



# INTERNSHIP REPORT

Research assistant in the field of  
Artificial Intelligence

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## INTRODUCTION

During my third year of engineering school (last master's year) at ISEP in Paris (Institut Supérieur d'Electronique de Paris, the Paris Higher Institute of Electronics), I studied the first semester in Norway at Oslo Metropolitan University (OsloMet) to pursue my studies and live abroad for an international experience. During this semester, I have followed courses about informatics and besides, I have worked for a company, Giamag technologies A/S in Norway for 5 months in the field of Health to carry out a project with 2 students who come from Germany and Netherlands.

I decided to gain more practical experiences to apply my theoretical knowledge about informatics, huge domain that enables the information access and the personalisation of the service, I applied then for an internship. For this final year internship, my hope was to have responsibilities, strategy and project management, and all these challenges that I wanted to rise to. Moreover, I wanted to stay in Norway for many reasons: First, I had to improve my skills in English and I noticed that the first semester was a real help for me, so I decided that staying one more semester could be a real opportunity. Secondly, the first semester abroad permitted an excellent professional and personal development. Indeed, I worked with exchange students, which allowed me a better understanding of how to work effectively with people from various cultures and backgrounds. I found myself outside of my comfort zone and it permitted me to improve myself a lot.

Then, at the end of 2017, I decided to look for an internship in Norway about new technologies. I went to many workshops in the digital field, and there I met one person who gave me the contact of Mr. Stefano Nichele, professor in Artificial Intelligence (AI) at OsloMet. We met during an interview, and he described a very interesting project as a research assistant in the field of Artificial Intelligence, specifically Swarm Robotics.

Therefore, during my six months internship, I got Mr. Stefano Nichele as a supervisor, who was in charge of giving me tasks and instructions. He is an associate professor at the Department of Computer Science and his main research focus is on Complex Systems, Artificial Intelligence and Artificial Life, Evolutionary Computation and Bio-inspired methods. Besides, he did a PhD on Evolvability, Complexity and Scalability of Cellular Evolutionary and Developmental Systems.

Robots have significant potential to change the world: replace manned machines, carry out tasks in environments that are either remote or hazardous such as space, sea or underground. However, lots of robots are manually programmed to carry out a mission. Nowadays, robots are becoming intelligent who can automatically learn new tasks and adapt to changes in environmental conditions. Evolution enables robots to have the potential to automatically generate the Artificial Intelligence that controls each robot, who can give the robot the capacity to face unforeseen changes.

This internship aims to explore the field of Artificial Intelligence in the context of Swarm Robotics. Therefore, one of my goals is to provide experimental set-up with robots for further research into the adaption in complex tasks and complex environments for robots. Furthermore, another goal of mine is to create a bridge between art and science and convey concepts of AI and swarm robotics to the general public through an art exposition at the end of the semester in collaboration with students in the Art Department.

## I. THE COMPANY

### 1. OsloMet – Oslo Metropolitan University

OsloMet - Oslo Metropolitan University (former HiOA) is Norway's third largest university, with more than 20,000 students and over 2000 employees. Four faculties of OsloMet located on two campuses, offer a unique range of programs qualifying students for professions within the modern welfare state. The faculty where I work is The Faculty of Technology, Art and Design (TKD). It offers higher education and research and development (R&D) activities within technical subjects, arts and design. The Faculty has approximately 3.000 students and 280 staff members and is situated in downtown Oslo.

#### ➤ Regional entrenchment, international orientation

Through a strong regional entrenchment, national ambitions, and an international orientation, OsloMet is establishing itself as a modern, professionally and vocationally oriented educational institution in the greater Oslo metropolitan area. This entails an interaction with a multicultural and international society, which enables their students and employees to develop the actions and competences necessary in multicultural and international working life.

Besides, Research and development (R&D) is a necessary and vital part of the university college's activities and should contribute towards developing a good and dynamic educational institution. In its overarching research strategy OsloMet highlights both interdisciplinary and regional cooperation. OsloMet's comparative advantage is that the institution performs research within the professions taught here. The university college creates value for society by developing knowledge that contributes to improved welfare. This research will give insights into the activities, frameworks, and conditions of sectors and occupational fields in a society that is continually changing.

### 2. My Department and Environment

#### ➤ Department of Computer Science

The Department of Computer Science has approximately 70 staff members and 800 students. Some research groups are into the Department about Universal Design of Information and Communication Technology (ICT), Autonomous Systems and Networks (ASN), Mathematical Modelling and Applied Artificial Intelligence. The ICT research group is concerned with identifying ICT barriers in order to remove them and they focus on a better understanding of the ICT challenges in diverse situations to ensure a universal design. The Mathematical Modelling research group consists of being able to use mathematics to formulate practical problems, which enables us to see connections and make predictions.

The ASN research group is focusing on Complex System, Cloud, Internet of Things (IoT), Big Data, Autonomous Systems, and a lot of more areas. The group's work involves autonomous

system and network in order to understand the future where there is a high density of autonomous.

Finally, the Applied Artificial Intelligence research group is where I am involved. Artificial Intelligence is a huge driver for digitalization of society and is radically changing the way we work. The Applied Artificial Intelligence group aims at bridging the gap between theory and applications in the real world. The research group conducts research activities in Machine Learning, Deep Learning, Robotics and Artificial Life, Evolutionary Computation in order to implement new technologies in the field of healthcare and neuroscience, computer vision, education and learning, ...

### ➤ My Work Environment

In this part, I will describe all the tools that I used during my internship to carry out my different projects:

- **Thymio II Robot**

Thymio II is a small robot which allows children to discover the universe of robotics and learn core concepts of programming. Designed for children and artificial intelligence enthusiasts of all ages, Thymio II is an excellent way to begin learning valuable skills quickly. Thymio can carry out numerous activities from basic movement and light configurations to executing complicated drawings and multi-robot performances. With Thymio, the basics of robotics and programming are opened through play, allowing for discovery and fun to drive learning.

The Thymio robot includes seven proximity sensors for obstacle detection, five are arranged along the front and two along the back of the robot. The sensors return values between 0 and 4,500, high values correspond to close obstacles. The robot has differential drive with the maximum wheel actuators set between -500 and 500 for each wheel. The main features of the robot include many sensors and actuators.

Besides, the robot has other sensors and actuators such as temperature, ground sensors, microphone to detect the frequency of the sound, is able to detect impacts, slot for SD card, speaker, ... you can look at the hardware of the robot in the appendix 6.



Figure 1: Thymio II Robot

- **Programming with Aseba**

The robot comes with pre-programmed behaviors for beginners, but advanced users can program Thymio through more common scripting language. The pre-programmed behaviors offer illustration of the possibilities of the robot. For instance, line following, reaction to shocks, hand following, etc. It can be programmed thanks to Aseba, which is a set of tools allowing novices to program robots easily and efficiently. The software is open source on the official website of Thymio and available for different platforms: Linux, Windows and Mac OS. Thymio II utilizes Aseba to provide several programming environments. Below, you can find all the software that Aseba provides:

- Visual programming: Made for children, programming Thymio by visually assembling event and action blocks as inputs and outputs.

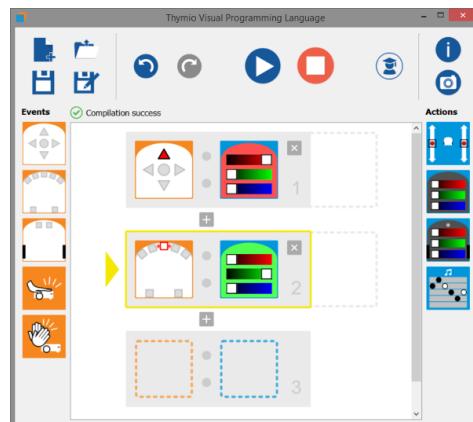


Figure 2: Visual Programming in Aseba

- Blockly: Assemble visual blocks, a bridge between visual programming and text programming

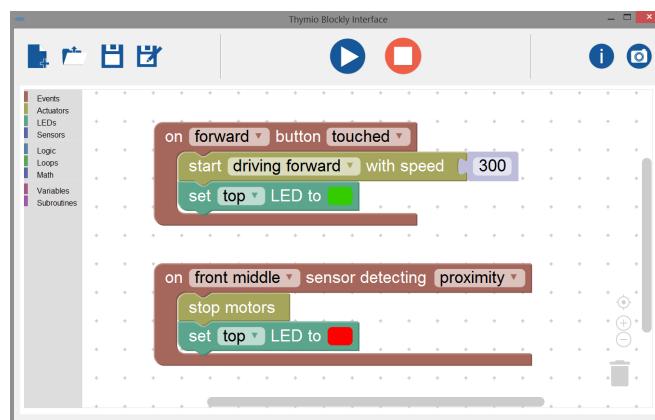


Figure 3: Block in Aseba

- Aseba Studio: Program Thymio II through text. It allows a higher level of control than visual programming or Blockly. This tool has its own language, but it is very similar to Python.

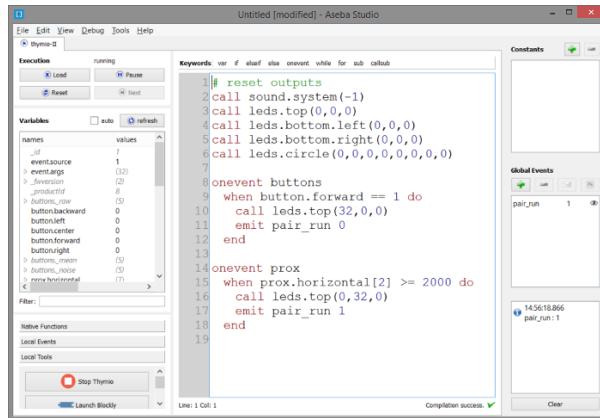


Figure 4: Aseba Studio

- **Raspberry Pi 3**

A Raspberry Pi 3 will be connected with the Thymio Robot. The Raspberry Pi is a credit-card-sized computer and can function as a proper desktop computer or be used to build smart devices. The Raspberry Pi will be connected to the Thymio robot and we can write a small software that can be sent from the Raspberry Pi and received data from the sensors of the robot. I choose Python language to write the code, but it can also be written in C, C++ ...



Figure 5: Raspberry Pi 3

## **II. Internship Context and Background**

### **1. Technical specifications**

Concerning the research about AI field, Stefano told me about doing a project on robots using artificial intelligence and being in collaboration with the Art Department for a project in order to make an exposition.

Then, the idea of the internship was to develop the project in preparation for the swarm intelligence application in the future. The goal is to handle robots, whose environment we will set up for the project and consider different options for AI to implement on the robots and choose the most suitable. The goal is to study how it works so that I could develop and setup the system in a way that it can support further swarm robotics experiments. The goal was not to develop an advanced version of swarm intelligence but to be able to describe the general concept of swarm robotics and swarm intelligence.

The second goal was to describe this general concept of swarm robotics and swarm intelligence to the general public, to non-experts, through an art exhibition in collaboration with students from the Art Department. Therefore, how to convey the AI part with the exhibition in a simple and intuitive way in order to describe the basic of how biological swarm work by using an artificial metaphor.

### **2. Related work**

The research of Mr. Nichele concerned Swarm Robotics. Given that my project is to develop a project for the swarm robotics in the future, I will give an overall of this field. Furthermore, I will describe a few papers concerned by Artificial Intelligence and Thymio robot.

The Swarm robotics is the study of how to coordinate large groups of relatively simple robots through the use of local rules. It takes its inspiration from societies of insects that can perform tasks that are beyond the capabilities of the individuals such as the honey-bee's dance, the wasp's nest-building, the construction of the termite mound, or the trail following of ants.

Social insects are able to exchange information (for example, presence of danger for their mates) and this implicit communication makes insects modify their behaviors because of the previous changes made by their mates in the environment.

Then, an organization emerges from the interactions between the individuals and the environment. These interactions are propagated throughout the colony and therefore the colony can solve tasks that could not be solved by a sole individual.

To conclude, swarm robotics is a field in which large number of robots are coordinated and can perform complex tasks in a more efficient way than a single robot.

Some publications present Thymio robot with implementation of AI.

In [1], they investigated a three-fold adaptive mechanism on evolution, individual and social learning to implement on the adaptation in a swarm of the Thymio robot. The conceptual framework is based on separating inheritable controller features from the learnable controller features and specifying adequate learning operators for the adaptive systems. This project is based on Artificial Neural Network technique, one of the commonly applied machine learning algorithms. I will explain later on the different techniques of AI in this report.

In [2], the article reported a successful evolution on neural network-based controllers in real robotic hardware to solve two single-robot tasks and one collective task. Furthermore, they demonstrate for the first time the adaptive capabilities of online evolution in real robotic hardware, including robots able to overcome faults injected in the motors of multiple units simultaneously, and to modify their behavior in response to changes in the task requirements.

In [3], a new local collision avoidance algorithm between multiple robots for real-time navigation is presented. This algorithm is based on multi agent system and quadratic optimization method for a collision free navigation and to compute the motion of each robot.

Besides, some other papers related methods that are used in Artificial Intelligence. These papers helped me to have a better understanding of the project and to see more clearly in which direction I wanted to go. Indeed, all these researches show the big interest in this field and just with a cheap and simple robot, some research questions about the adaption in complex tasks and complex environments for robots can be answered. These papers help also to understand the way of thinking to answer a problem

Therefore, the goal was to understand the way of thinking of these papers in order to be able to answer a question in this field.

### **III. METHODOLOGY OF THE WORK**

In this chapter, I will describe all my work to achieve my goals, which are researches into different options for AI to implement on the robots and choose the most suitable for the adaption in complex tasks and complex environments for robots and create a bridge between art and science.

First, I will explain the set-up made up of robots. Besides, I will make a brief description of the different AIs that could be used for my work of which AI as chosen and the method that could be used in the future.

Then, I will expose different ideas we had for the exposition and which one we chose to show in front of the audience.

#### **1. Swarm Robotics applied to Thymio robots**

##### **➤ The robot and the Environment**

For this project, my first task was to understand how robots work and how I can make a good environment to let them have their own world in order to create interaction between themselves and the environment. As mentioned above, I worked with the Thymio Robot, which is quite easy to take in hand.

The robot can be connected with a USB dongle given with the purchase of the robot and controlled by a computer, but since I have to work with a minimum 4-5 robots to have a minimum of interactions, we had to use something else.

The idea was to connect a Raspberry Pi to each robot. Indeed, with a Raspberry Pi, I can remotely control, update and deploy the robot controllers through SSH or VNC.

VNC lets the other computer process all of the graphic drawings and so forth and captures, in essence, a screenshot and sends that back to the computer. SSH permits to have access to the command line of the Raspberry Pi remotely from another computer or device on the same network using SSH: The Raspberry Pi will act as a remote device.

We used VNC because it is much faster, less information is required to display everything. Therefore, I can control as much as Raspberry Pi I want from my own laptop since we are connected on the same network. Besides, I used a Raspberry Pi to customize programs on Python, more that is possible to do with the Aseba software.

Moreover, a Power Bank is connected to the Thymio robot in order to have a longer experiment time. Indeed, robots take a lot of energy for those experimentations and we could be restricted without them. Besides, the robot is not suited for long experiments as the controller board gets overheated and leads to breaking robots. The Power Bank is also used to turn on the Raspberry Pi.

For this project, robots will be linked with Power Bank and Raspberry Pi. However, we have to find something to place this equipment on the robot and that's pleasant to see. Therefore, we have to make a case and can be useful to maintain this equipment on the top of the robot because the robot will be in motion. Therefore, a case was made by a 3D printer.

As you can just below this text, the figure shows the system:

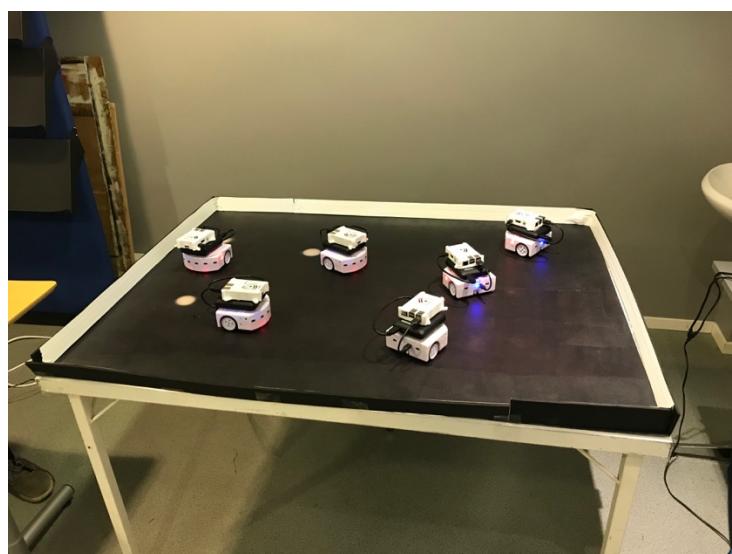


*Figure 6: Experimental Thymio II Robot*

The goal is to search into different options for AI to implement on the robots and choose the most suitable for the adaption in complex tasks and complex environments.

Therefore, after robots the robots were ready for some experiments, I had to specify the environment and also which was the fitness function. Fitness Function evaluates how close a given solution is to the optimum solution of the desired problem.

For this project, the task consists to avoid static and dynamic obstacles (walls, other robots) on a table. Indeed, obstacle avoidance is an essential component to achieve successful navigation. Below, you can see the environment:



*Figure 7: Environment used for the experiments*

## ➤ Description of various AIs

This chapter is a brief description of the different AIs studied during my semester.

- **Artificial Neural Network (ANN)**

ANNs are statistical models directly inspired by, and partially modeled on biological neural networks. They are capable of modeling and processing nonlinear relationships between inputs and outputs in parallel. The related algorithms are part of the broader field of machine learning and can be used in many applications as discussed. Artificial neural networks are characterized by containing adaptive weights along paths between neurons that can be tuned by a learning algorithm that learns from observed data in order to improve the model.

ANN is generally used in cases where what has happened in past is repeated almost exactly in same way. For example, say we are playing the game of Black Jack against a computer. An intelligent opponent based on ANN would be a very good opponent in this. With time, ANN will train itself for all possible cases of card flow. And given that we are not shuffling cards with a dealer, ANN will be able to memorize every single call. It is a kind of machine learning technique which has enormous memory.

A simple neural network can be represented as shown in the figure below:

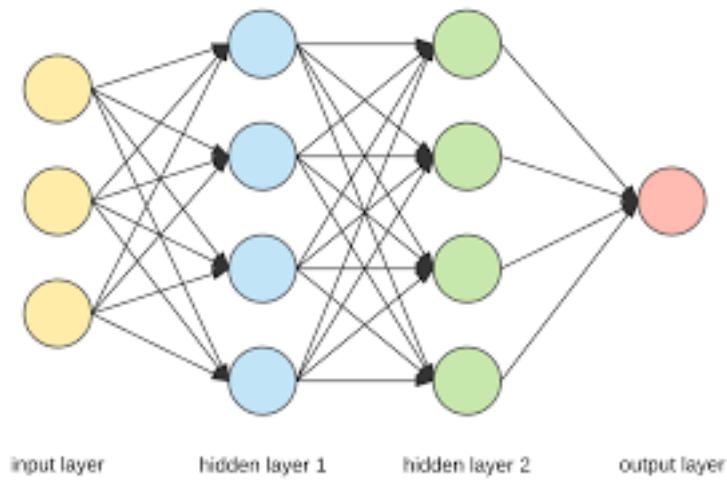


Figure 8: Neural Network

In this picture, the only known values in the above diagram are the inputs. The first idea is assigning random weights to all the linkage to start the algorithms. Then, recalibrate the weight between all the layers and repeat the process until the fitness function is as expected.

In a simple model, the first layer is the input layer, followed by one hidden layer, and lastly by an output layer. Each layer can contain one or more neurons.

- **Genetic Algorithm (GA)**

Genetic Algorithm (GA) is a collection of algorithms and techniques that can be used to solve a variety of problems. GA is an adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. GA uses algorithms and techniques to create multiple solutions to the given problem, and then the best solution is the one chosen. To do this GA has a simple process, which is in four parts. First, a pool of random potential solutions is created that serves as the first generation. For the best results, this pool should have adequate diversity (filled with members that differ more than they are similar).

Second, the fitness of each member is computed.

Third, members of the population go through a selection process based on the fitness of each individual. The most fit members are chosen for crossover.

The fourth and last step, feature the parents, who are recombined to form a new individual. Mutation may also be performed to avoid local optimum. After all the steps have been performed, the termination process is next. If the population convergence to a single solution than the algorithm is terminated.

- **Fuzzy Logic**

Fuzzy logic is a logic operations method based on many-valued logic rather than binary logic (two-valued logic). Two-valued logic often considers 0 to be false and 1 to be true. However, fuzzy logic deals with truth values between 0 and 1, and these values are considered as intensity (degrees) of truth.

Fuzzy logic can be used to describe how information is processed inside human brains. Fuzzy logic includes 0 and 1 as extreme cases of truth but also includes the various states of truth in between that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness."

- **Swarm Intelligence**

Swarm Intelligence comes from biological insights related to the enormous capabilities that social insects possess to solve daily-life problems within their colonies.

Therefore, Swarm Intelligence provides a new framework for the design and implementation of systems consisting of many agents that are able to cooperate in order to solve highly complex problems. The potential benefits of such approach are several:

- robustness: the failure of individual elements does not degrade significantly the performance of the entire system;
- simplicity: the individual behavior is simple but still it allows to reduce the complexity of individuals;
- scalability: the control mechanisms used does not depend on the agents' number within a swarm.

## ➤ AI method of choice

This chapter is the choice of the of AI technique to implemented on the robots.

In theory, all techniques above have the capacity to be utilized for this project. And through researching the various methods discussed and examining the various AIs, a choice was finally reached.

PSO, ANN and GA, all these methods require to be implemented on robots with a sufficiently complex functional structure. The robot must possess capabilities of perception, decision, evaluation of the action and a relatively high computational power and/or memory. However, it was my first project and task in this field, so I was not able to do it in six months in addition to my project of the exposition at this same time. Besides, our robot is quite simple, so it is very hard to implement this type of AI.

Our objective is to develop a simple and reactive obstacle avoidance tool that can be implemented on the Thymio robot.

In this context, the fuzzy logic is certainly one of the most adopted and easy approaches in this report for a beginner as me. The advantage of using fuzzy logic for navigation is that it allows the easy combination of various behaviors outputs through a command fusion process.

According to this paper, [4], I tried to implement fuzzy logic into the robots and which following is the method for my project:

First, the goal is to determine the speed of right and left wheels based on the distance of the obstacles around the robot measured by the sensors of the robots. We first proceeded to determine the value of the sensors in order to calculate the distance on possible obstacle.

Obstacle Direction	Sensors	Distances given
Frontal Obstacle	S1 or/and	DF1
	S2 or/and	DF2
	S3 or/and	DF3
Left Obstacle	S0 or /and	DF0
	S1 or/and	DF1
	S2 or/and	DF2
Right Obstacle	S4 or/and	DF4
	S3 or/and	DF3
	S2 or/and	DF2

Figure 9: The Measured Distances Obstacles-Robot

The meaning of « or/and » is when the robot has to turn to the left because of a right obstacle, this obstacle could have been detected just by the sensor 4 but also by the sensor 4 and 3 at the same time. The same method for frontal obstacle and left obstacle.

Secondly, we proceeded to determine all the events that can happen. In the figure 10 below, there is all the situations:

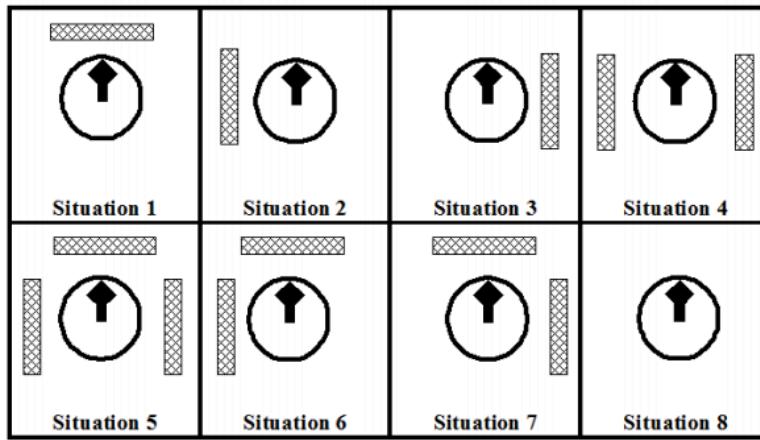


Figure 10: The situations of avoidance obstacle

Finally, the last step is to elaborate the inference rules to determine the robot's behavior according to its intrinsic parameters... According to different distances measured by the robot sensors, each values combination of these input variables, a command presented by the outputs variables (motor\_right\_target and motor\_left\_target) is associated with it.

The inference rules definition is based on the figure 10 which shows the different cases of avoidance obstacles that the robot can undergo during its navigation. Each situation is defined by a set of inference rules depending on the distances of obstacles-robot. For example, we give the set rules of situation 1: «Front close». The robot stops and performs randomly one of the following maneuvers:

- Deviation to the right.
- Deviation to the left.
- A half-rotation.

The figure below shows this example:

If	Distance given	Fuzzy Value	Then	Action
	DF0	Far		Deviation in right
	DF1	Near		Motor_right_target = 0
	DF2	Near		
	DF3	Near		Motor_left_target = 50
	DF4	Far		

Figure 11: Rule Interference of "Front Close"

Therefore, I programmed some codes on Aseba and Python to do this project. For example, if the sensor S4 notices an obstacle, I will just make a pace for motor\_left\_target and stop the right wheel. However, if the sensor S4 and S3 notice an obstacle, it means that the obstacle is closer to the robot. Therefore, I will make the pace of the left wheel faster to avoid the collision. You can check these codes in the appendix 7.

Besides, a collective intelligence emerged from the local interactions between the robots. Therefore, some aspects of the Swarm Intelligence are an interesting alternative to classical approaches to robotics because of some properties of problem solving by social insects: flexible, robust, decentralized and self-organized. Indeed, some tasks may be too complex for a single robot to perform but can be performed with the help of other robots.

We are reaching a stage in technology where it is no longer possible to use traditional, centralized, hierarchical command and control techniques to deal with systems that have thousands or even millions of dynamical changes. The type of solution swarm robotics offers, and swarm intelligence in general, is the only way of moving forward.

## 2. The bridge between Art and Science

*Title: Reflection and Reasoning Concerning the Development and Use of Thermochromics Paint in Pheromone Performance with Swarm Robotics*

### ➤ The idea

Mr. Stefano Nicelle in his research tries to work closely with the arts. Indeed, artists always want to paint or make representations of today's world. For instance, an exposition was presented at the "Grand Palais" in Paris named "Artists & Robots" from the 5 April 2018 to the 9 July 2018. This exposition is an opportunity to experience works of art produced with the help of increasingly sophisticated robots. It offers a gateway to an immersive and interactive world. My tutor understands that and wants to make our research available for artists and make it possible to convey science and in particular AI and robotics to the general public.

Therefore, for the last 3 months of my internship, I was in collaboration with 2 students from the Art Department, Haakon H. Roen and Stephanie C.A. Hoekebe. From the get-go, this project, using the tools of swarm robotics in an artistic manner, was linked to the possible idea of illustrating or performing behavior taken from the natural world. One such behavior taken to be of applicable nature was the form of pheromone-based communication found in social insects such as ants and bees. Since social insects display sophisticated behavior among many agents based on relatively simple action patterns exhibited by the individual agent, several aspects of their nature have been used as inspiration for research into multi-agent swarm robotics. In the form of communication taken as inspiration in this project, pheromones, a form of chemical substance, are deposited to mark certain areas with information in order to assist other insects at a later time. An example is the marking of areas containing food, so that other agents of a colony can detect a food source more easily (Luke & Panait, 2004, [5]).

When thinking about using and illustrating such behavior with Thymio robots, which were the tools first presented to us, we considered different types of systems and environments that these robots could move and interact with. The goal was to develop an environment that allowed interaction between the acting agents (i.e. the robots) and also the environment itself, hopefully in a meaningful and easily perceivable way.

We thought of using different types of mirrors attached to the robots, sending light around the room, letting them move on a thin layer of sand so that their movement would make grooves and then a trail, so that the audience could see the ongoing movement, and so on. Another idea would be to make the robots choreography. Indeed, Thymio can listen outside noise and perceive the frequency of the music. The idea would be to make the robots dance together according to the music they listen. For instance, a music with high tempo will make the robots go fast and have a high cadence. By contrast, low tempo will make a small cadence and another choreography.

In the end, we decided upon taking a flat, closed off, rectangular surface as the physical area for the robots to move. We had seen this had been done successfully in other art projects such as the Portuguese artist Leonel Moura's BeBot (2017, [6]) made for the Astana Expo, where a similar type of robots is placed on a great sheet of paper in the exhibition. Equipped with pens of different colors, they move around to produce abstract expressionist-looking drawings that later are hung as separate pieces in the exhibition space (Moura, 2017, [6]). The end-goal for the Moura's performance is therefore a classical form of artistic expression, easily interpreted as such, whereas in the pheromone performance, the performance is the artistic expression itself.

The performance seeks to display a form of Artificial Life, where robots emulate behavior taken from the natural world (Penny, 2017, [7]). We therefore did not feel the need to let the robots make any lasting, permanent impact on the surface for the sake of getting a drawing or illustration of the actions but wanted the surface to accentuate and mirror the action as it happened. Since the actual programming and experimentation around that was a big part of the project, it was also important that the actions performed on the surface didn't destroy it but had a reversible nature. Our decision, then, was to paint the whole flat surface with thermochromics paint.

## ➤ Method

Thermochromism is when a chemical compound undergoes a reversible or irreversible change between two states possessing different absorption spectra. This typically happens either by a change in crystalline structure, pH-change, loss of crystalline water from the substance, equilibrium exchange between donor and receptor, or ring opening in molecules (Talmani, 2015, [8]). In our case, we used a form of thermochromics pigment with a mixture of Leuco dyes in it that at room temperature it has solid black color, but when it heated up above ca. 33°C it transforms to clear or white. This process is reversible as it turns back to black when the temperature decreases back beneath the tipping point around 33°C. We then mixed the pigment powder with a liquid acrylic medium and used a roller to spread it evenly over a 1 x 1,3 m sheet of Plexiglas. The solution was fairly thin, so we needed 3 coats to make a fairly even surface, and even then, some irregularities could be seen. If this was to be done again, it might be useful to have a thicker medium, and ideally a bit more paint. Even so, we ended up with a flat surface upon which, the Thymio robots could move freely, and, equipped with a source of light heat, could make a color-changing path based on their movement.

A container is attached to the bottom of the Thymio robot with very cold or very hot water. To make the containers, we first had a session experimenting with different materials on the painted surface. We tried both metal, glass and plastic in different thicknesses in order to see which ones were most suitable for our aim. Plastic and glass did not transport the heat quickly enough to get the surface to change color when the containers were in motion. For the color to change, the containers in plastic and glass had to stand on the painted surface for a longer time. The possessions of the transparency of the glass and plastic made an interesting effect, where one could see the changing color. However, due to the problem around the transportation of heat, we continued with a metal container. We also discovered that one important property

of the container was that it needed to be completely flat on the bottom in order to have a larger contact surface and leave a bold and thick line. When we had made a choice around the material of the containers, the next question became how to make or where to buy the metal containers, and how to fasten them to the robots. The metal containers were bought and were originally used to hold spices. To fasten the containers to the robots we made rubber bands from the inner tube of a bicycle and car and glued them together.

Just as the release of pheromones in nature has a temporal effect, the change of color does not last forever either. It has to be enhanced or renewed by other robots or it will disappear, and new paths emerge. The temporality of the color change gives the possibility of experimenting with different heat sources and ways of behavior patterns for the robots without being limited by any permanent change.

### ➤ Computer Part

Concerning the programming part, each robot has the same system used for finding the fitness function. Also, different cases were used during this exposition. First, we have 6 robots on the surface with hot water in the container. Consequently, it will create a small world with random behaviors and the robot will create a white mark and a white path. The code used is the same than for my first project, i.e. just avoid obstacles, walls and the other robots. The second case is to have some robots with hot water in their containers but also to have some with frozen water in the container. Therefore, the white path that create some robots will be removed by some other robots. Then, the last case is to have some robots with hot water, some with frozen water but some other robots who have to find and follow the white paths or the contrary, i.e. avoid these white paths. For the last case, the code used was the same for the robots with hot or frozen water but for those who have to follow or find the white was programmed with another code. Indeed, the fact to avoid the environment is still present but I attached the fact that they have to see the color difference and to follow or not this kind of color. Indeed, the ground sensors of the robots display different number in accordance with the color of the ground and the goal was just to make the robot able to follow the white path with the help of the ground sensor on the right and the one on the left. Therefore, when a ground sensor notices a color difference, I just had to see if the other ground sensor noticed the same color and after this inspection, turn the robot to the left or the right or go forward. Indeed, if the right ground sensor notices there is a white path and not the left one and the goal is to follow this path, the robot has to turn to the right. We make the same technique after 0,1 second of actualization. You can check all this code in the appendix 7 and the YouTube video of all cases presented on this chapter on the appendix 8.

All these cases are representations of the animal world with the pheromone effect. Indeed, some animals leave pheromones in the atmosphere and create kind of social behavior in the animal world. Our exposition is a way for us to understand this world and to demonstrate, with our skills, to the audience. We did the exposition on the TKD Day Spring 2018. This goal of this day is to meet all the employees of the Faculty Art and Design in order to inspire employees

for the next projects. We presented our work and also, a poster made by the 2 students from the Art Department, Mr. Nichèle and myself. You can see the poster in the appendix 9.

### 3. Secondary Missions

My primary goal was to develop the project in preparation for the swarm intelligence application and to be in collaboration Art Department students to create a bridge between art and computer. However, I carried out other missions during this internship. First, as mentioned in the first mission, I had to do a case for the Raspberry Pi. Some cases exist on Internet to buy but the goal was to do it in a cheaper way, so we had chosen the 3D printing case. At the university, there is a room called "Makerspace" which is a creative playground for everyone. Here you can 3D print, laser cut, program and otherwise create what you want. I attended to some courses about 3D printing and make a case for the Raspberry Pi, you can find the models I made on my GitHub, see appendix 7.

Moreover, I was part of the organization of a workshop at the University. On the 3rd, May, workshop on Autonomous and Adaptive systems took place at the university. The goal of the workshop was to promote research, education, and industrial actors working with Autonomous Systems in the Eastern Norway region.

The workshop served as a meeting point for students, researchers, and companies in order to share experiences, promote synergies, and display the important role of Autonomous Systems in enabling future sustainable economic activity and to solve societal challenges. During this day, keynote speaker talked about interesting project, students presented their project with posters or demo, etc.

My tutor asked me if I wanted to be part of the organization and my answer was yes. I attended the meetings and gave little ideas for this day. For instance, I submitted the idea to have a prize for the audience at the end of the day. Indeed, just after the last keynote speaker presentation in the amphitheater, to display on the screen a questionnaire with the website Kahoot. Kahoot is a website specialized in quizzes. It is very easy to use for everybody because you can answer the questionnaire on your mobile phone. Therefore, the goal was to ask questions about the whole day and to check if people were aware about all the conferences, demos and posters. The local committee assigned myself with doing all the prizes process. Then I had to talk with people who were going to present conferences to have relevant questions, think about the prizes and all about the good process to know who the best poster student is, etc.

Finally, I was part of the committee of a group called "Artificial Intelligence Club" which the idea is to do a meeting with all the people who are interested about AI field to share ideas, projects, etc.

## **IV. Results and Discussion**

### **1. Results**

The first conclusion of my work and maybe the most important is that I opened up during this experience. The missions that my tutor gave to me at the beginning were fulfilled and I would say that the results were more than the expected. Concerning the AI part, it was very difficult at first to do research in a field as a beginner. The first two months was, sometimes, difficult to understand and to see in which way I was going. However, with the help of my tutor and the work I did, everything became clearer with time and I was able to make decisions to carry out the project.

The exposition was a total success. Indeed, conveying concepts of AI and swarm robotics to the general public through an art exposition is very hard. However, the audience was very interested in our demo and lot of people came to know more about the project.

Some parts of the project could be improved, and some perspective can be envisaged in the future.

### **2. Work Discussion**

Concerning the part of the work, some perspectives can be envisaged. First, I would say to implement some other AI techniques into the robots. Lot of interesting AI methods can be implemented in order to make a robot cleverer and to resolve more complex tasks. For example, a robot cannot push a box alone but with the help of other robots, he will be able to do it. Lot of examples can be thought to show more that interactions between robots can solve tasks that could not be solved by a sole individual, as societies of insects.

Besides, another idea is to buy more elaborated robots in order to make more complex tasks: a robot with more complex functional structure. For example, a robot with an arm or a camera will be more able to have perception and evaluation to take better decisions.

Concerning the part of the exposition, some nice perspectives can be envisaged. Indeed, Mr. Nichele sent an abstract for the conference Open Fields 2018 - International Conference on Art, Science, Technology and Humanities (<http://openfields2018.rixc.lv/openconf.php>). Furthermore, we will also send an abstract for Alife 2018. The ALIFE conference is the major meeting of the artificial life research community since 1987. The 2018 Conference on Artificial Life (ALIFE 2018) will take place outside both Europe and the US, in Miraikan, Tokyo, Japan, from July 23-27.

I am very proud to be able to send abstracts of our work to some conferences and maybe to journals in the future. Indeed, the goal at first was no to send abstracts in conferences but just to get involved in the AI life and to develop a project in preparation for the swarm intelligence application in the future.

Besides, my tutor told me that with five or six months more work on this project, we would be able to make an exposition in Norwegian museums. However, nice perspectives can be considered for the next student who wants to improve this project.

Concerning our project, when I went to the exposition “Artists & Robots” in Paris, engineers and artists insist on the interaction between the audience and the work. Indeed, to express the AI part with an exhibition in a simple and intuitive way is difficult and people would be more able to understand and would be interested with interaction. Therefore, the paint on the table can be heated with hairdryers. Consequently, the audience could interact with the robots in making white path not due to the robots but due to the audience.

In addition, some other ideas for the exposition can be considered. Indeed, the robot can be used for many things and we thought about using different types of mirrors attached to the robots or make the robots dance together according to different music. These ideas can be planned to do in the future.

### 3. Personal Discussion

From a personal point of view, this internship was very enriching in many aspects. I would describe my internship as a positive and instructive experience. First, to be able to work abroad is an important characteristic for an engineer nowadays. I had to adapt to a new culture and a new way of life. Immersing myself in a foreign environment permits myself to have more flexibility and determination. Besides, my decision to work abroad opened my mind.

This internship brought me new vision and perspectives of the research work. Indeed, my last internship was in a commercial enterprise, which is quite different. I met many people who came to research through different path and have different personal vision of what is research. I became aware of the importance to do research in the actual world. I created a network outside of my local environment and may become influential later on for projects. Finally, this experience permitted to be more creative. I was exposed to a vast set of new ideas. Combining this experience with my background and knowledge help myself to provide more innovative solutions.

However, working abroad is not as easy as working in the country of origin. Indeed, it is more difficult to be confident and to take part of a discussion when you have an idea because of your language and you hope that people will understand you well. Besides, Norway is an English-speaking country, but the official language is Norwegian. Sometimes, I could not take part of the discussion. However, I learned about myself, what I am capable of, my skills and my limitations. It permitted me to improve myself about my limitations and to work on these.

Concerning my future professional career, I changed my mind about the research world and work in this field at the beginning before working in a company. I think being a researcher makes you more aware of the actual world and you become a better problem solver because you think a lot about how things work to solve global challenges. This experience was inspiring to see how some of the researchers were able to independently carry out their interests and

perform their own experiments. Indeed, the scope of my project was very open, as different research directions could have been pursued depending on the results and personal interest.

Besides, my wish is to work in the AI field. The exponential growth of disruptive technologies, the need in financial services are instances show the growth of AI in our life. Therefore, I applied for a PhD position in the same university in Norway. Indeed, the last year with my work in the Health and AI fields made me realize that my wish is to carry out same projects. I applied for a PhD positon about the Self-adapting patient monitoring: decision support for Smart-Hospital and Home-Hospital solutions. The project will be carried out in a close collaboration with health experts at OsloMet, in partnership with one of Norway's most advanced hospitals, a provider of medical class monitoring systems, Equivital Ltd (UK), and IBM Norway. This project combines Machine Learning / AI, IoT and Computer Science.

## **CONCLUSION**

This second internship in a research field was a wonderful and enriching experience, from both a professional and personal point of view.

My first internship was in a business company so working in a university and discovering the research field was something new for me but something I wanted to do. Moreover, this internship took place abroad.

After some little struggles, due to my inexperience, I found my footing into the university and the research field. Supported by my tutor and some employees, I was encouraged to give my ideas and bring a new look on the research. Besides, my tutor let me have lot of responsibilities to show my background and all my knowledge that I have learned at the school in France.

The mission, which was clearly defined at the beginning, gave me a method, precision and organization in my work. Furthermore, it broadens my horizons, develops my skills and gives me career opportunities. I have achieved the objectives given by my tutor within the allotted time but also the objectives that I entrusted myself.

Therefore, following this internship, my wish is to work abroad and to follow the research field into the new technologies as IoT, Big Data and Artificial Intelligence. In the future, I have wanted, since a long time ago to have a job with strategic decisions and to have lot of responsibilities. However, working in the research field for some years is a real advantage before having a position in the business or strategy.

Last but not least, this internship reinforces my wish to guide myself towards the digital world.

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## Appendix 1: Internship Agreement



INSTITUT SUPERIEUR D'ELECTRONIQUE DE PARIS  
28, rue Notre-Dame-des-Champs 75006 PARIS

Tél : 00 33 1 49 54 52 00

### INTERNSHIP AGREEMENT

#### **ARTICLE 1: Signatories of agreement - Content and location of placement.**

The following agreement regulates the relationship between the Company identified below (hereafter referred to as "the Company"):

Designation of the company :

OSLO AND AKERSHUS UNIVERSITY COLLEGE OF APPLIED SCIENCES  
POSTBOKS 4 ST. OLAVS PLESS  
0130 OSLO  
NORWAY

represented by : DIANECE HABIB

and Mr.Dieudonné ABOUD,  
Director of I.S.E.P. – Institut Supérieur d'Electronique de Paris,

and the work placement of : **Mr Benjamin BOCQUILLON**  
Engineering student in ISEP, referred to as "the student (hereunder referred to as "the Trainee"), and registered as a student of the School.

Description of work placement as approved by the School : System / Lab for evolutionary swarm robotics

**Company supervisor** (title, first name, surname, position) : **Mr Stefano NICHELE** ASSOCIATE PROFESSOR

#### Location of placement :

OSLO AND AKERSHUS UNIVERSITY COLLEGE OF APPLIED SCIENCES  
Pilestredet 35  
0130 OSLO  
NORWAY

**Academic tutor or supervisor** (title, first name, surname) : **Mr Jérémie SUBLIME**  
Full telephone number : 33 1 49 54 52 19  
E-mail address : jeremie.sublime@isep.fr

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## ARTICLE 2: Objectives of placement

The main purpose of this work placement is for the Trainee to apply in a practical way the skills and knowledge acquired at the School.

The subject of the placement should be mutually agreed upon by the Company and the School and should take into consideration the general educational programme of the School and the Trainee's area of specialisation. Any important change in the subject of the placement should meet with the approval of the School.

The Trainee should provide the School with a description of the work placement prior to the signature of the agreement.

## ARTICLE 3: Dates of Placement

### Dates of Placement:

The work placement will take place  
From : 08/01/2018 to 29/06/2018

A rider should be added to the agreement in case of extension of the duration of the Placement at the request of the Company and the Trainee.

In the case of end-of-study final year placements, the date of termination of the placement should not exceed the date of the final viva voce examination assessing the placement. For other types of placements any extension should take into consideration the academic calendar in force.

### Conditions of Placement

The Trainee will be required to be present at the workplace for a maximum of    hours per week.

Details of special circumstances where the Trainee is required to be present at the workplace at night, on Sundays or on public holidays should be outlined here : \_\_\_\_\_

## ARTICLE 4: Completion of Work Placement - Report - Jury - Evaluation

On completion of the work placement, the Company shall issue a certificate of satisfactory completion and an evaluation form that should be sent to the School. The Trainee should submit a Work Placement Report in compliance with the academic requirements of the School. A copy of the Report should be sent to the Company Supervisor as required. Details of the report may be discussed during the jury in keeping with the academic requirements of the School.

## ARTICLE 5: Status of Trainee – Conditions of Supervision

The Trainee shall remain a student of the School throughout the entire period of the work placement and will be monitored by the School. The Company shall appoint a Company Supervisor who will provide technical supervision and ensure the placement is carried out under optimum conditions. If the Trainee is required to return to School during the Placement to attend classes or meetings, the School should duly inform the company of the dates.

## ARTICLE 6: Discipline

The Trainee shall comply with the rules and regulations and code of conduct of the Company, and in particular with hours of work and Company health, safety and hygiene guidelines throughout the period of the placement. Only the School can take disciplinary action against the Trainee. Any case of misconduct should be reported by the Company to the School and supported by evidence.

The Company may terminate the Placement prematurely in case of gross misconduct on the part of the Trainee under article 10 of the present agreement.

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## ARTICLE 7: Compensation and benefits - Reimbursement of costs

The Trainee may receive compensation.

The amount of this compensation is set at :

**195,20 NOK gross per hour**  
 (i.e. approx. € 2283,00 EUR gross per month)

The terms of payment are as follows : \_\_\_\_\_

If the trainee receives fringe benefits or benefits in kind (e.g. free meals, etc.), the corresponding amount should not be added to the monthly compensation.

Travel and living expenses incurred by the Trainee on official business at the Company's request, as well as any training costs pertaining to the Placement shall be incurred by the Company in accordance with the Company's normal practice and terms.  
 Details of fringe benefits and benefits in kind : .....  
 .....  
 .....

## ARTICLE 8: Sociale Welfare:

Throughout the Placement, the Trainee continues to benefit from student status under *French Sécurité Sociale coverage*, regardless of any other conditions acquired during the Placement. The school must obtain prior approval from *French Sécurité Sociale* for all placements undertaken abroad.

### 8.1. Health and Sickness coverage for Placements abroad:

*Coverage from French student status:*

\*Wherever applicable the Trainee should complete the form requesting the extension of existing health and sickness coverage abroad:

For Placements undertaken by nationals of the European Economic Community in the European Economic Area, Trainees should be in possession of a valid European Health Insurance Card.

For Placements undertaken in Quebec by French nationals, Trainees must be in possession of form SE401Q (104 for placements undertaken in companies; 106 for placements undertaken in universities).

\*In all other cases:

Trainees who incur medical costs abroad can be reimbursed by the mutual insurance organisation that handles their student French *Sécurité Sociale* health and sickness coverage upon their return by providing receipts of costs incurred. The amount of the reimbursement is calculated on the basis of standard French rates. Important differences may exist between the costs paid and the reimbursement received.

The student must take out complementary medical insurance with an organisation of their choice (e.g. student or other mutual insurance organisation, ad hoc private insurance company, etc.) to fully cover their stay in the foreign country,

Exceptions: if the Company provides the Trainee with statutory local medical insurance coverage (see 2 below), the Trainee may choose to benefit from it. However, the Trainee should carefully consider the extent of the coverage provided before making his/her choice.

*Coverage provided by the Company:*

The Company should tick the appropriate box below to indicate whether it will provide health and sickness medical coverage for the Trainee, in accordance with local regulations

YES (this coverage will complement rights and benefits provided by French student *Sécurité sociale coverage*)

NO (the Trainee will only be covered by the extension of existing French health and sickness cover abroad)

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## 8.2. Insurance coverage for Accidents in the Workplace for Trainees abroad:

- 1) In order to benefit from French legislation on accidents in the workplace, the Placement:  
 should not exceed 6 months including all extensions  
 should not include any form of remuneration entitling the Trainee to workplace accident insurance in the foreign country (compensation or gratuities not exceeding **15.00% of the ceiling of the French Sécurité sociale** for a statutory 35 hour working week under condition of obtaining the agreement of the CPAM)  
 should take place exclusively in the Company designated in this agreement  
 should take place exclusively in the foreign country mentioned in this agreement.
- 2) Notification of accidents to the French Sécurité Sociale in the workplace is the responsibility of the School. The Company must inform the School in writing no later than 48 hours after the accident.
- 3) coverage for accidents in the workplace includes accidents that occur:  
 Within the perimeter of the place of work and during the hours of work;  
 On the inward or outward journey between the Trainee's place of residence and place of work abroad;  
 On the inward or outward journey between the Trainee's normal place of residence in France and the place of his/her Placement abroad;  
 On an external assignment entrusted to the Trainee by the Company and covered by a Company authorisation.
- 4) The Company undertakes to cover the Trainee against risk of accident in the workplace, risk of accident on the way to and from the place of work and risk of occupational illnesses or disease, and to make all necessary notifications and declarations duly if any one of the conditions outlined in paragraph 8.2-1 is not fulfilled.
- 5) Under all circumstances  
 the Company must immediately notify the School if the Trainee suffers an accident in the workplace during the Placement;  
 the Company should provide full insurance coverage for the Trainee if he/she is required to undertake assignments outside the perimeter of the place of work or in another country.

Whenever the required conditions are not fulfilled the Company undertakes to take out all necessary policies to ensure the protection and coverage of the Trainee, and to make all necessary declarations in case of an accident in the workplace.

## ARTICLE 9: Civil Liability and Insurance

Each of the three parties involved (i.e. the Company, the School and the Trainee) declare they are in possession of a valid civil liability insurance policy.

Regardless of the nature of the placement and the country of destination, the Trainee undertakes to take out an insurance policy covering accidents and providing assistance in case of need of medical repatriation, legal aid, etc.  
 If the Company puts a motor vehicle at the disposal of the Trainee, it should ascertain that the insurance policy for the vehicle covers its use by the Trainee.  
 If the Trainee uses his/her own vehicle or a vehicle loaned by a third party for the purpose of his/her Placement, he/she should declare this to the insurer of the vehicle and pay any supplementary insurance coverage.

## ARTICLE 10: Absence and Termination of Placement

### Temporary Absence

All absences should be notified by the Company to the School.  
 A rider signed by the signatories of this agreement should be appended to the present agreement in case of absences exceeding one week for determined reasons or due to unforeseen circumstances and authorised by the Company.

### Termination of Placement

If one of the three parties (Company, School or Student) wishes to prematurely terminate the Placement this party should immediately inform the other parties and confirm this request in writing. The reasons given shall be examined carefully in close consultation with all parties and the final decision made at the end of the consultation.

## ARTICLE 11: Secrecy and Duty of Confidentiality

Absolute confidentiality must be observed at all times. The Trainee undertakes that under no circumstances shall he/she publish any information about the company or divulge this information to a third party without the prior agreement of the Company. This condition also applies to the Work Placement Report. This condition applies for and after the duration of the Placement. The Trainee undertakes not to remove or keep any document or copy thereof or software of whatever nature appertaining to the Company without its consent.

N.B. The Company reserves the right to restrict the circulation or the Work Placement Report or to request the removal of restricted or confidential information from the Report in the interests of confidentiality. All persons who read the report in the line of their professional duty shall equally observe professional confidentiality and shall not divulge information contained therein.

**ARTICLE 12: Recruitment**

If a contract of employment between the Company and the Trainee comes into effect before the date of the end of the Placement, the present agreement becomes immediately null and void and the Trainee shall no longer be under the responsibility of the Director of the School, who should be informed before the contract is signed.

**ARTICLE 13: Miscellaneous Clause**

The Trainee cannot expect to avail himself/herself of computing facilities provided by the School for activities related to his/her Placement.

**ARTICLE 14: Applicable Law – Jurisdiction**

The present Agreement is governed by French law. Any unresolved conflict shall be settled by the relevant French court entertaining jurisdiction in the matter.

Trainee personal address : \_\_\_\_\_

Name of the degree : Diplôme d'ingénieur

Signed at (place) : PARIS

on (date) : Wednesday, 13 decembre 2017

THE DIRECTOR OF THE SCHOOL (1)  
(or appointed representative) – Signature

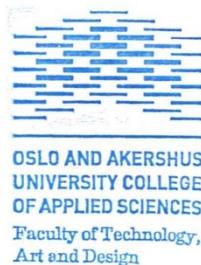


THE TRAINEE  
Signature

Academic Tutor or Supervisor  
Signature

Sophie CARLANDER  
Responsable des relations entreprises

Jérémie SUBLIME



The Head of the Company  
or appointed representative (1)  
Name & Signature

LAURENCE HABIB  
L. Heid.

(I) The signature should be preceded by :  
"I have read the terms of this contract and agree to adhere to them"

The internship supervisor for the Company

Name & Signature

STEPHANO NICOLINI  
Stephano

17-15249 9554

Institut Supérieur d'Electronique de Paris – ISEP  
Internship Department  
28 rue Notre Dame des Champs 75006 Paris - France  
Tél : 00 33 1 49 54 52 22  
stages@isep.fr Internet : http://www.isep.fr

## Appendix 2: Work Contract (In Norwegian)

### Arbeidsavtale for timelønnnet medarbeiter med oppdrag etter separat timelisten

Dette er din arbeidsavtale. For å endre og legge til opplysninger, samt signere avtalen, gå til:

<https://tilsatt.hioa.no/timelaererskjema/#/bekreft/ac7065b8-cdd3-11e7-bcd3-02426311885d>

Når du har gjort dine endringer, klikk på Send, og du blir sendt videre til elektronisk signering. Du trenger BankID eller tilsvarende for å signere dokumentet.

**NB!** Avtalen skal endres og signeres elektronisk. Har du mottatt avtalen i papirutgave må du likevel gå inn på lenken for å endre og signere."

#### 1.1 Arbeidstaker

Navn	Benjamin Bocquillon
Fødselsnummer	46089506190
Adresse	Olav M. Troviks vei, 12-14 H0107
Postnummer og sted	0864 OSLO
Telefonnummer	+33601191247
E-post	bocquillon.bj@gmail.com
Hovedarbeidsgiver	HiOA TKD - Stefano Nichele
Stillingsprosent i annen fast hovedstilling	

#### 2.1 Tidsrom og omfang

Beskrivelse av oppdraget	Project on system/lab for evolutionary and swarm robotics
Høyeste utdanning	Masterstudent
Tiltredelsesdato	08.01.2018
Tilsettingsforholdet opphører	30.06.2018

Maks antall timer	350
Ansiennitet	

## 2.2 Arbeidssted for tiden ved HiOA

Fakultet/avdeling	TKD - Technology, art and design
Institutt	Computer Science
Utdanning	Informatics, Engineering
Kontaktperson	Stefano Nichele

## 3. Lønn og kontering

Stillingskode	1069
Stillingsbetegnelse	Førstefullmektig
Lønnsramme	3
Alt	9
Tj.ann	
Lønnstrinn	41
Timelønn	195,2
Kontering	
Konto	5112
Budsjettenthet/kostnadssted	16300
Formål	

Arbeidsordre	200432-100
Sum til utbetaling	

## Appendix 3: Résumé



### BENJAMIN BOCQUILLON

23 years old - Paris/France

+33 601191247 - [bocquillon.bj@gmail.com](mailto:bocquillon.bj@gmail.com)

**French student in third year of engineering school,**

I'm looking forward to finding a PhD in order to broaden my knowledge with a new challenge and a rewarding experience.

#### EDUCATION

- **ENGINEERING DIPLOMA – Business Intelligence Speciality** Graduating in August 2018  
*ISEP (Institut Supérieur d'Electronique de Paris)* focusing on electronics, computers and telecommunications
- Preparatory class for “Grandes Ecoles” in math & physics 2013/2015
- Scientific Baccalaureate specializing in mathematics and Latin 2013

#### RELEVANT COURSES

- Digital System – Electronics and Signal: MATLAB, Arduino, ...
- Fundamental Sciences: Logic and Set Theory, Applied Probability, Applied and Numerical Analysis, ...
- Advanced Algorithmic and Programming: JAVA, Python
- Data Analysis, Big Data and Data Bases: R, NoSQL, ...
- Methods and Tools for BI: project of 3 months about Data Base and Data Warehouse

#### SKILLS

- Experience with high level programming languages such as SQL, R, HTML & CSS, Matlab, Java and Python;
- Experience with evolving approaches and technologies such as Big Data, Artificial Intelligence, Machine Learning and Robotics;
- Adaptability and Flexibility;
- Well-developed public speaking skills and excellent team player;
- French: Native speaker;
- English: Fluent;
- Chinese, Spanish, Norwegian: Basics.

## RESEARCH EXPERIENCE

- **MASTER'S RESEARCHER AT OSLO MET (NORWAY)** Jan. 2018 – June. 2018

Swarm Robotics project: I carried out a project in the field of Artificial Intelligence, specifically Swarm Robotics. The goal was to program autonomous robots called Thymio II in order to explore the collective behavior of swarms on real robots. Keywords: Implementation of methods (Neural Networks, Evolutionary Algorithms) in Python. Exposure to Deep Learning, Neural Networks and related fields.

Besides, I collaborated with the Art Department in an exposition to build a bridge between art and science. For this exposition, 10 Thymio robots initially made random movements and lines on a blank canvas; Each of these robots reacted to a certain color, so when they detected these colors they would stop moving randomly and finally create a unique painting based on emergent behavior and stigmergy.

## RELEVANT EXPERIENCE

- **ACADEMIC SEMESTER AT OSLO MET (NORWAY)** Sept. 2017 – Jan. 2018

Higher Education and International project: conferences, lessons and team-working as part of my third year of engineering school. Simultaneously, I carried out a project for a Norwegian company in the field of research and health, for which the aim was to understand and apply the process from the creation of a technical innovation to its implementation into the market.

- **CITY ONE – SERVICE PROVIDER (4500 employees, €180M of net sales)** Feb. 2017 – Aug. 2017

Internship at Internal communication and quality service: The principal objective of my mission was to think about a strategy for internal communication with the aim of designing and developing new tools in order to improve the distribution of internal information for employees, such as Intranet and an internal tool for the quality service of the company.

- **COMPUTATION PROJECT** Jan. 2016 - June 2016

Created a database and website

Worked with a team of six peers in a scientific and technical environment. The project required teamwork and professionalism applying classroom knowledge to a real-world situation. Our team monitored and oversaw the project to completion. The goal was to create a website to meet people who practise the same activity in the same area.

- **ELECTRONICS PROJECT** Sept. 2015 – Jan. 2016

Learned how interfaces interact between the physical world

Created a project with specific requirements with limited amount of time. The project required us to learn and use software quickly in order to find relevant information related to digital engineering. The goal was to program an autonomous robot which reacted to the environment (digital signal processing, implementation of fast Fourier Transform, ...).

- **FOOTBALL REFEREE OF NATIONAL TEAM (PSG, MARSEILLE, ...)** 2012/2016

Umpired male teams of under 20-year-olds: Ability to manage players with the team coaches, to make decisions quickly and under pressure, to handle conflicts and to adapt to diverse environments.

## PRIZES AND ACTIVITIES

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• Member of Local Committee on Autonomy Day 2018 at OSLO MET</li> <li>• National Certified Football Referee 2015/2016</li> <li>• Top of the Class of Youth Referee Program 2014</li> </ul> | <ul style="list-style-type: none"> <li>• 5 Years of Competitive Tennis 2011</li> <li>• Travelled and explored diverse regions and cultures</li> <li>• Driving Licence</li> </ul> |
|---|--|

**LIST OF REFERENCES****STEFANO NICHELE #1**

Title: Associate Professor – Dept. of Computer Science  
Company: OsloMet  
Phone: +47 45134015  
Mail: stenic@oslomet.no  
Relationship: My tutor concerning my project as researcher assistant in the field of Swarm Robotics

**RAJA CHIKY #2**

Title: Head of research and Full Professor in Informatics  
Company: ISEP – école d'ingénieur du numérique (Paris, France)  
Phone: +33 684674595  
Mail: raja.chiky@isep.fr  
Relationship: My internal supervisor in my school

**PAUL DOMMERSNES #3**

Title: Technology Development at Giamag Technologies A/S Kjeller and Professor II, Department of Physics at NTNU  
Company: Giamag Technologies A/S and NTNU  
Phone: +47 94186110  
Mail: paul.dommersnes@gmail.com  
Relationship: My external supervisor for my academic semester in Oslo in 2017 for my contribution to the company Giamag Technologies A/S

## Appendix 4: Cover Letter for PhD Application

9 Rue de Lessard  
77230 ROUVRES  
France

May 2nd, 2018

OsloMet – Oslo Metropolitan University  
PO box 4 St. Olavs plass  
NO-0130 Oslo, Norway  
Phone: +47 67 23 50 00

Dear Madam or Sir,

I am writing to express my interest in the PhD position at the Oslo Metropolitan University in Oslo. I will graduate with my Engineering Diploma in Electronics and Informatics (Business Intelligence specialization) from ISEP, Engineering School in Paris this August. I am confident my 5 years of courses and projects in Higher Education will allow me to contribute to the successful coordination of this project.

Previously, I have worked on several relevant projects that have provided me with the skill sets I need to be an effective PhD worker. These projects include: Electronics projects, Informatics projects and Big Data projects during my years at school. Besides, I have worked for a company, Giamag technologies A/S in Norway for 5 months in the field of Health. I have also worked for 6 months as a Research Assistant at Oslo Met in the field of Swarm Robotics. This year in Norway has exposed the Health, Deep Learning, Neural Networks and related fields. A strong interest has appeared, and it is my desire to pursue in this field.

Moreover, I have completed courses in relevant areas in my school such as Programming (Python, Java, R, ...), Methods and Tools for BI (Business Intelligence), Database and Big Data, Data Analysis. All of which have provided me the foundations to complete the projects discussed above.

Finally, I have been in tight collaboration for the PhD proposal with Ms. Zouganely and Mr. Azidi, the two-main professors associated to the project I applied for. We agree on the comprehension of the project, about the issues and the way we will improve the health field through our work.

For me, this is a plan that I have considered in depth and already explored via my studies, and I hope that my candidacy will be of interest to you. Thank you beforehand for your consideration. I remain at your disposal should you require any further information.

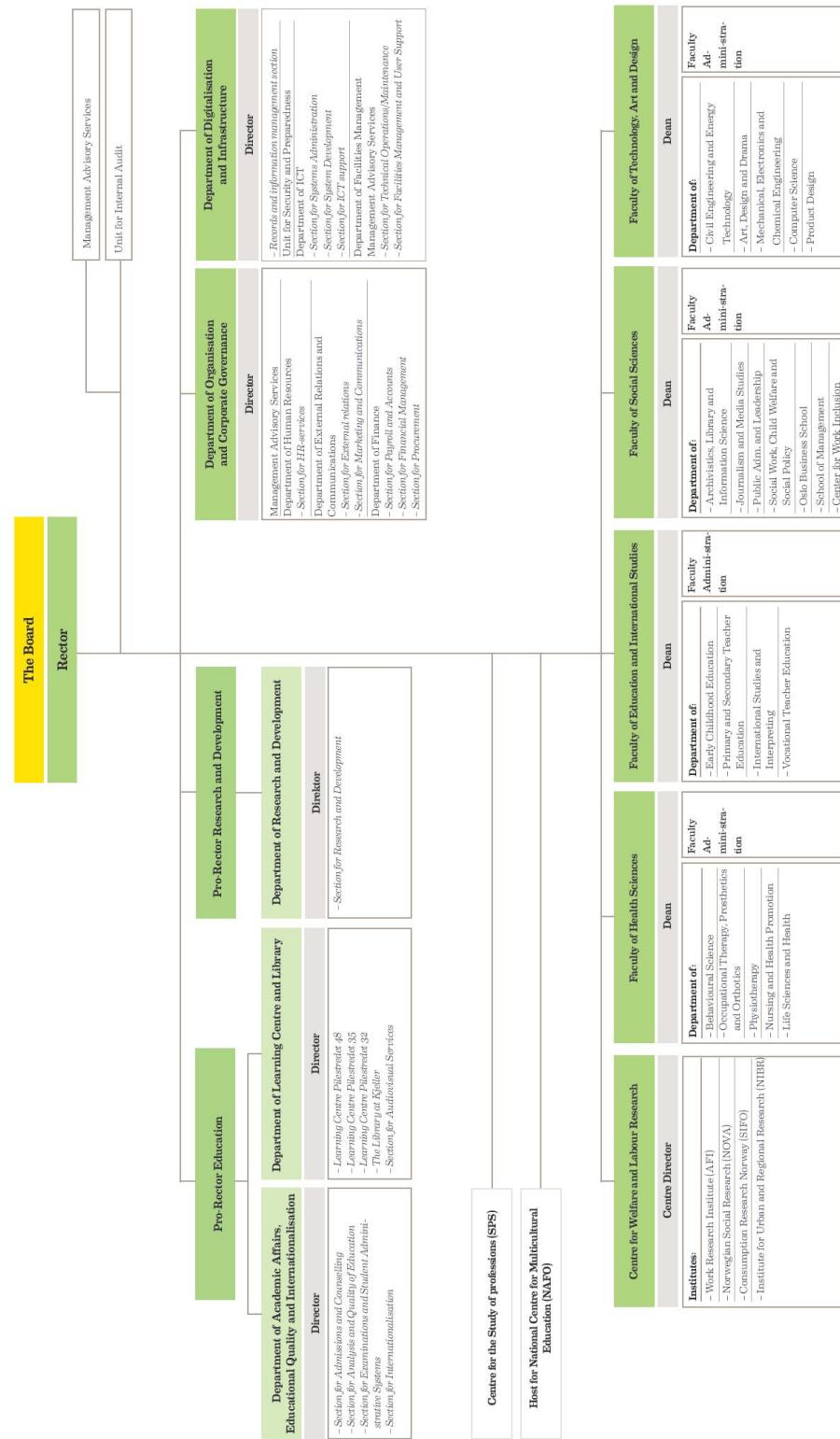
I look forward to hearing from you.

Yours faithfully,

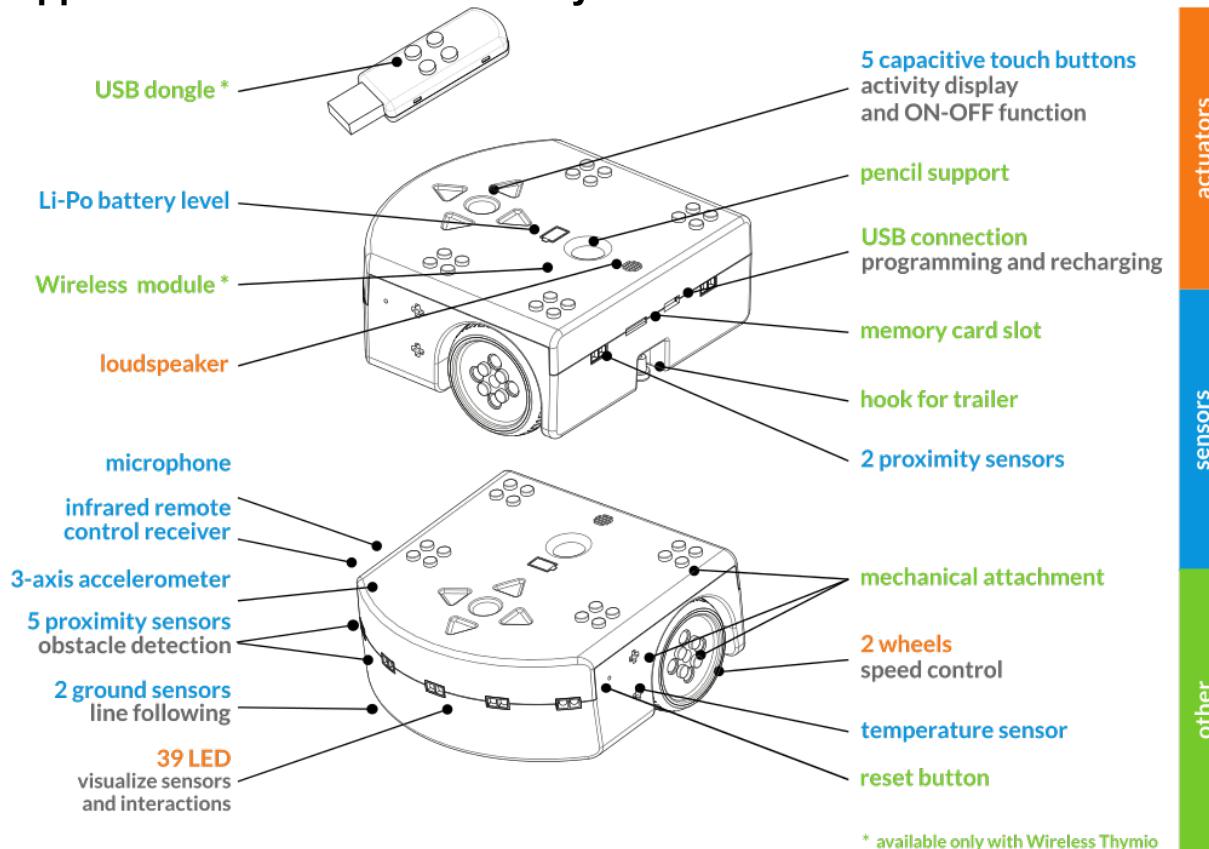
Benjamin Bocquillon

## Appendix 5: Organization Chart OsloMet

OsloMet – Oslo Metropolitan University



## Appendix 6: Hardware of the Thymio



## Appendix 7: Code Python and Aseba

Link to my GitHub to check all my codes:

<https://github.com/Benjaminbocquillonhioa/thymio-art>

## Appendix 8: YouTube videos

Link of the project: [https://www.youtube.com/watch?v=hA\\_YsC6mLP0&feature=youtu.be](https://www.youtube.com/watch?v=hA_YsC6mLP0&feature=youtu.be)

Link for swarm robotics with only water:

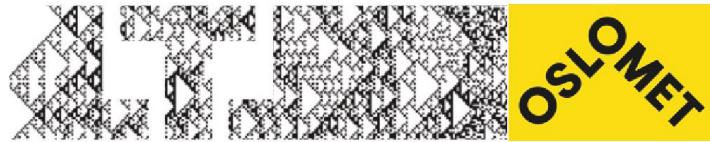
<https://youtu.be/lpNmUvYimoY>  
<https://youtu.be/BpPmMPQYFyU>

Link for swarm robotics with hot and cold water:

<https://youtu.be/7ZGMLvMMFlw>  
[https://youtu.be/\\_LxQGwkxEgw](https://youtu.be/_LxQGwkxEgw)

## Appendix 9: Poster for the exposition

Benjamin Bocquillon  
 Stephanie C. A. Hoebeke  
 Haakon H. Roen  
 Stefano Nichele



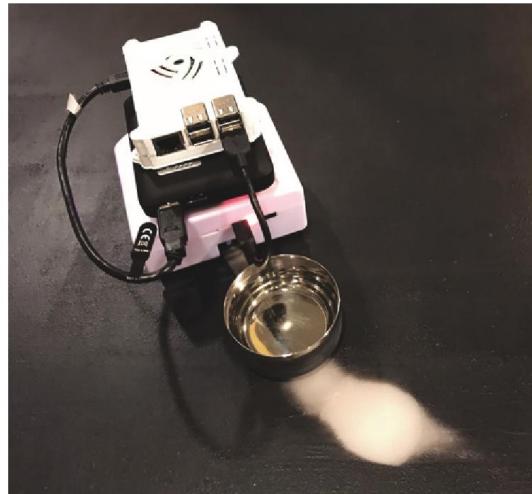
# PHEROMONE PERFORMANCE WITH SWARM ROBOTICS

**Inspired by the pheromone-based form of communication found in various species of social insects such as bees and ants, thymio robots are placed on a heat sensitive surface that changes colour based on their movements. The robots interact both among themselves and with the environment, and thus produce a continuously evolving pattern that emerges solely based on their movement, or lack thereof.**

Several aspects of the behaviour of social insects has served as inspiration for multi-agent research in swarm robotics because they exhibit sophisticated behaviour among many agents based on relatively simple action patterns displayed by the individual agent. One of these is pheromone-based communication. Here pheromones, a form of chemical substance, are deposited to mark certain areas with information in order to assist other insects at a later time. An example is the marking of areas containing food, so that other agents of a colony can detect a food source more easily (Luke & Panait, 2004, s. 1).

This project's use of pheromone-inspired behaviour is based on a programmed behaviour of thymio robots, relatively small robots (11 cm x 11.2 cm x 5.3 cm) equipped with several visual sensors all around the sides and underneath (Thymio, 2018). Movement is made possible by two wheels on each side of the body, and as the individual robots move, it temporarily changes the colour of the underlying surface from black to white. The robots are programmed to notice the change of colour on the ground, and to follow its trail, but just as the release of pheromones in nature has a temporal effect, the change of colour doesn't last forever either. It has to be enhanced or renewed by other robots or it will disappear, and new paths emerge.

The change in colour is triggered by a small metal bowl that is attached at the back of each robot with a rubber band. These bowls are filled with hot water, and this heat is transferred through the metal towards the ground surface. This surface is covered with a form of thermochromic paint that at room-temperature looks black, but with exposure to heat above approximately 40°C turns colourless. This is due to a reversible isomerization of the pigment molecules where the two forms have different absorption spectra, and therefore looks different (black/colourless). The pigment changes back when the temperature lowers below the tipping point, and can therefore be used as a dynamic surface constantly changing between the two states.



Thymio robot transforming the painted surface

The use of swarm robotics leaving traces upon a surface based on their shared movement is inspired by other art projects such as the Portuguese artist Leonel Moura's BeBot (2017) made for the Astana Expo, where a similar type of robots are placed on great sheets of paper in the exhibition. Equipped with pens of different colours, they move around to produce abstract expressionist-looking drawings that later are hung as separate pieces in the exhibition space (Moura, 2017). The end-goal for the Moura's performance is therefore a classical form of artistic expression, easily interpreted as such, whereas in the pheromone performance, the performance is the artistic expression itself. The performance, rather, seeks to display a form of Artificial Life, where robots emulate behaviour taken from the natural world (Penny, 2017, s. 141-142).

### Sources

- Luke, S. & Panait, L. (2004). *A Pheromone-base Utility Model For Collaborative Foraging*. Fairfax, Virginia: George Mason University
- Moura, L. (2017). BEBOT. Hentet fra: <http://www.leonelmoura.com/index.php/robot-art/bebot/>
- Thymio (2018). What is Tymio Composed of. Hentet fra: <https://www.thymio.org/en/thymiospecifications>
- Penny, S. (2017). *Making Sense: Cognition, Computing, Art, and Embodiment*. Cambridge, Massachusetts: MIT Press