Collective Behavior Simulation of Mobile Robots Using Lego NXT Sets

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***Abstract* — For response to the challenges of Industry 4.0 a new subject the "Simulation of Multi-agent Mobile Robots" was introduced into the curriculum of Mechatronic Engineering MSc course. It was an important aspect to make the study program for practice-oriented. Lego NXT sets were used for the simulation collective behavior of mobile robots. The paper summarizes the experiences of these practices.**

I. INTRODUCTION

The forth industrial revolution holds the name of Industry 4.0 and focuses on the smart technology and the automation of production by introducing intelligent robotic systems based on artificial intelligence.

The aim of robotics is to compensate the demand on labor market while improving the quality and also the efficiency of production. Japan was the predecessor of the introduction of industrial robots in the 1980s. This was the first success story of artificial intelligence applications after the crisis in 1970s.

In the Executive Summary World Robotics for 2018. year about the industrial robots the International Federation of Robotics announced that the robot sales increased by 30% to 381,335 units in year 2017. (Fig. 1) This is a new peak for the fifth year in a row. The main drivers of this exceptional growth in 2017 were the metal industry (+55%) and the electrical/electronics industry (+33%). [1]

TABLE I.
THE DEFINITIONS OF ARTIFICIAL INTELLIGENCE

	Human	Rational
Think	„The exciting new effort to make computers think …, machines with minds, in the full and literal things" [2] "The automation of activities that we associate with human thinking, activities such as decision-making, problem solving, learning…" [3]	„The study of mental faculties through the use of computational models." [4] "The study of the computations that make it possible to perceive, reason, and act." [5]
Act	"The art of creating machines that perform functions that require intelligence when performed by people" [6] "The study of how to make computers do things at which, at the moment, people are better." [7]	„A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes." [8] "The branch of computer science that is concerned with the automation of intelligent behavior." [9]

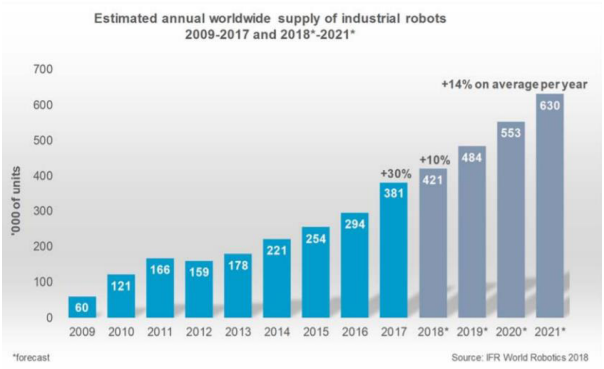

Figure 1. Estimated annual worldwide supply of industrial robots 2009-2017 and 2018-20121 [1]

The robot sales in the automotive industry increased by 22% and remained still the major customer of industrial robots with a share of 33% of the total supply in 2017. There are five major markets representing 73% of the total global sales volume in 2017: China, Japan, the Republic of Korea, the United States and Germany.

The enterprises of Middle-Transdanubian Region already plan to investigate into the smart manufacturing and need the relevant, and high quality human resources.

Óbuda University is prepared for the challenges of the industry and introduced a new subject with the topics of the simulation of multi-agent mobile robots into the curriculum of Mechatronic Engineering MSc course.

II. ARTIFICIAL INTELLIGENCE AND THE INTELLIGENT AGENTS

John McCarthy formulated the definition of artificial intelligence in Dartmouth College in 1956. Several other definitions are presented in the Table I. Before that this field of informatics held the name of cybernetics which was the science of control at that time. The agent technology was developed in 1990s.

A. Intelligent Agents

In artificial intelligence, an intelligent agent is an autonomous entity which observes the environment through sensors and acts upon it using actuators. [10] Some definitions of intelligent agents emphasize their autonomy, and so prefer the term autonomous intelligent agents. Still other authors [11] considered goal-directed behavior as the essence of intelligence and so prefer a term borrowed from economics, rational agent.

TABLE II.
ROBOT COMPLEXITY [12]

Computing Performance [MIPS]	Biological Example	Function	Capability
10	insect	Transportation, guarding, floor cleaning	Mobile operation
5 000	lizard	Lawn mowers, cleaning, garbage collection, warehousing, transportation	No adapting to changing environment
100 000	mouse	Service	Reinforced learning
5 000 000	monkey	Internal simulation for complex problem solving	Fast learning, object and parameters recognition
100 000 000	human	Abstraction and generalization, application of AI	Symbolic thinking, concept using

The structure of intelligent agent is presented in Fig.2. The humans are not in all cases rational. Unlike rationality the agents can imitate also human behaviors.

The agents can be also divided in depend of realization on software or hardware agents. The hardware agents are commonly known as robots. (Table I.)

The most commonly used industrial robots are fixed but the last time the customer increasingly prefer mobile robots. The Table II. shows the required computing performance for realization several capabilities.

B. The Agents Environment

The part of robot simulation is the programming of robots environment.

(1) Accessible – non accessible

The environment is accessible when agent sensing devices have access to the entire state of the environment.

(2) Deterministic – non deterministic

The environment is deterministic if the next state of the environment is clearly defined by its current state and the actions chosen by the agent.

(3) Episodic – non episodic

The environment is episodic if the agent's experience is split into episodes in which the agent's behavior does not depend on the actions of the previous episodes.

(4) Static – Dynamic

The environment is dynamic if it can change while the agent is thinking. If the environment does not change over time, but the agent's performance can do it, the environment is semi-dynamic.

(5) Discrete – Continoues

The environment is discrete if there is a clearly defined finite set of perceptions and actions.

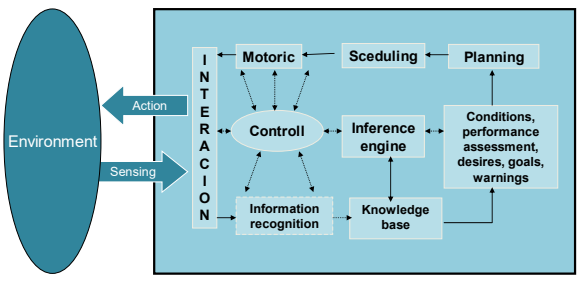

Figure 2. The Intelligent Agent

III. LEGO NXT ROBOTS

LEGO NXT is available since 2006. Two years later the NXT 2.0 was announced. In the original version three motors and four sensors were available (ultrasonic, sonic, light and collide sensors).

The 2.0 version had more parts and had a new colour sensor in the kit. The Brick had an USB interface and four robots could be created. This kit had a special version called 'Educational version' specially designed for educational purposes.

Fig.3. presents the typical structure of NXT robots.

IV. SIMULATED ROBOTS BEHAVIOR

Six different behavioral patterns were selected fro realization.

(1) Coward: this type of robot goes forward slowly and when faces with any kind of barrier it moves backward and changes its direction

(2) Curious: this robot moves with a moderate velocity and when meets another robot or a wall it stops and waits for a while and then moves into another direction

(3) Hungry/voracious: this robot moves around quickly and search for energy source. If the robot meets any barrier it doesn't stop but goes forward at a moderate speed.

(4) Aggressive: this individual goes through fast and in case of disturbance it doesn't change its direction and moves forward without any stop

(5) Hyperactive: this robot goes through very fast and avoid collision with rapid change of its direction

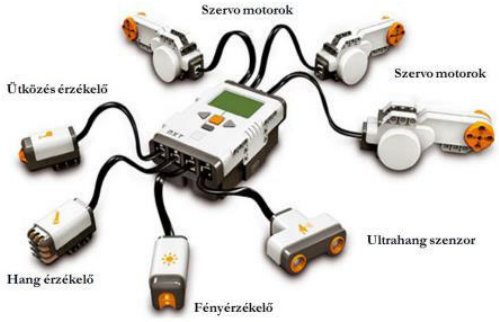

Figure 3. The LEGO NXT robot

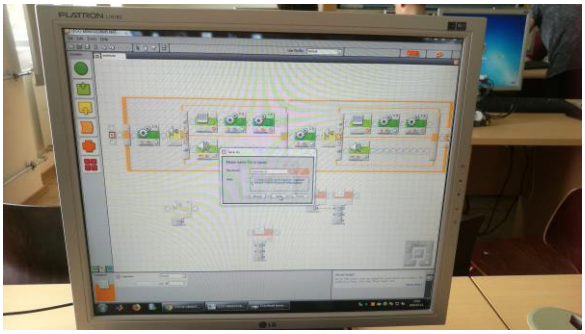

Figure 4. The software development environment of Mindstorms LEGO NXT robot

Fig.4. shows the software development environment of Mindstorms LEGO NXT robot. The different robots were programmed for different behavior pattern. The testing situation is presented on Fig.5.

V. LEGO MINDSTORMS EV3 ROBOTS

Lego Mindstorms EV3 was released as the third generation of LEGO robot series in 2013. In its name the EV refers to evolution and 3 means the third generation. The main advantage of the EV3 set is renewed the programmable brick in which the processor was changed from ARM7 to a stronger and faster ARM9 CPU. Compared to the former NXT and NXT2 versions the EV3 brick contains a USB connection and an SD card slot which can be used up to 32GB.

A. LEGO Mindstorms EV3 Sets

The brick's display also was changed in size. Wifi and Bluetooth connections are also available. The set contains a complete tutorial for building and programming 5 robots (EV3RSTORM, TRACK3R, SPIK3R, GRIPP3R, R3PTAR).

There are two kind of EV3 sets namely Home edition and Educational version. The EV3 home edition set contains 1 programmable brick, 2 large motors and 1 medium motors, 3 sensors (further sensors are available as extras), 1 remote controller which also can be used as a beacon, USB cable and hundreds of LEGO building components. The Educational version contains more sensors.

The EV3 can be fully programmed and controlled in its own software environment called LEGO Mindstorms EV3 home edition is based on LabView environment and the brick can be programmed by using blocks. The Educational version contains teacher resources, tutorials, lesson plans, classroom materials, etc. [15].

A benefit of EV3 robots is that they can be programmed and controlled on Android and IoS platform. The Robot commander app and the EV3 programmer app are available for both platforms. The apps connect to the brick via Bluetooth without using a computer. The programming app uses drag-and-drop programming interface. These application contains pre-programmed codes for the 5 robots (EV3RSTORM, TRACK3R, SPIK3R, GRIPP3R, R3PTAR) and own programmes also can be uploaded to the robots.

Through the advanced functionality, the EV3 robots are more appropriate for behavior patterns realization.

Figure 5. The moving LEGO NXT robot

B. Sensors

The Home edition contains 1 touch sensor, 1 infrared and 1 colour sensor. The Educational version contains 2 touch sensors, 1 colour sensor, 1 ultrasonic sensor and 1 gyroscope. The microphone from the NXT2 set is compatible with the EV3 set.

Using the touch sensor, the robot 'feels' when it bumps into its environment. The sensor detects when the button is pressed or released. The touch sensor can be used as a trigger when the aim of the use of this sensor is not the detection of its environment but the control of the robot's motors. The touch sensor also reacts to a double click function.

The infrared sensor can be used in two ways. The sensor can measure the distance and force the robot to react or can follow an IR source (generally the remote controller) in beacon mode. On the other hand the IR sensor can detect the remote controller's commands and force the robot to fulfil it.

The colour sensor can detect the colour of the surface or the intensity of light. 7 colours can be detected and each colour has its own numeral value (ie. white equals to 1). This sensor must be close to the surface up to 1-2 centimetres for perfect detection). If the sensor measures its environment's light intensity it can be done in two ways: the sensor emits red light and measure the reflection (reflection light intensity) or just measures the environment's light intensity without producing any outgoing light source (ambient light intensity).

The ultrasonic sensor measures the distance of the surrounding objects up to more than 2 metres. The sensor emits high frequency sound waves and measures the reflectance and time. If at least two robots use ultrasonic sensor the robot can only listen to these signals and use them for interaction.

The gyroscope detects changes in rotation and orientation. The rotation is measured in rotation per second and the maximum value is 440 degrees per second. The sample rate of the sensor is 1kHz. Angles can be measured and balancing robots can be built by using gyro sensor.

Large and medium motors are also can be used as sensors as the motors are equipped with a built-in rotation sensor. The sensor can measure the total number of rotations or the angle of rotation in degrees [16].

CONCLUSIONS

(1) The robotics and smart manufacturing are a part of interest of artificial intelligence.

(2) The multi-agent mobile robots are a perspective field of research in the age of Industry 4.0.

(3) The LEGO NXT robot sets were successful used for simulation of collective behavior of robots.

(4) The LEGO EV3 robot sets provides more possibilities for experiments.

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