Colour based LEGO robot controlling

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***Abstract*— Collaborative robots are capable of work performed jointly by humans and robots, the safety aspects of which are of fundamental importance in relation to the design of the work environment. Robots and people can only move freely in the workplace in appropriate places, there are also prohibited areas for robots and workers. To differentiate this, the colour-based work area designation is one of the simplest and, in some respects, cost-effective solutions. During our tests, we used the LEGO Mindstorms EV3 robot to examine the detection capabilities of the robot's colour and light sensor, the effect of different programming options on the robot's movement, and the proper detection of the red and blue areas. As a summary, we can draw the conclusion that the sensors of mobile robots are suitable for navigation purposes, they are able to accurately recognize and distinguish colours and can therefore be used well even in an industrial environment to achieve both navigation and related occupational safety goals.**

Keywords*— *LEGO, robot, color based control

I. LEGO ROBOTICS

With the development of robotics, there is an increasing demand for the environmental interaction of an intelligent device to be as large as possible. This is especially true for collaborative robotic techniques when the robot has to work with a real person, an operator and a workspace.

Environmental information does not only mean the exact definition of an object, but in many cases the image and colour information obtained about the object is what is formulated as an input parameter. Nowadays, robot control also assumes as many input parameters as possible. The careful design of the integration of robots into the environment is necessary, it raises not only control but also safety issues.

Nearly 60% of the human brain contains image data, and a certain part contains colour information. If we want to manage the robot in a human-compliant manner, it would be very beneficial to implement the management of colour information as input parameters. Such an input parameter can not only support the robot's own "decision", but can also be a control parameter that can even decide the robot's route, the robot's movement, the creation of trajectories, the exact spatial coordinate of each other. Image processing with a single camera system is obviously suitable for this, the use of much simpler colour sensors, which can produce a well-defined spectral dependence, can give significant results.

The Danish LEGO -obviously due to keeping the market used has changed with the times and offers a component and building element environment that is more than a game, but a real development environment. It is worth getting to know LEGO robots at a very young age, so preschoolers can already meet the concept of algorithm, robot, program, or decision tree. The sensors of the robots are properly programmed, we can give our robot countless instructions, and with the help of these we can even simulate artificial intelligence and free will, it is up to us to equip our machine with what features. These qualities can simulate for example hyperactivity, disinterest, joy, kindness, injury. The hyperactive robot moves forward without stopping until it detects an obstacle on the first sensor (it can be anything, a tree, a table, a wall, or even another robot that is currently in motion), here a random generator draws a lottery that the robot turn right or left, then continue on your way, ad infinitum [1].

II. RGB TECHNICS AND COLOUR SENSORS

RBG is derived from the English terms red, green, blue and supports the creation of different shades of colors based on an additive model. This is based on the fact that any color can be produced from a mixture of red, green and blue colors of different strengths. Based on this, all colors consist of these three main components. The intensity of the individual basic components (RGB) is changed between 0 and 255 values in the case of eight-bit representation. Depending on the desired color, if all three components are set to the maximum value, a white color is obtained. (255R, 255G, 255B) By definition, the code for the pure red color; 255R, 0G, 0B.

Figure 1 illustrates the resolution of the visible range into three basic colors. To mix a "specific color" in the figure; 0.08R+0.96G+0.02B component required. [2]

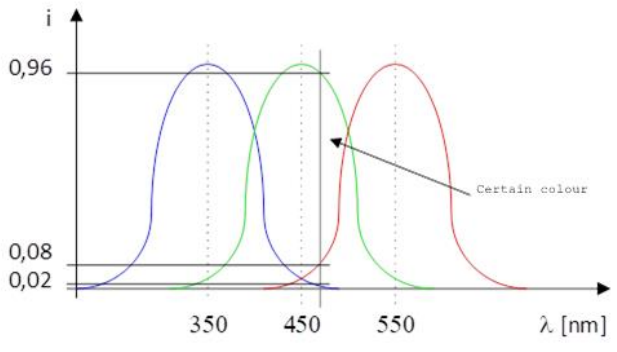

Fig. 1. Additive RGB technics [2]

The RBG color model is used in many places, televisions, monitors, digital displays, where all colors can be displayed by combining the three colors. The two-way interpretation of the model is self-explanatory, since during imaging and color measurement, the R, G, B components of the source of the given wavelength must be determined as coefficients.

Among the light sources, the most well-known light source that operates our civilization is the sun, which provides heat, light and energy to sustain life on earth. The light produced by the chemical reaction of individual organisms is called bioluminescence. Thus, in the case of individual insects or deep-sea animals, these characteristics typically serve the survival of the given individual, may play a role in hiding, hunting, communication, or even self-reproduction. Incandescent lamps and halogen lighting fixtures are traditionally the most common artificial light sources, and they can be of various types and shapes. These lighting devices work with electricity and produce light with very poor efficiency. A few percent of the absorbed electrical power will be visible light, the majority product will be infrared light and heat.

Lasers are strong, intense and uniform light sources that can be widely used in industrial devices, communication, telecommunications, measuring technology, medical applications, measurements, or even in the entertainment industry. Nowadays, the most common ones are based on semiconductors, Laser LEDs (LLED). their spectrum is very small (monochromes). Xenon light sources, in addition to everyday lighting, they are used in decorations and illuminated signs. The light source is xenon gas excited by electric current and driven by a current generator. Their efficiency and life expectancy is much better than that of incandescent lamps.

An LED is a semiconductor-based light source that uses electroluminescence to emit light. When an electric current is applied to the semiconductor, it emits photons during the processes taking place at the P-N junction. We can distinguish several types, even depending on the use. SMD LEDs, due to their size, they are mainly used in places where the possibilities are limited, in terms of size, for example, they are used on printed circuit boards or displays. COB LEDs are high-performance light sources that are used in lamps, which can be achieved by using several discrete LEDs. RGB LEDs combine the three basic colors, screen technology, background light, production of variable color temperature.

The UV LED emits radiation in the ultraviolet spectrum, which is used for medical purposes, sterilization, or the activation of fluorescent materials. The IR LED provides infrared radiation and is used in night vision cameras and remote controls. The infrared range is also often used because Si-based semiconductors work with the best efficiency at this wavelength (780-900nm, depending on additives). High Power LED is mainly used for lighting in cars, public areas, and households. LEDs are well-deserved light sources, as their lifetime, efficiency, and parameter constancy significantly exceed those of the above-mentioned devices. The automation of production has been solved, so the relative costs are also more favorable.

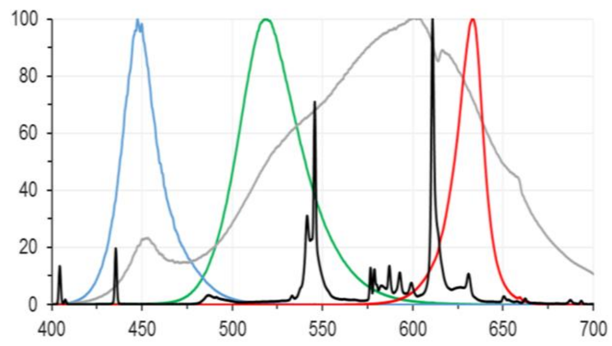

Fig. 2. Spectral intensity of different LED souces compared to a composite light source [3]

The light sensor converts the intensity of the light in its environment into an electrical voltage signal. During operation, the energy of electrons stimulated by incoming photons exceeds the threshold energy of the depleted layer of a silicon semiconductor PN junction. As a result, the UAK voltage of the PN junction increases. Ideally, this is the photodiode, or in a larger size, depending on the technology, the solar cell. It can be said that all semiconductors are photosensitive, since the PN transition depends on the amount of free electrons everywhere. Color perception means determining the RGB coefficients. One way to do this is to choose a semiconductor that is sensitive to the appropriate wavelength. [4] [5]

The other more frequently used method is when choosing a broad spectrum sensor. In front of each photodetector that detects the three basic colors, I place the red, green and blue basic color filter. To "separate" the components of the three basic colors, the color separation mirror process is also used, primarily in imaging devices (CCD) and high-resolution cameras.

The light sensor of LEGO Mindstorms EV3 offers several functional possibilities, depending on the perception of colors, in the navigation of the robot case. The sensor can be used in two ways, one is the reflectance number, which detects the reflected strength of natural or artificial light in the environment. It is able to recognize, avoid and move objects, it recognizes lines even based on color, so we can navigate our robot depending on the program. [6]

The other option is the light source number, which detects the light sources directed at it. This can also work as described above, and allows absolute coordinate navigation, object detection, and distance determination. In the case of LEGO Mindstorms EV3, the setting of the sensors can strongly influence the result obtained. It does not matter at all what angle the incident light receives the sensor, which can be adjusted with the correct positioning to achieve the desired result. [7] [8]

Light-based robot navigation can work in two ways, LIDAR (light detection and ranging) and optical flow. In the case of LIDAR technology, the system emits laser beams, then detects the beams reflected from the objects, and based on the measurement of the reflection time, the system creates a three-dimensional map of the environment. LiDAR is particularly useful in complex, dynamic environments because it can determine the distance and position of objects with high accuracy. It was first used to survey larger areas, as it 'sees' into the subsurface layers. In the case of optical flow, the robot uses cameras to process visual information from the environment.

Optical flow is based on the analysis of movement patterns between successive frames, which allows the robot to determine speed and direction. This technique is particularly beneficial in indoor environments where the GPS signal is weak or unavailable. It is important to mention that the visual displacement is not necessarily the same as the real displacement.

The use of autonomous robots in healthcare applications can offer significant benefits in hospitals and other healthcare facilities. With the help of light-based navigation, robots can safely and efficiently transport medicines, medical devices and other necessary items between different departments. This reduces the potential for human error and increases operational efficiency. This technology is used in many industrial production plants (for example, pharmaceutical factories). Despite how widespread these solutions are and light-based robot navigation offers many advantages, it also faces many challenges. One of the main challenges is cost-effectiveness, as LIDAR systems can be expensive, which limits the widespread adoption of the technology. In addition, light-based navigation systems can be sensitive to environmental factors, such as changes in light conditions or dust, which can affect the accuracy of the system. In industrial conditions, this is a big challenge for operators. [9] [10]

III. MODELLING AND RESULTS

In order to create the most realistic artificial industrial environment model possible, the system was assembled over a uniform, smooth, white surface, the PAR RGBW led light sources illuminated the surface from above. Three pieces of PAR RGBW led were used, with which the lighting of the model environment could be divided into three sections and the lighting of these sections could be changed in small steps.

The selection of the surface was based on a smooth surface so that the LEGO Mindstorms EV3 robot could easily move and turn on it if necessary, as well as a non-reflective surface, which ensured the correct detection of the color and light sensor. [11] [12]

The PAR RGBW LED lamps used for lighting are equipped with 54 3-watt LED light sources, the red, green, blue and white LEDs are located separately, so they can be regulated separately (12-R, 18-G, 18-B, 6-W). The total power of these light sources is 162 watts. PAR lights can have a variety of functions, such as built-in programs, DMX control or wireless remote control, allowing for ease of use and versatile setup. These lamps are often used in live stage performances, concerts, DJ sets, clubs, but they can also serve as a popular lighting device in the home environment, for example as mood lighting or to create light effects. In addition to hobby use, they are also suitable for creating professional applications.

A DMX connector is available for controlling the LED light sources, where the light intensity and, of course, other properties (such as the flashing and its frequency) can be infinitely adjusted between 0 and 100 values. The DMX control of the PAR RGBW led light source (Figure 8-5), the color composition, intensity and possibly flashing of the light was solved with an FTS DMX 512 controller. DMX 512 is a standard communication protocol in lighting that enables communication and control of lighting devices such as LED lights, dimmers, LED moving light heads and effects. "DMX" stands for "Digital Multiplex", while "512" indicates the transmission capacity of the protocol, which means 512 channels.

This protocol works through a serial digital communication system that provides one-way data transfer. Each DMX device has a unique address (DMX address) that can be specified by setting the control unit. The control unit sends the DMX signal messages, which contain the parameters of the various lighting effects, such as color, brightness or movement. The DMX 512 protocol is very flexible and allows the simultaneous control of many devices. It is often used in live stage performances and concerts, where precise and synchronized lighting effects are required. The protocol enables the creation of synchronized light effects, as well as the dynamic control and programming of lights.

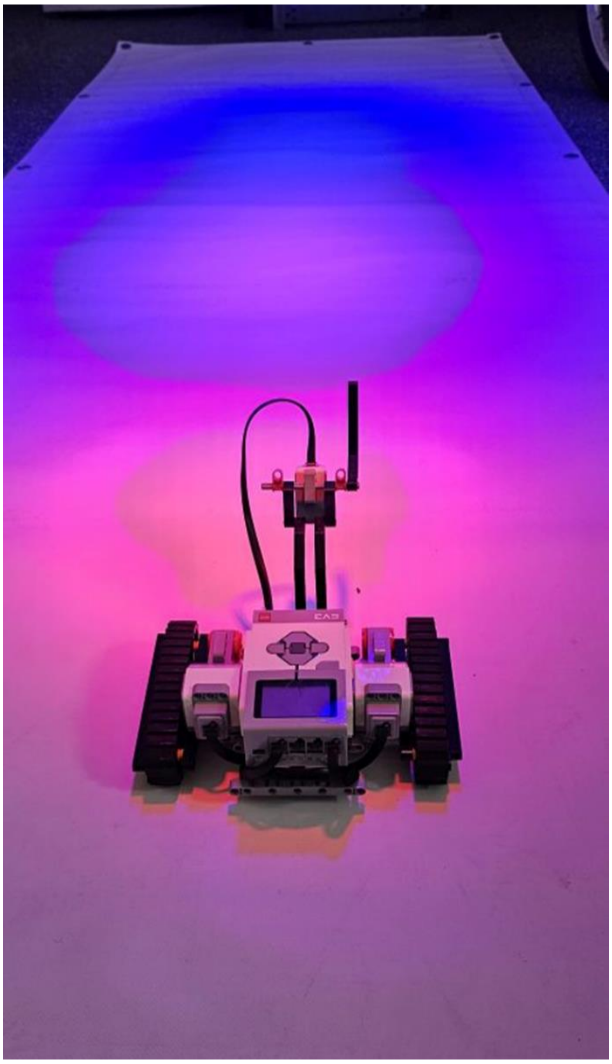

Fig. 3. Working area with the lighting [1]

We also programmed the LEGO Mindstorms EV3 robot on its own programming interface, where the robot, simulating industrial conditions (Figures 8-10, 8-11), moves forward or backward between sectors marked with different colors according to whether it is red, blue or both is the surface illuminated.

In the blue-lit areas, the mobile robot can move freely, which in this case means the forward movement of the EV3 robot with tank drive, then the crawler on both sides rotates at 75% of the maximum engine speed. The areas illuminated by red light are not accessible to the robot, only the worker can move freely in this zone. The EV3 robot detects red color and starts moving backwards, its movement is in a straight line due to the value of -5 on both sides of the tank drive. After leaving the forbidden area, the robot stops and starts again in the other direction. If the space is illuminated with both lights, both the robot and the worker can use it freely. In this case, the EV3 robot continues to move.

Fig. 4. LED light sources [1]

The lighting of the work area is uniform due to the location of the three PAR LED illuminators, the light of the three illuminators overlaps a little, and the colors can be changed freely. In the case of our current model, a part illuminated with both colors was located between the red and blue areas, so the robot changed its movement at the border areas. The color fidelity of the above images is not perfect, in reality the red, blue and the area containing both are well recognized even by the robot.

Through the MATLAB interface, we tested what the robot "sees" during its progress. We took into account the change in the intensity of the red and blue colors, where the robot starts to perceive the second color and how long it perceives the first. In the first step, we checked the connection between LEGO Mindstorms EV3 and the computer. As a second step, an empty graph was created, which is constantly updated with new measured data. The Y-axis of the graph shows the intensity values (0-100) and we read the color sensor continuously for 60 seconds using a while loop.

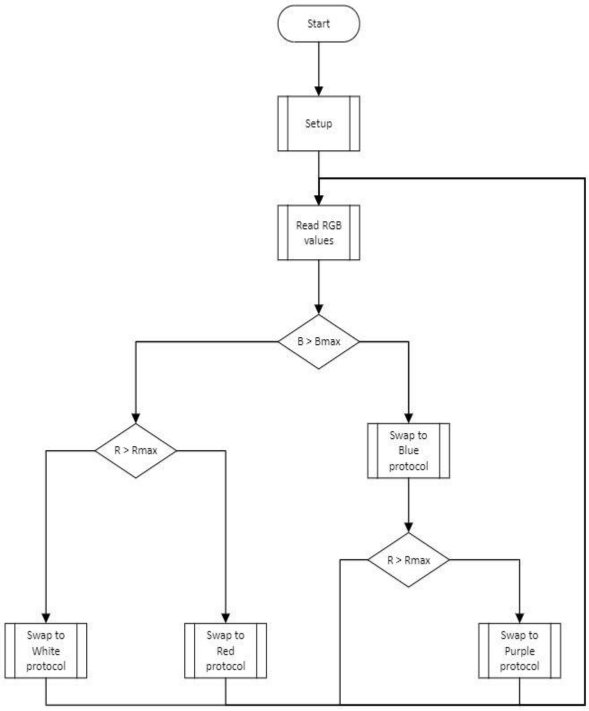

Fig. 5. Programme flowchart [1]

The intensity of the red and then the blue color was read and displayed on the graph. During data display, the graph was updated in real time with the new data using the animated line and draw-now functions. This code ensures that the intensity of the red color measured by the LEGO EV3 color sensor is continuously displayed on a graph in MATLAB, so it is easy to follow the change in the intensity of the red color over time. In the case of the color blue, we proceeded in a similar way. [10] [13]

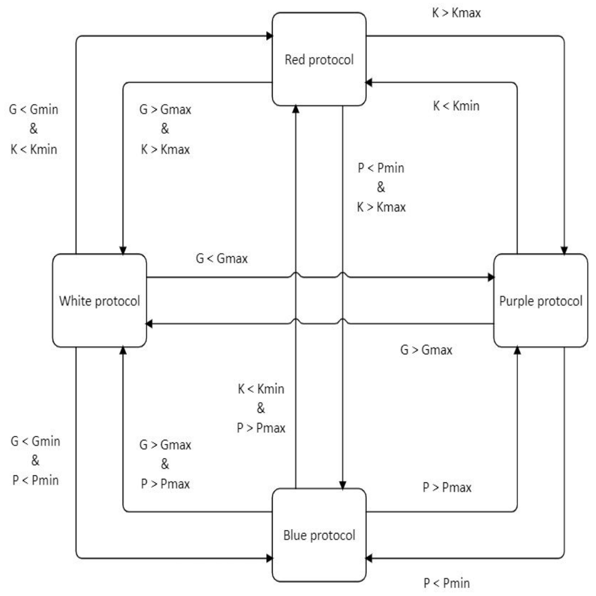

Fig. 6. Status diagram [1]

It can be concluded that both the red and blue colors were well recognized by the EV3 robot, during its forward progress the location of the color transition can be clearly recognized on the graph, the decreasing intensity of red, while the increasing intensity of blue can be detected. This can be significant because, in industrial conditions, the robot, like a human, can distinguish the areas marked with light and change its movement speed and direction accordingly.

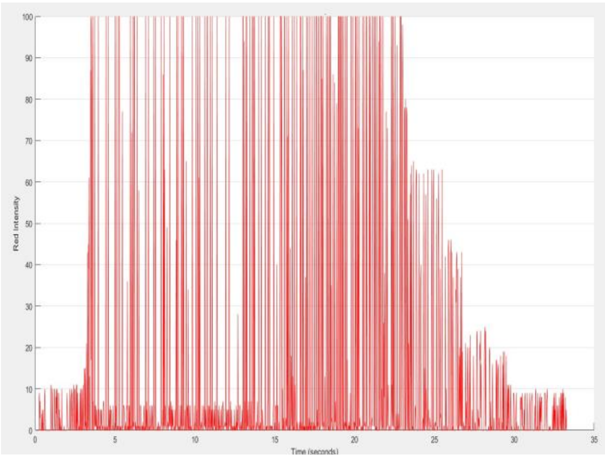

Fig. 7. Changes in red colour intensity [10]

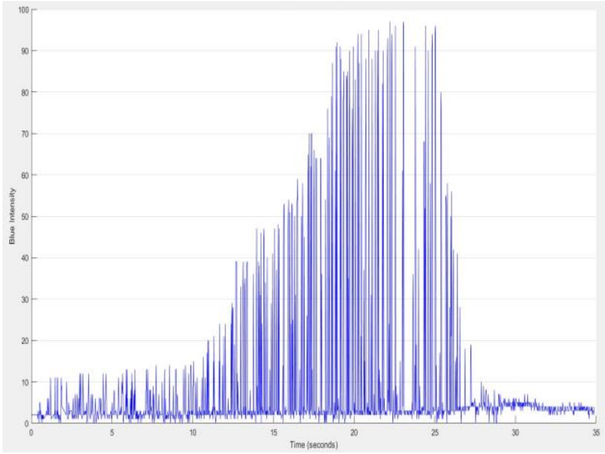

Fig. 8. Changes in blue colour intensity [10]

IV. Summary

One of the conditions for the use of mobile robots in industrial production is that they can find their way around their environment independently, which they can solve in several ways. One way of doing this is light and color perception, when they navigate by recognizing them during their movements. With the help of the sensors of the LEGO Mindstorms EV3 robot, light-based mobile robot navigation can be well simulated, and the behavior of the robots can be modeled by creating the appropriate industrial environment.

Collaborative robots are capable of work performed jointly by humans and robots, the safety aspects of which are of fundamental importance in relation to the design of the work environment. Robots and people can only move freely in the workplace in appropriate places, there are also prohibited areas for robots and workers. To differentiate this, color-based work area designation is one of the simplest and, in some respects, cost-effective solutions.

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As a summary, we can draw the conclusion that the sensors of mobile robots are suitable for navigation purposes, they are able to accurately recognize and distinguish colors and can therefore be used well even in an industrial environment to achieve both navigation and related occupational safety goals. The concept of color-marked work areas is suitable for the widespread use of collaborative robots.

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