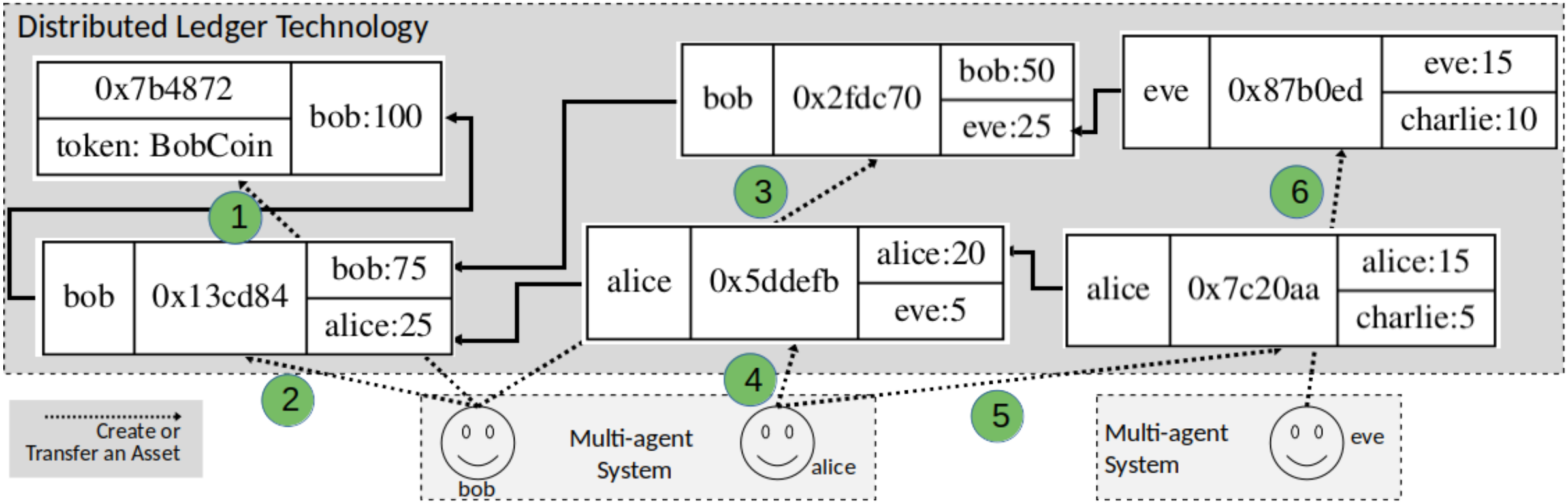
registration of ownership of artifacts;

declaration of promises or agreements.

Allowing the agents to manipulate assets and wallets directly in the DLT.



Divisible asset such as cryptocurrency



buildWallet-CLI

Creates two files with an ECDSA keyset in Base58.

DESCRIPTION

```
velluscinum buildWallet <filename>
```

Parameters	Description
`<filename>`	The name of the files that will storage the public and private ECDSA key.

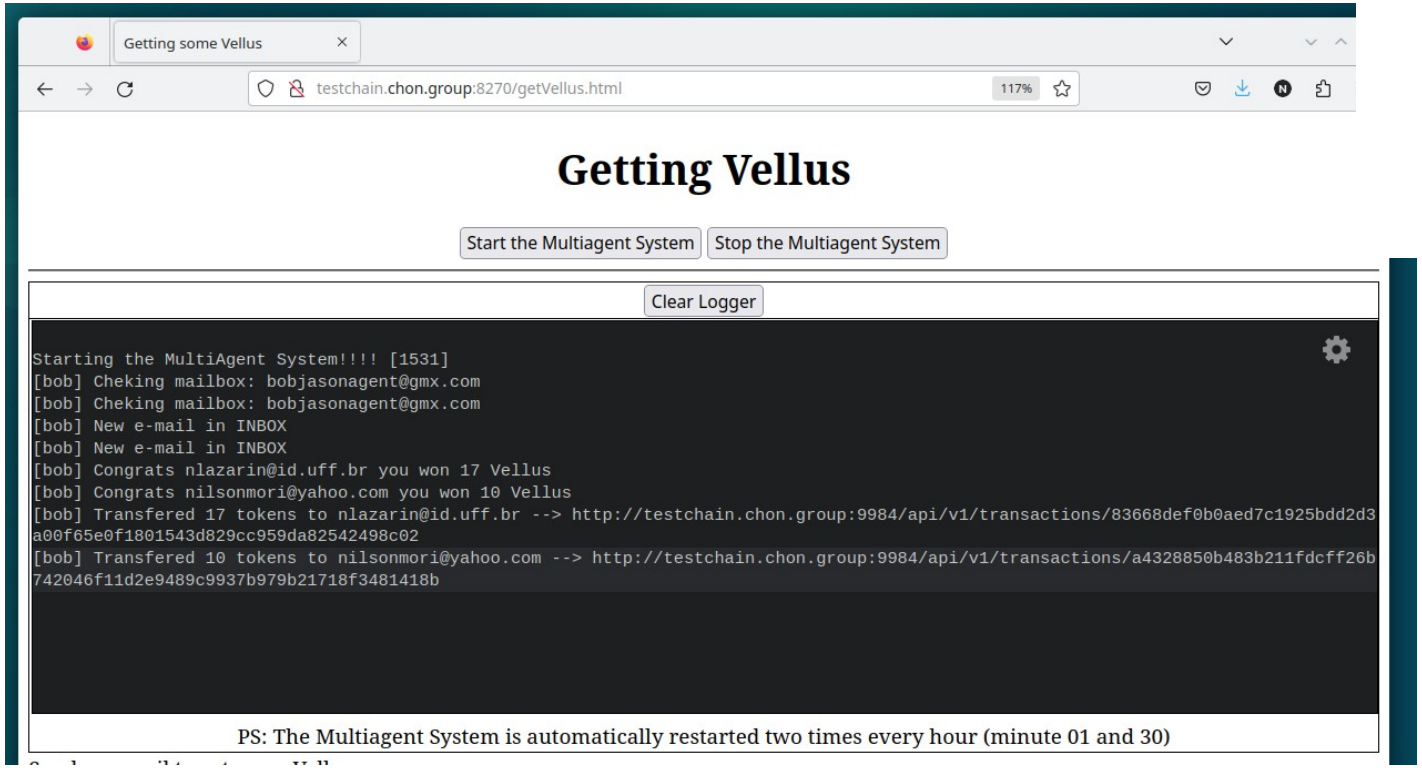
EXAMPLE

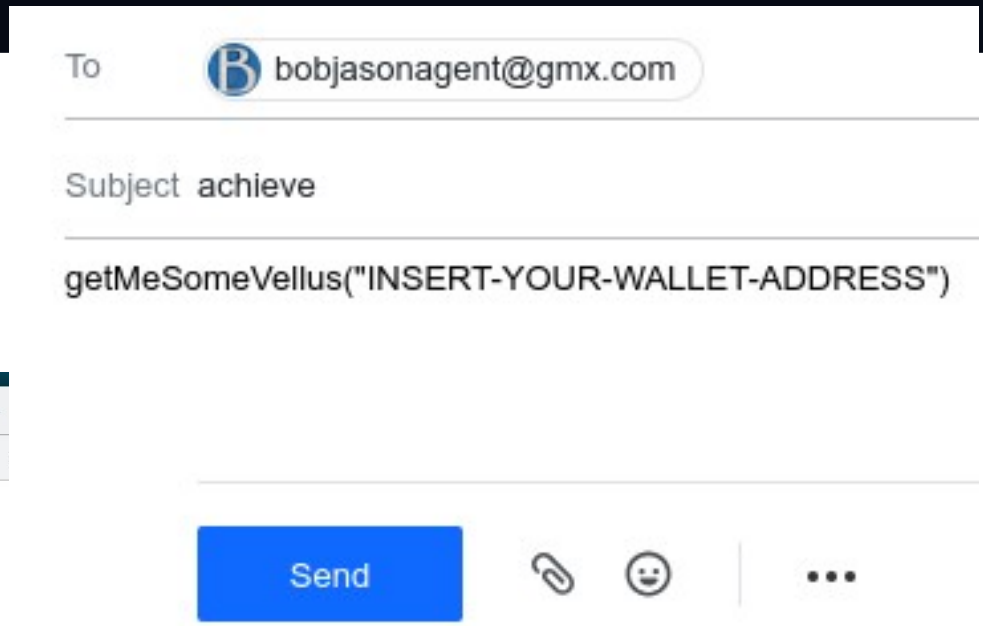
```
velluscinum buildWallet bob
```

```
nilson@dell:~$ velluscinum buildWallet bob
[Velluscinum] Build Wallet... 5nbmmHUSjqsAL6D6jbpKpXQW9UQTHg4YpD84hweNEmLH
nilson@dell:~$ ls
bob.privateKey  bob.publicKey
nilson@dell:~$
```

Getting some Vellus

http://testchain.chon.group:8270/getVellus.html

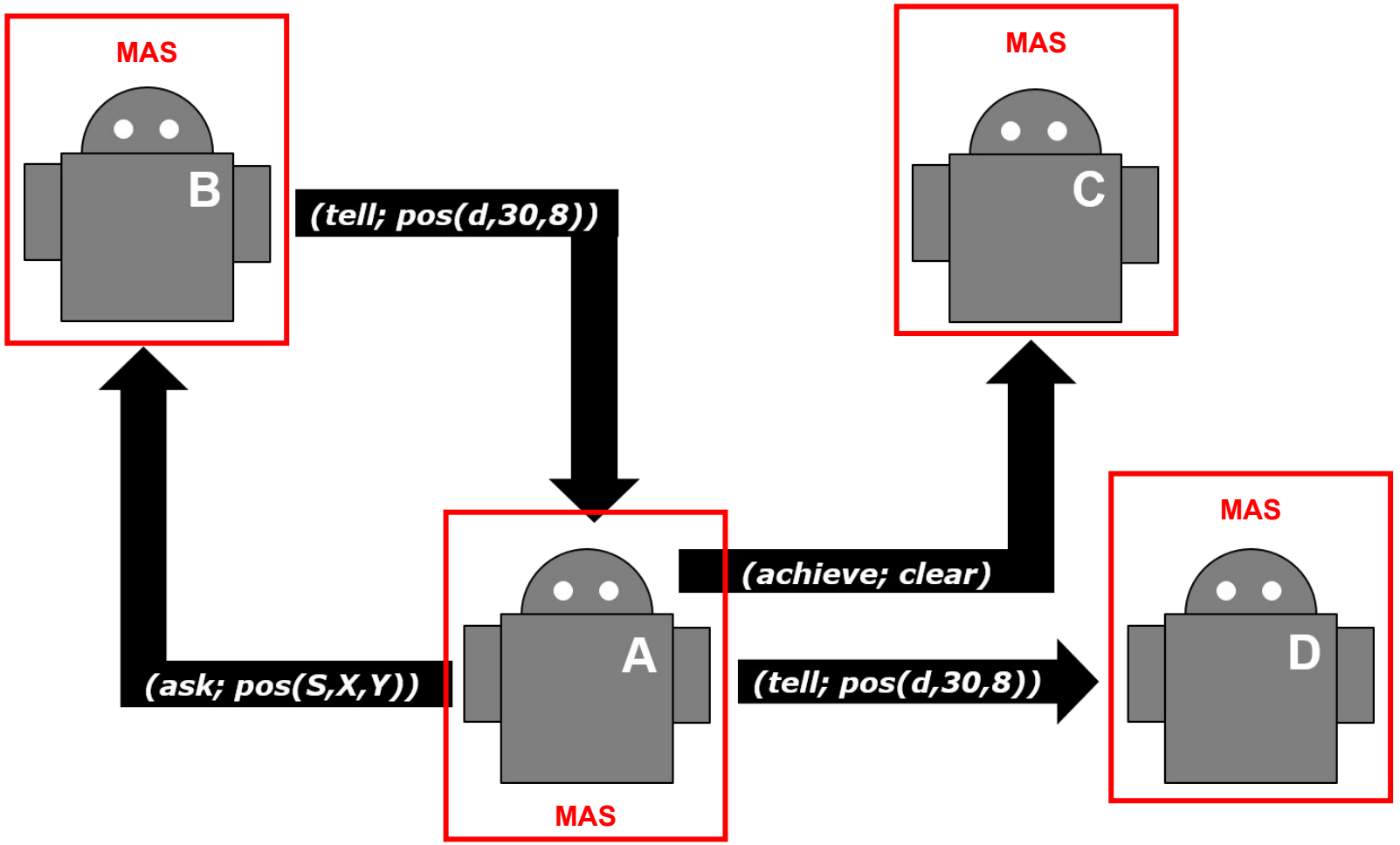




https://github.com/chon-group/distributedAndEmbeddedAI/blob/main/workshops/sepex/2024/projects/chiefGlutonVellus.chon

Image credits:
https://smurfs.fandom.com/wiki/Chef_Smurf
https://smurfs.fandom.com/pt/wiki/Fominha
https://smurfs.fandom.com/pt-br/wiki/%C3%81rvore_de_Dinheiro

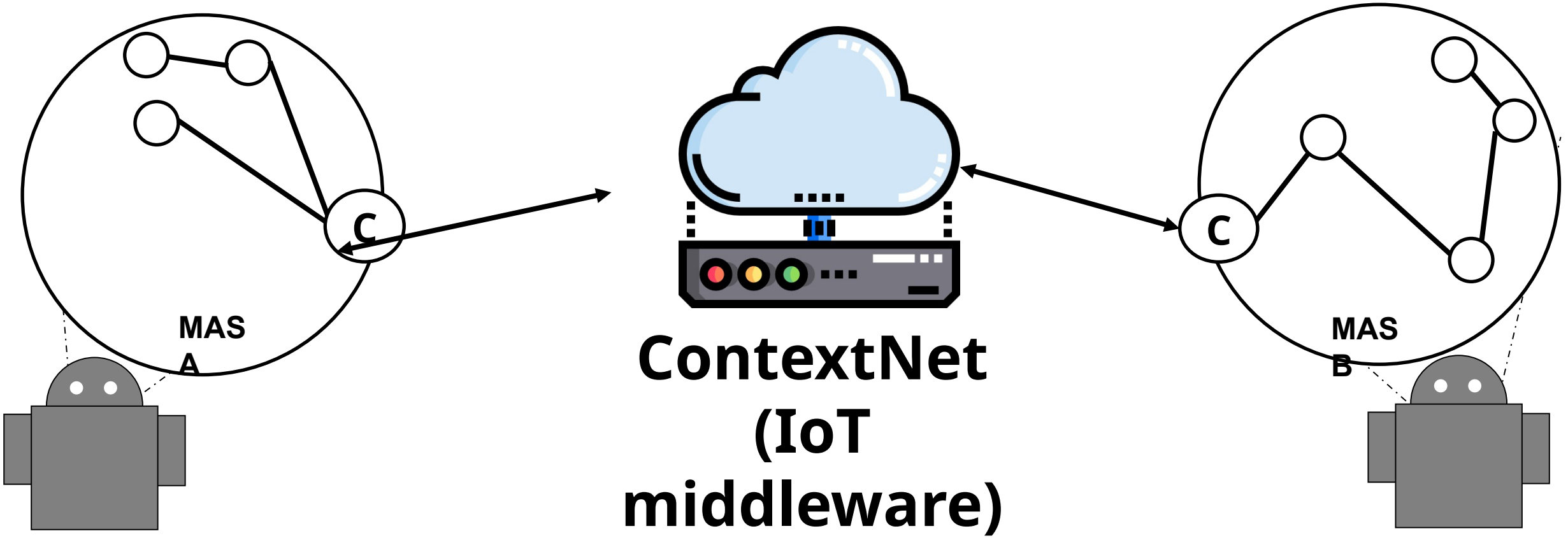
Collaborative MultiAgent System



https://github.com/chon-group/Hermes

Hermes Agents: Server Communication

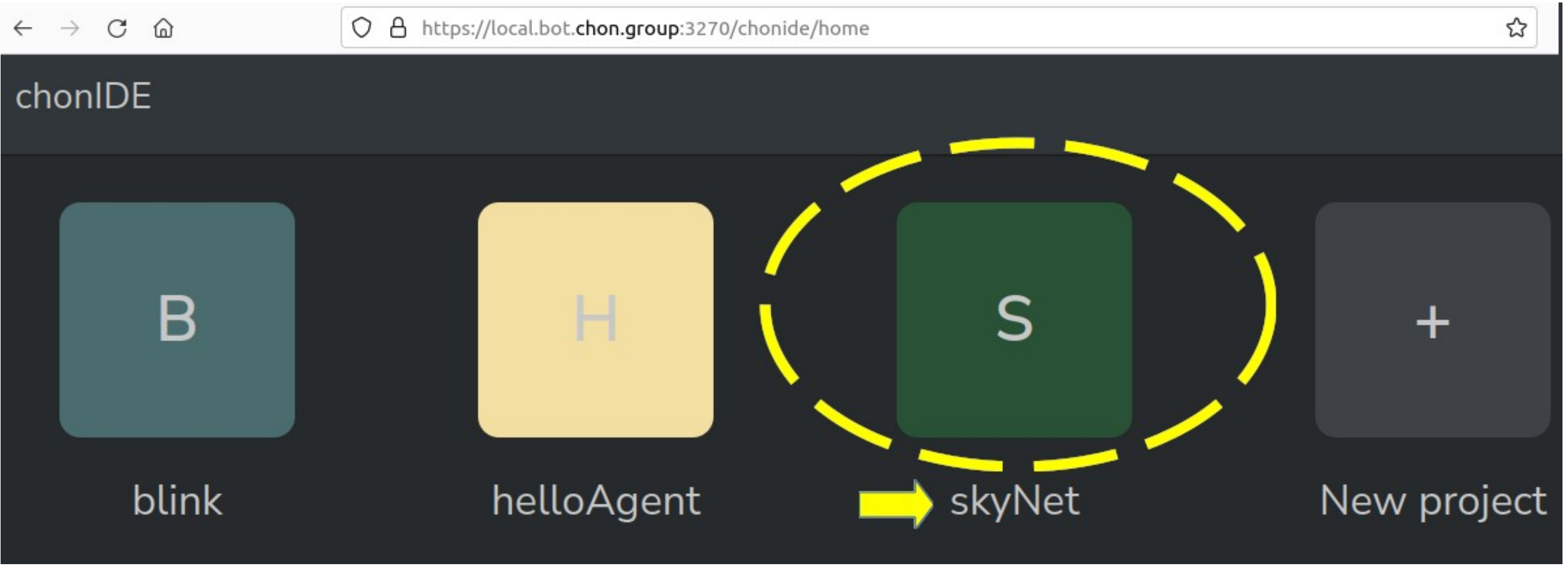
Public Server: skynet.chon.group - UDP Port: 5500



Hermes Agents: Internal Actions

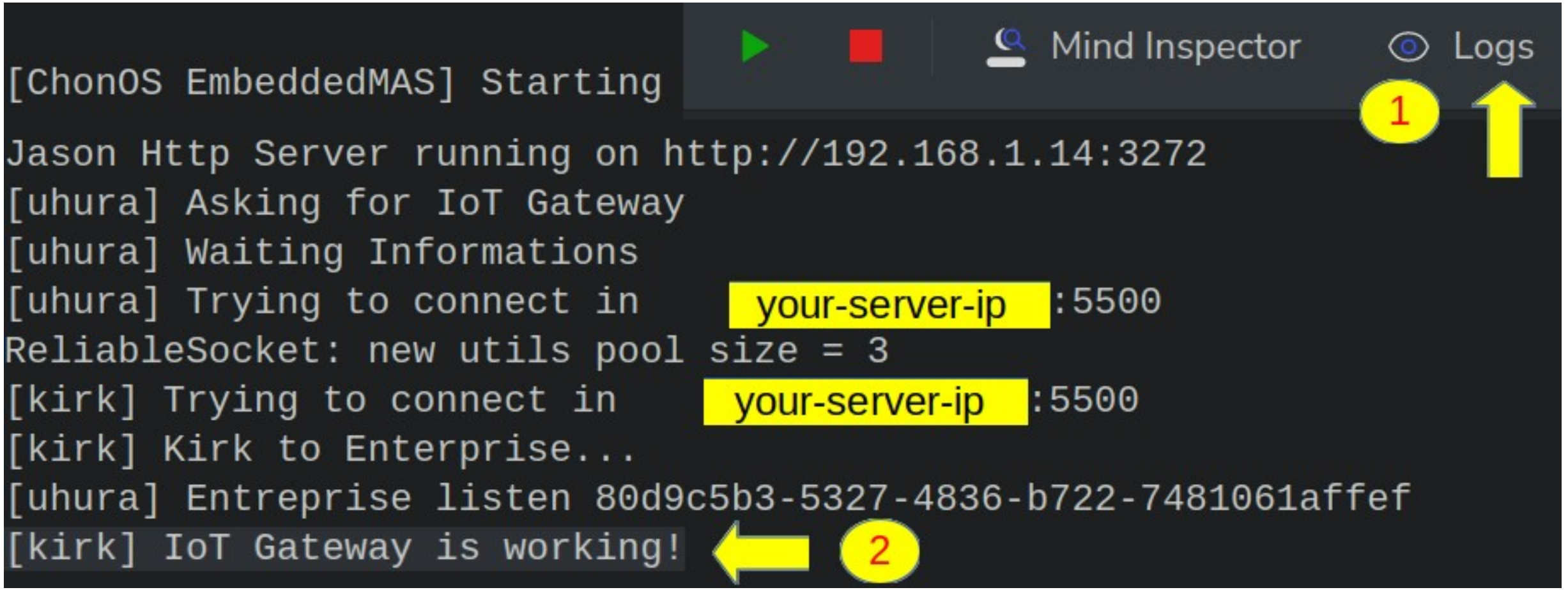
Hermes	.hermes.configureContextNetConnection("***X***",***G***,***E***,***U***)	Configures an ContextNet network. Where ***X*** is a string that represents an network name; ***G*** is a literal that represents the FQDN or the network address of an gateway; ***E*** is a number that represents the network port of an gateway; ***U*** is a literal that represents the identification of the device in the network.
	.hermes.connect("***X***")	Joins at "***X***" ContextNet network.
	.hermes.sendOut(***D***,***f***,***M***)	Dispatches a message to another MAS. Where ***D*** is a literal that represents the identification of the recipient MAS; ***f*** is a illocutionary force (*tell* | *untell* | *achieve* | *unachieve*); ***M*** is a literal that represents the message.
	.hermes.moveOut(***D***,***b***,***A***)	Carries over the agents to other MAS. Where ***D*** is a literal that represents the identification of the recipient MAS; ***b*** is a bio-inspired protocol (*inquilinism* | *mutualism* | *predation*); ***A*** is one, all, or a set of agents (i.e., all, agent or [$agent_1$, $agent_2$, $agent_n$])
	.hermes.disconnect("***X***");	Disconnects at "***X***" ContextNet network.

Hello SkyNet

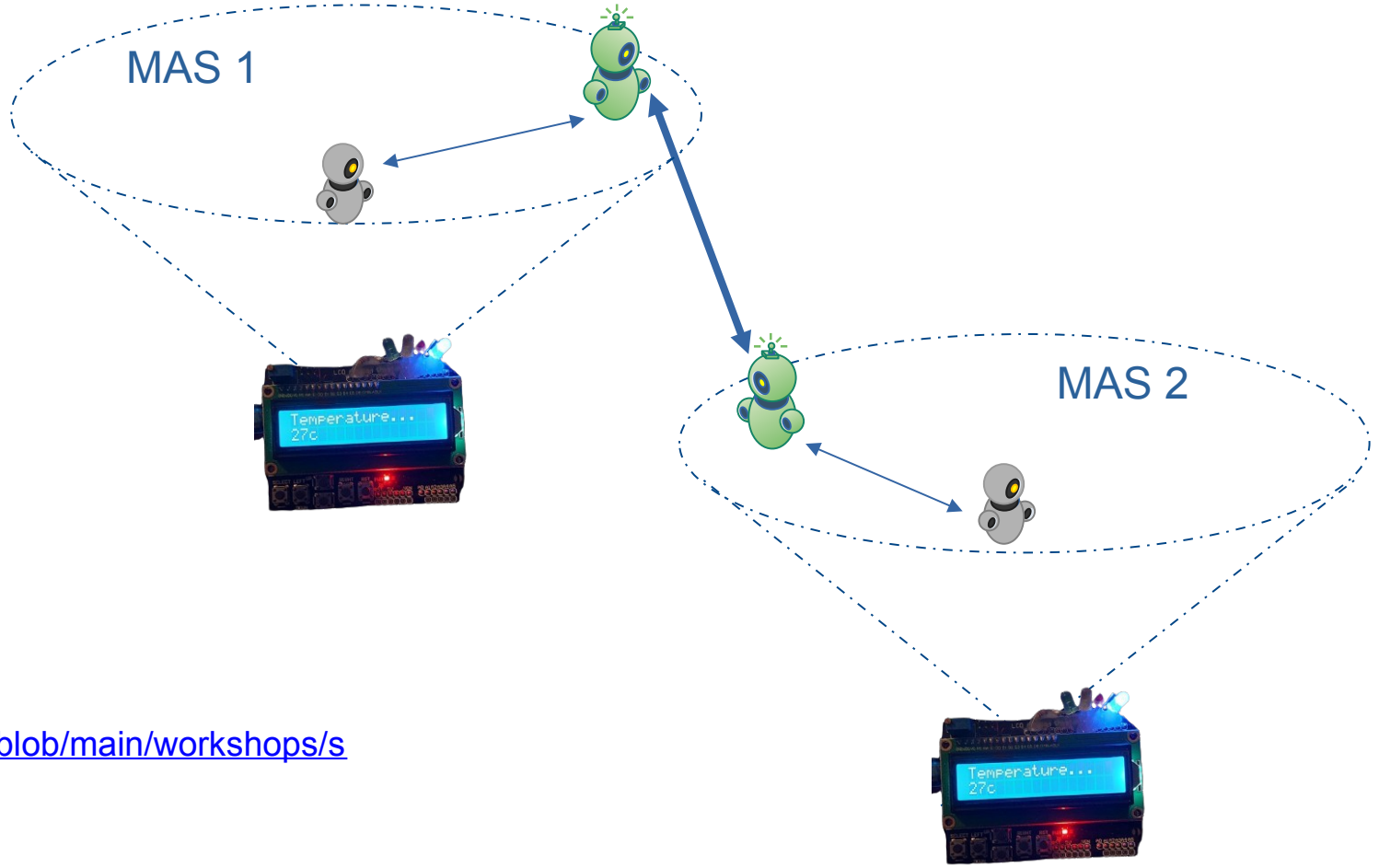


Hello SkyNet

Hello SkyNet



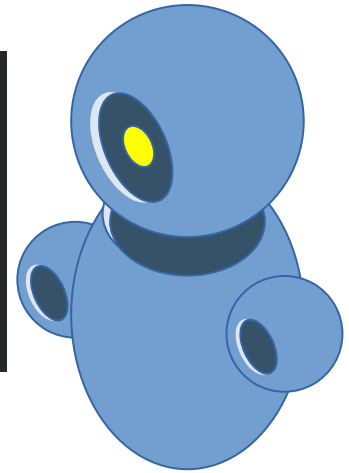
Example: MAS Communication

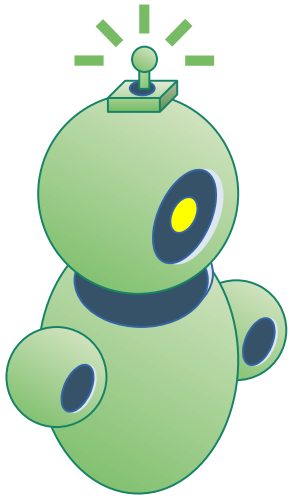


https://github.com/chon-group/distributedAndEmbeddedAI/blob/main/workshops/sepex/2024/projects/communicatorAGENT.chon

Example: MAS 1

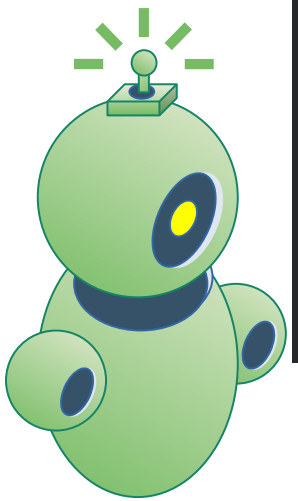
```
+rainLast24hrs(R): R > 50 <-
        .print("New perception-> rainLevel: ",R," mm");
        .concat("Atention rain level is ",R," mm", RainLevelMessage);
        .send(agentHERMES,achieve,forward(RainLevelMessage)).
```





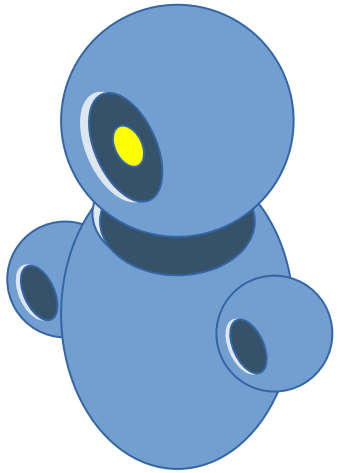
```
+!forward(Message) <-
        ?neighborUUID(N);
        .print("Forwarding a message to ", N);
        .sendOut(N, achieve, showMessage(Message)).
```

Example: MAS 2



```
+!showMessage(Message)[source(Device)] <-
        .print("I received the following message: ", Message);
        .send(agentARGO, achieve, infoLCD(Message)).
```

```
+!infoLCD(Message) <-
        .random(R); .wait(2000*R);
        .argo.act(Message).
```



Simple Exercise

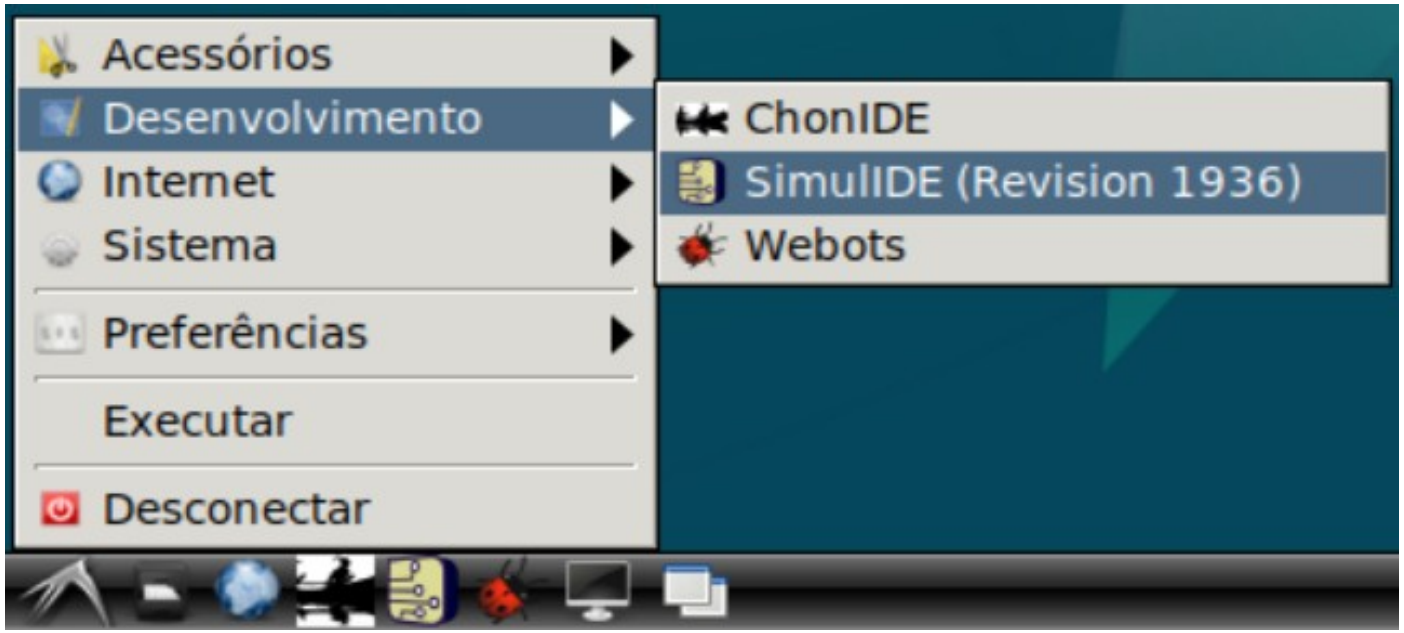
Adjust to:

- turn on the **green LED** in **MAS 2** if the rain intensity less than 50mm in **MAS 1**;
- turn on the **yellow LED** in **MAS 2** if the rain intensity exceeds 50mm in **MAS 1**;
- turn on the **red LED** in **MAS 2** if the the rain intensity exceeds 80mm in **MAS 1;**

OTHER TOOLS

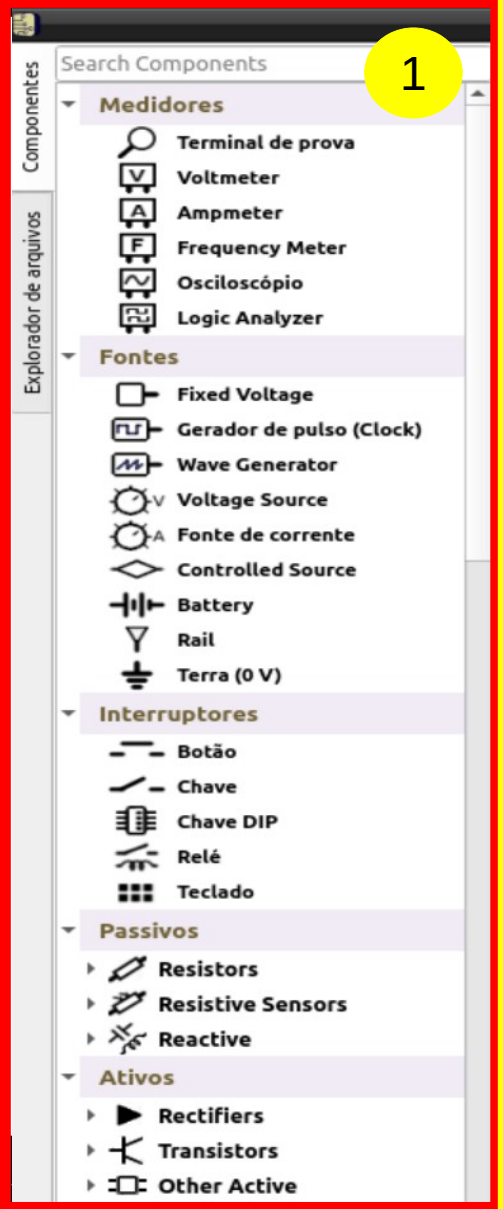
SimulIDE Circuit Simulator

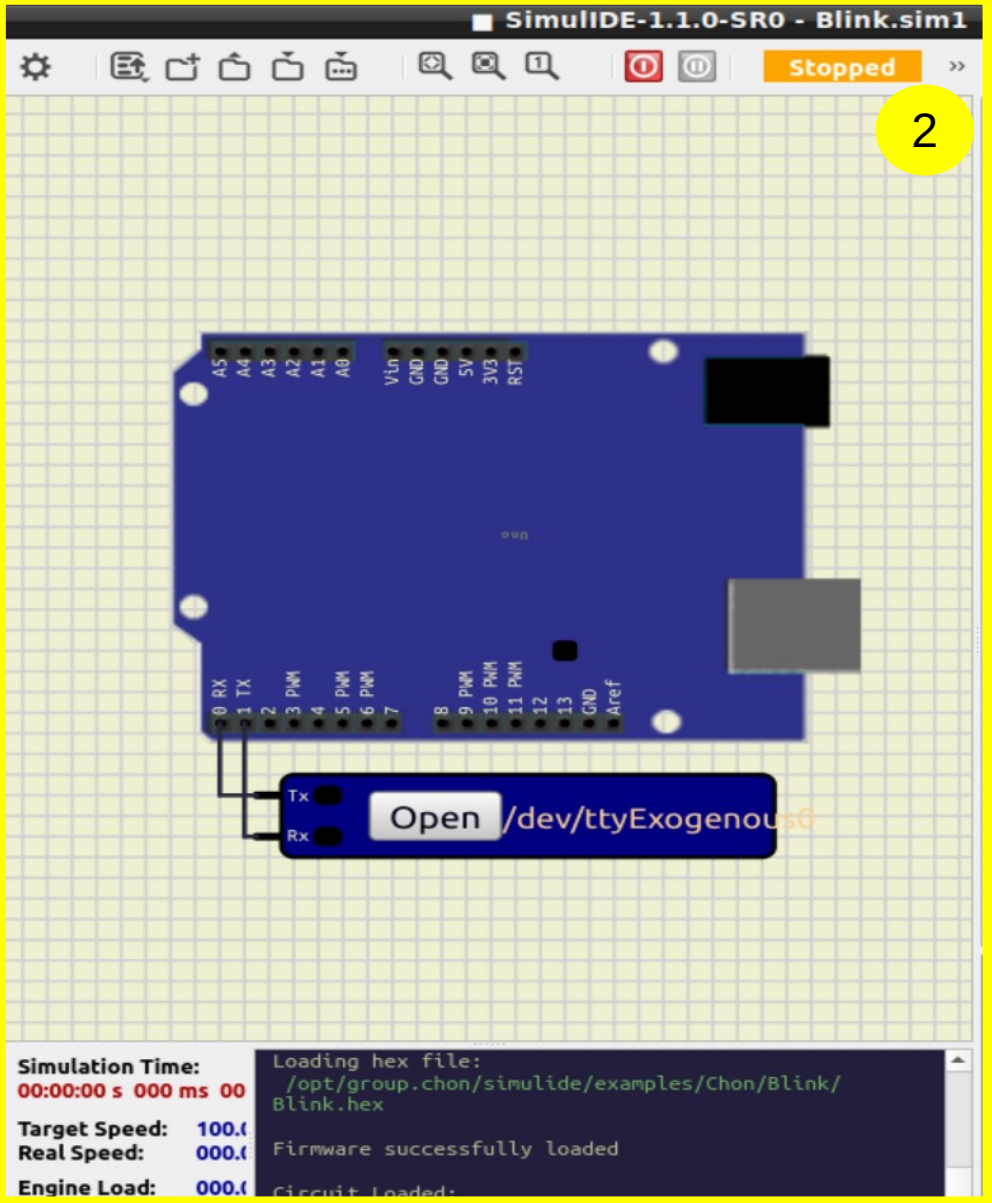
by Chon Group

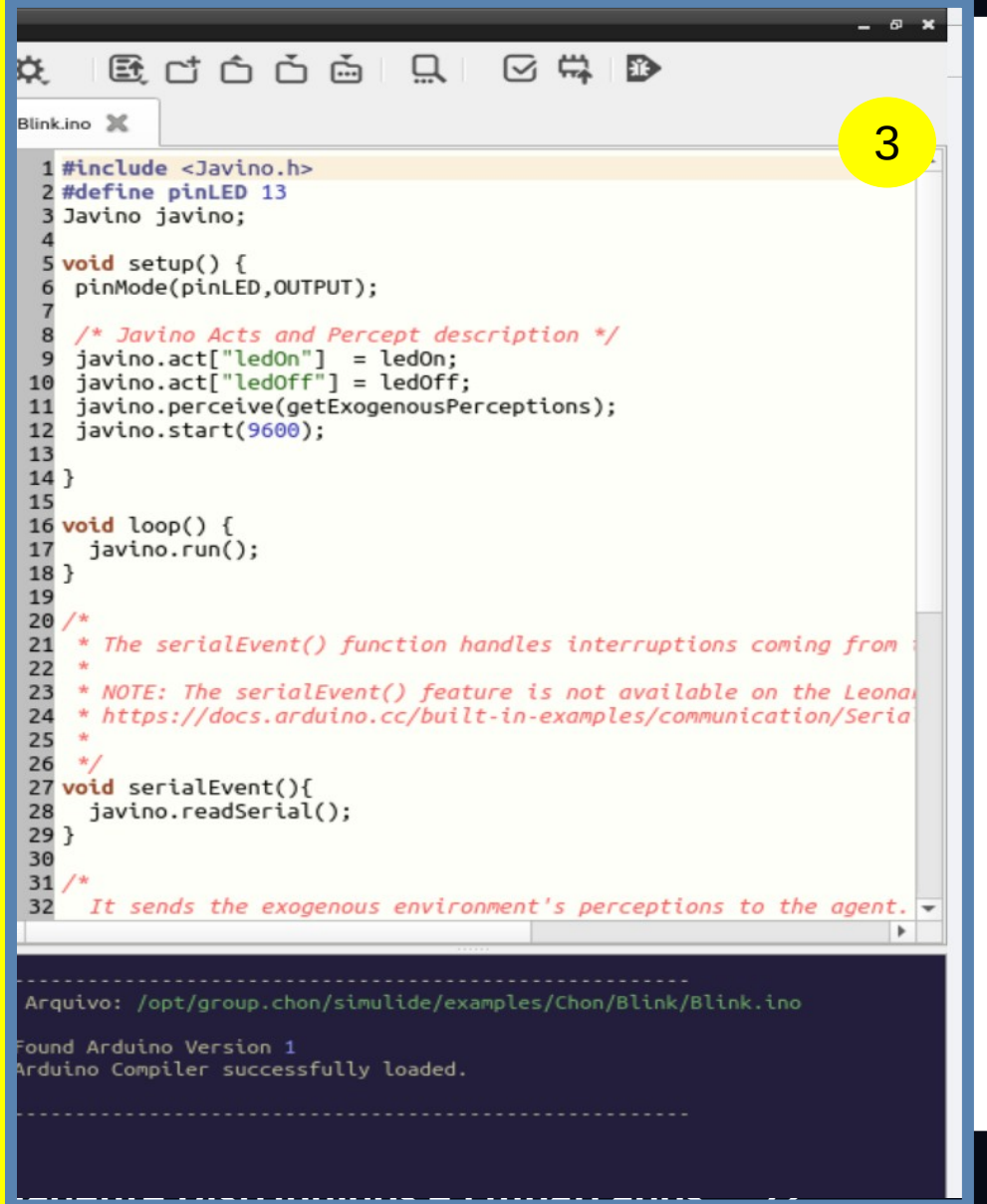


How to install?
https://github.com/chon-group/dpkg-simulide

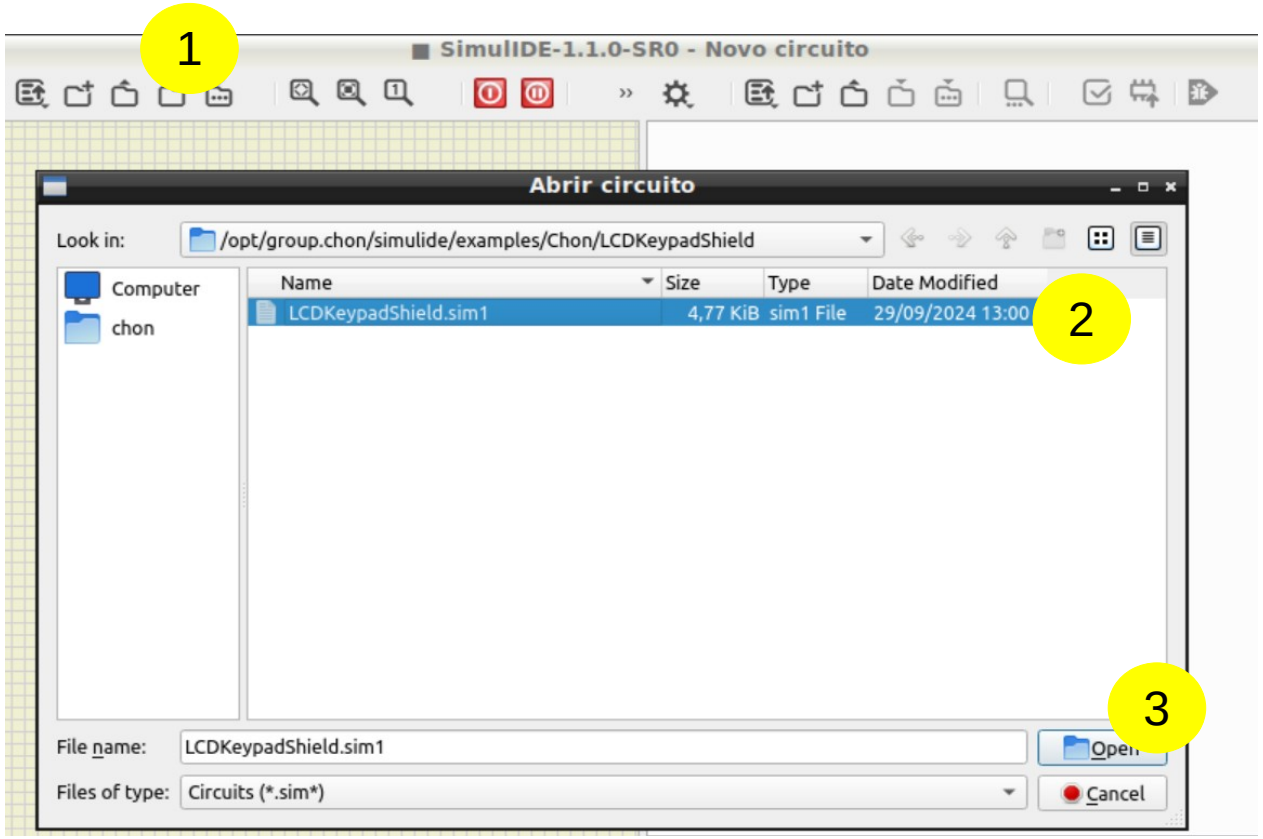
SimulIDE

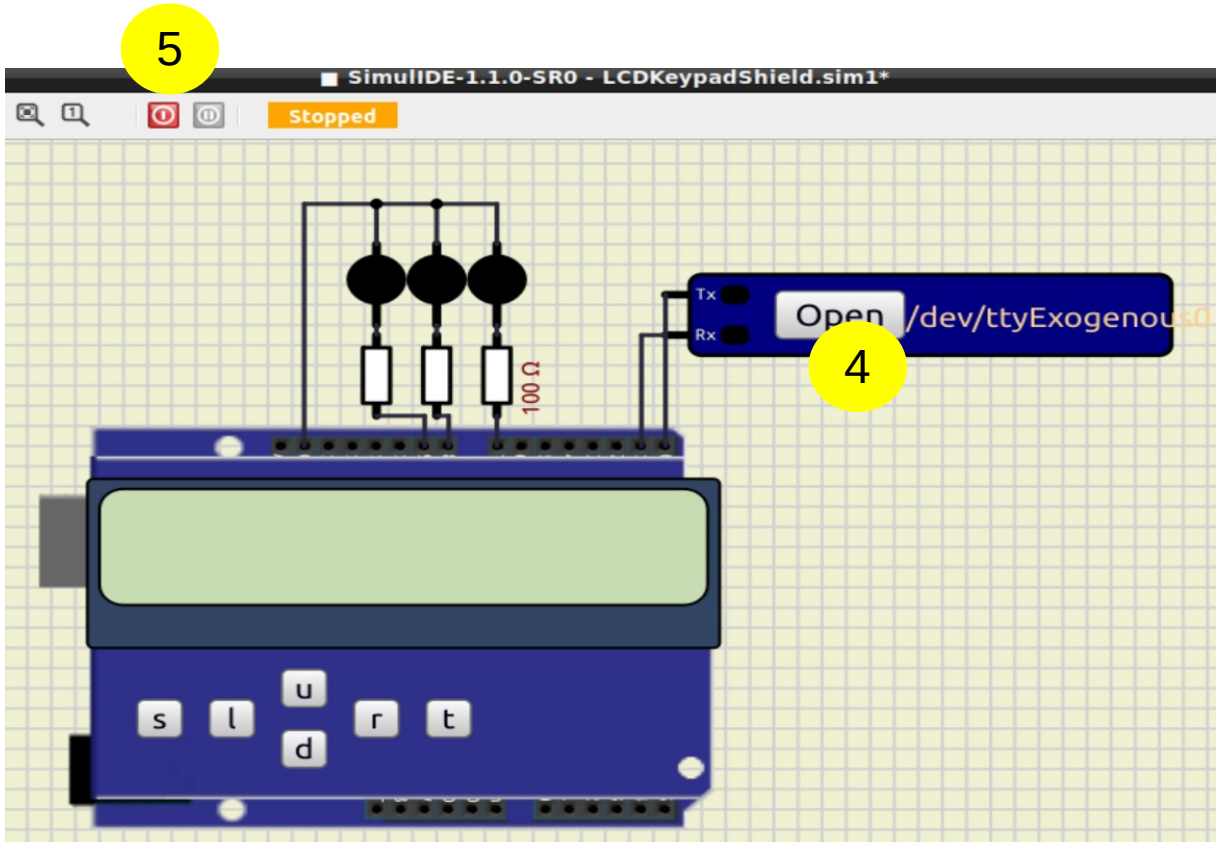

Componentes
Explorador de arquivos
Search Components
1
Medidores
Terminal de prova
Voltmeter
Ampmeter
Frequency Meter
Osciloscópio
Logic Analyzer
Fontes
Fixed Voltage
Gerador de pulso (Clock)
Wave Generator
Voltage Source
Fonte de corrente
Controlled Source
Battery
Rail
Terra (0 V)
Interruptores
Botão
Chave
Chave DIP
Relé
Teclado
Passivos
Resistors
Resistive Sensors
Reactive
Ativos
Rectifiers
Transistors
Other Active


SimulIDE-1.1.0-SR0 - Blink.sim1
Stopped
2
Tx
Rx
Open
/dev/ttyExogenou
Simulation Time:
00:00:00 s 000 ms 00
Target Speed:
Real Speed:
Engine Load:
Loading hex file:
/opt/group.chon/simulide/examples/Chon/Blink/
Blink.hex
Firmware successfully loaded

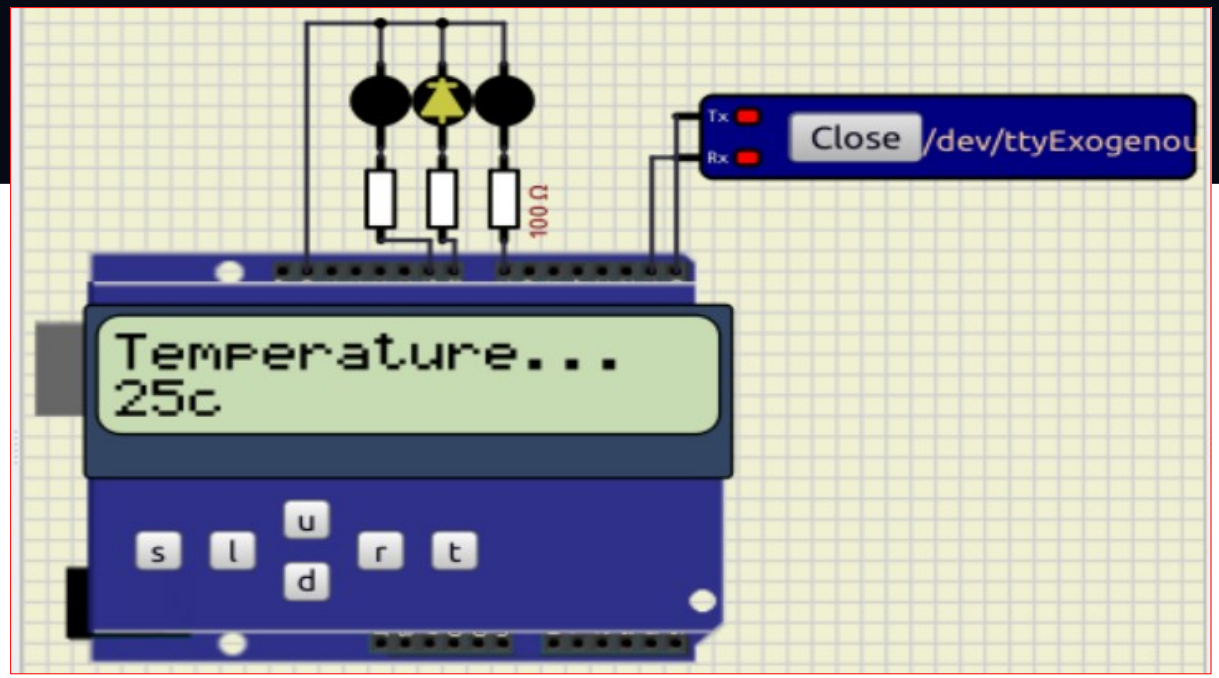

Blink.ino
3
#include <Javino.h>
#define pinLED 13
Javino javino;
void setup() {
pinMode(pinLED,OUTPUT);
/* Javino Acts and Percept description */
javino.act["ledOn"] = ledOn;
javino.act["ledOff"] = ledOff;
javino.perceive(getExogenousPerceptions);
javino.start(9600);
}
void loop() {
javino.run();
}
/*
* The serialEvent() function handles interruptions coming from
*
* NOTE: The serialEvent() feature is not available on the Leona
* https://docs.arduino.cc/built-in-examples/communication/Seria
*
*/
void serialEvent(){
javino.readSerial();
}
/*
It sends the exogenous environment's perceptions to the agent.
Arquivo: /opt/group.chon/simulide/examples/Chon/Blink/Blink.ino
Found Arduino Version 1
Arduino Compiler successfully loaded.

SimulIDE


1
SimulIDE-1.1.0-SR0 - Novo circuito
Abrir circuito
Look in:
/opt/group.chon/simulide/examples/Chon/LCDKeypadShield
Computer
chon
Name
Size
Type
Date Modified
LCDKeypadShield.sim1
4,77 KiB
sim1 File
29/09/2024 13:00
2
3
File name:
LCDKeypadShield.sim1
Open
Files of type:
Circuits (*.sim*)
Cancel


5
SimulIDE-1.1.0-SR0 - LCDKeypadShield.sim1*
Stopped
Tx
Rx
Open
/dev/ttyExogenou
4
100 Ω
s
l
u
d
r
t

SimulIDE



chon@chonide: ~

Arquivo Editar Abas Ajuda

```
chon@chonide:~$ javino /dev/ttyEmulatedPort0
javino@ttyEmulatedPort0$ write yellowAlert
javino@ttyEmulatedPort0$ request getPercepts
temperature(25);rainLast24hrs(0);humidity(50);
javino@ttyEmulatedPort0$
```

Acknowledgements

THANK YOU!

CEFET/RJ
Uned Nova Friburgo