Multi-Agent System and Digital Twin Models for Security Study of Cyber-Physical System

Individual Plan
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1 Background & main objective

This internship is the occasion for LCIS and Fraunhofer IESE to collaborate on this project, through communication with Emilia Cioroaica, who already worked on Digital Twins[1][2] and already collaborated with LCIS[3].

The research work should provide the following outcomes:

- State of the art of most important security issues of cyber-physical systems;
- Development of a simple model for security analysis of Cyber-Physical systems using Digital Twins and Multi-Agent Systems, in a combined way;
- Experimental analysis and evaluation of the proposed model by simulation.

During the thesis work, We will provide preliminary results to the research questions below such as highlighting main features of both models with regards to a security study.

To carry out the project, it could be useful to have some basic knowledge on the Digital Twins and Multi-Agent Systems concepts since it will be at the center of this research work. Moreover, it is important to be comfortable with the main keywords related to the security of cyber-physical systems.

2 Research question & method

2.1 Questions

The aim of this internship project is to investigate three research questions:

1. What are the interesting features of both digital twins and multi-agent systems for studying security of cyber-physical systems?

2. How could digital twins and multi-agent systems be combined to offer better support for a security study of cyber-physical systems?

3. What security claims of a system can be made from integrating multi-agent systems and digital twins?

2.2 Objectives and tasks

From the three questions above, we can derive these objectives which are then divided into tasks:

- Find the main attack models on cyber-physical systems
  - Look for the various existing attack models
  - Choose one and explain the choice
  - If time allows, choose other ones
- Define a Multi-Agent System model to study security

- Define what a Multi-Agent System is: the concept is quite old, which implies that a lot of people had the time to add their own ideas of it, making it hard to have a clear grasp of the subject

  - Choose a suitable model for our usage

  - Look for a Multi-Agent System (MAS) simulator: the simulator has to be simple enough to be used in the time allotted for the project

- Define a Digital Twin model to study security

  - Define what a Digital Twin is

  - Choose a suitable model for our usage

  - Look for a Digital Twin (DT) simulator: the simulator has to be simple enough to be used in the time allotted for the project

- Compare both models at a security study level

- Define a MAS and DT combined model from the comparison

  - Compare both models from the security study perspective

  - Establish how both models can complement each other: there are many ways to combine them. We could imagine an hybrid model, or create a bigger model including the two others separated.

2.3 Method

In order to establish the state of the art, we are going to use mainly Google Scholar and Scopus to look for papers or articles and Zotero to save them.

The results from the state of the art will lead us to our model creation. Then we will simulate this model with the chosen simulator to check if it works as we want and if we can extract some security claims in relation with the chosen attack model.

From a reproducibility perspective, we will try to provide every sources of paper and tool we use when possible, and will state it when it is not, which is unlikely in our case. Indeed, most of the tool we will use should be free. Some papers may require institutional access or a fee to access the full document.

2.4 Ethics and Sustainability

This work will talk about attacks on cyber-physical systems and may present examples which could be used outside of this work context. However, since the project is primarily concerned with theoretical concepts, this is unlikely.

In computer science, simulation is often something very energy consuming. We will try to tend to optimized solutions but this is not the main goal of this project. We will not focus on a sustainable solution for security of Cyber-Physical systems (CPS) analysis.

2.5 Limitations

Definitions of both Multi-Agent systems and Digital Twins do not have a consensus. We will have to choose one that could limit the set of possible interpretations of these two concepts.

In addition to this, this work will only focus on one specific vulnerability model and will not be generalized at the end of the 5 months.

As a limitation, we can also take the duration of the project into consideration. Indeed this is a 5 months project.

2.6 Risks

Falling behind schedule, especially during the state of the art, is a real risk. Indeed, this is an exploratory project and if we do not converge into conclusion quickly enough, we might run out of time. That is what the regular meetings are for. The supervisors have the occasion to give feedback and advices in order to avoid this.

Another risk could be to enter lockdown again, meaning that we lose the access to the lab supplies. But this possibility is unlikely and this project does not need any more equipment than the computer we are working on and several software. We could easily deal with this problem by taking the computer at home and staying in close communication with the lab (through mails and remote meetings).

3 Evaluation & news value

3.1 Evaluation

As a qualitative measure to evaluate our work, it is asked to report all the progress we made during the week, and what we are planning to do the following week, during each meeting. This way, a regular feedback on our work is given. It is also possible to submit our paper for peer review in order to obtain more, and a more diverse, feedback.

3.2 News value

The Multi-agent system is an interesting concept nowadays since systems tends to become decentralized[4], in order, for instance, to avoid any potential single point of failure vulnerabilities. In the other hand, Digital Twins are emerging in the industry field to monitor machines or systems thanks to their virtual copies[5]. However, only few examples of the combination of both have been done, making this research work interesting to study further.

4 Pre-study

The literature we will study should focus on MAS or embedded MAS, DT, main security issues of CPS, MAS simulators, DT simulators, MAS and DT mixed models. As stated in the method section, we will used Google Scholar and Scopus to do our researches and Zotero to save them.

Also, the laboratory provided us with some preliminary works that may help on the project:
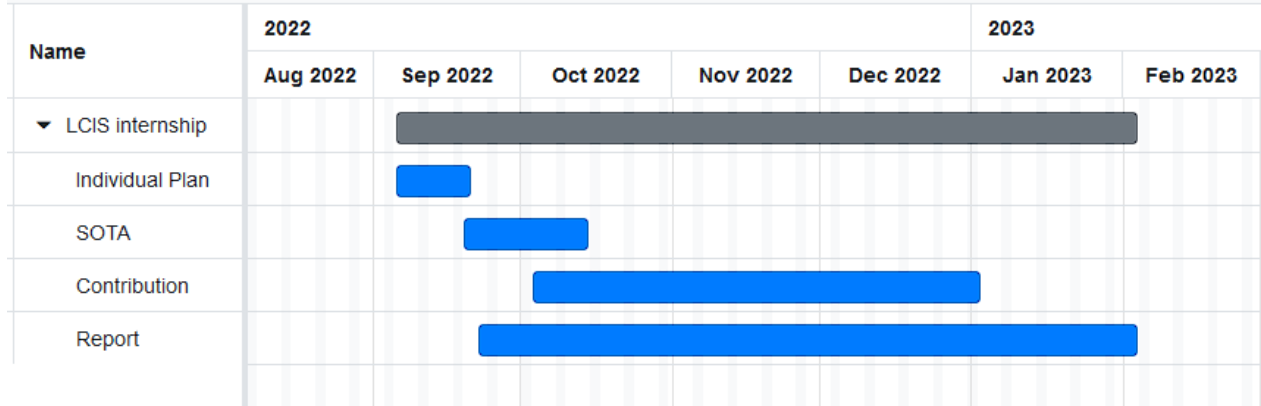
Figure 1: Degree project gantt

- a report from an intern on how to secure embedded MAS[6],

- a master thesis on trust in MAS[7],

- a paper on the safety of collaborating robots[2],

- and finally a paper on trust in Ecosystems[1].

From these references, we were able to build up a preliminary library containing the four works above and these documents: [8], [9], [10], [11], [12].

5 Condition & schedule

For this project, we will need computers with an internet access to do our researches. The Zotero software will be a good help for saving the papers found. We will also need a simulator of MAS and a simulator of DT. Which one exactly will be decided in the state of the art.

Here is an overview of what is planned. This schedule is likely to change during the degree project. You can also find a more detailed and graphical schedule on Figure 1.

- Setting up the project: 2 weeks

- State of the art: 1 month

- Personal contribution: 3 months

- Personal contribution writing refining: 3 weeks

A supervision will be done regularly on the basis of weekly meetings and additional meetings if needed. In these meetings we will present the work in progress which will be analysed by the supervisor before giving a feedback on the work done and advises on the incoming one. Monthly, a meeting with all the project's actors will be done, which will represent our intermediate goals' milestones.

6 References

References

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