Application of color sensor programming with LEGO-Mindstorms NXT 2.0 to recreate a simplistic plague detection scenario

Aplicación de programación de sensor de color con LEGO-Mindstorms NXT 2.0 para recrear un escenario simplista de detección de plaga

Dayana Viedma Ariza[1], Aldair Meza Palacio[1], Isaac Pertuz Aragón[1], Cristian Medrano Pulido[1],
Elizabeth Acosta Logreira[2], Javier Roldán Mckinley[3]
[1]: Semillero DIMER Group, Mechanical Engineering, Universidad del Atlántico, Barranquilla, Colombia
[2]: Semillero Go-Innovations, Industrial Engineering, Universidad del Atlántico, Barranquilla, Colombia
[3]: DIMER Research Group, Mechanical Engineering, Universidad del Atlántico, Barranquilla, Colombia
dayavied2011@gmail.com
aldair2994@gmail.com
isaacpertuz@hotmail.com
cristian-amp@hotmail.com
elyacosta805@gmail.com
javierroldan@mail.uniatlantico.edu.co

Abstract— A hands-on assignment framed under the learning by project approach was assigned trying to offer an engaging theme for students from different Engineering undergraduate programs. Many concepts in Mechatronics were integrated in a very friendly way with LEGO-Mindstorms hardware. A vehicle concept to assist the plague detection in agriculture that was raised after project completion is proposed.

Key Word **— educational Robotics; LEGO color sensor; Mechatronics**

Resumen— **Una tarea práctica diseñada bajo el enfoque de aprendizaje por proyecto tratando de ofrecer un tema motivador para estudiantes de diversos programas de pregrado de Ingeniería es profundizada. Diferentes conceptos de Mecatrónica se integraron se integraron de una manera muy amigable usando el equipo LEGO-Mindstorms. Como resultado del desarrollo de proyecto, se propone el concepto de un vehículo para ayudar en la detección de plaga en agricultura.**

Palabras clave— **Robótica educacional; sensor de color LEGO; Mecatrónica**

I.   INTRODUCTION

First attempts to detect plague and pest effect in crops using technology were supported initially by aerial direct inspection [1], [2] and aided later with pictures taken by human at the crop place [3], [4], analyzed, inclusive, with infrared analysis [5]. The evolution of plague detection has mainly used image processing to detect diverse plant diseases as powdery mildew on rose using Open CV [6] and severity of the damage on the coffee leaves using Matlab [7], among others. Current applications of image processing are useful to identify diseased leaf, stem, fruit, and quantify affected area and its shape [8], which is achieved by different methods of analysis, such as neural networks, thresholding, dual-segmented analysis, fuzzy logic, feature base rules, etc. [9]. The automated systems for plague detection are easier to implement in greenhouse plants rather than open field crops [10]. For plantations, the use of mobile robots to integrate the detection tool becomes very useful, since it provides not only mobility but real time communication.

On the other hand, LEGO systems have been widely used in academic scenarios for mobile robotics platforms [11], [12], [13], [14], with its sensors for vision and color recognition [15], [16], makes a very convenient framework for course projects that integrate mobile systems for color recognition, line following, obstacle detection, and vehicle interaction, among the most common cases. This paper presents the highlights of an undergraduate course work using LEGO-NXT hardware. A LEGO vehicle is used to simulate an illustrative (basic) plague detection robot, by setting the color sensor to identify the color of the supposed plague on the leaf. At the end, the experience was useful to propose a full scale vehicle concept for open field crops. While the plague detection problem is very complex since the great amount of variables involved, the staged scenario was useful to provide a potential real life application of Robotics.

II.   MOTIVATION

Trying to offer a hands-on experience to the students on the project based learning approach [17], a comprehensive in-class work project was assigned in the course Basic Mechatronics Applied to Time and Methods, 2016-1 term. The project was intended to be an engaging topic for students from various undergraduate Engineering programs: Industrial, Mechanical, Chemical and Agroindustry. Fig. 1 presents the scheme of the problem statement. It was required to build a LEGO robot to program a color sensor to identify a specific color, which would be the simulated color of a plague on a leaf. The color identification would occur while the car follows a path that defines the crop contour. The distances a and b are to be determined depending on the hardware limitations.

III.   PROJECT DEVELOPMENT

The solution of the proposed problem required the construction of a basic vehicle following the instructions in [18], Fig. 2. The vehicle is comprised of: two rotary actuators with built-in rotation sensors (+360° servo type motors), a color sensor, an infrared sensor and a controller (NXT 2.0). The steps involved in the coordinated detection of the color while following the "crop path" are summarized in the algorithm in Fig. 3. The graphical programming of the algorithm in LEGO Mindstorms NXT 2.0 graphical environment is presented in Fig. 4.
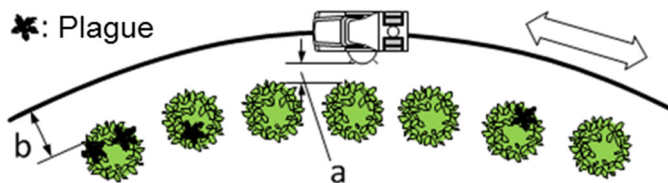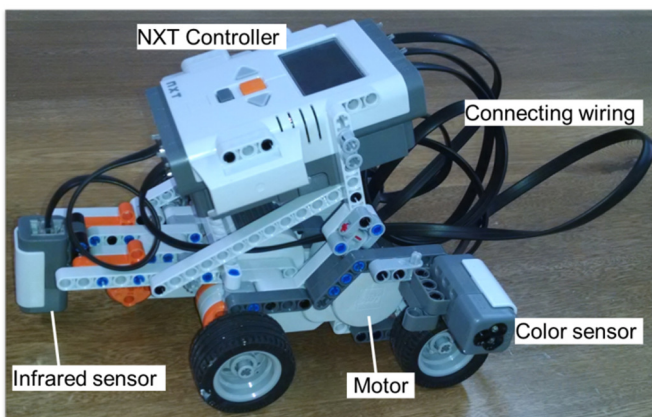

Figure 1. Assigned project scheme.

Figure 2. Components of the LEGO vehicle.

Fig. 5 explains the color sensor set-up to detect the plague. It has to be selected "Color sensor", Fig. 5.a, since the sensor can also work as a color light lamp. In Fig. 5.b is illustrated the

plague color set. There are two choices: "Inside Range" and "Outside Range". The latter mode was chosen; with the plague color outside the range.
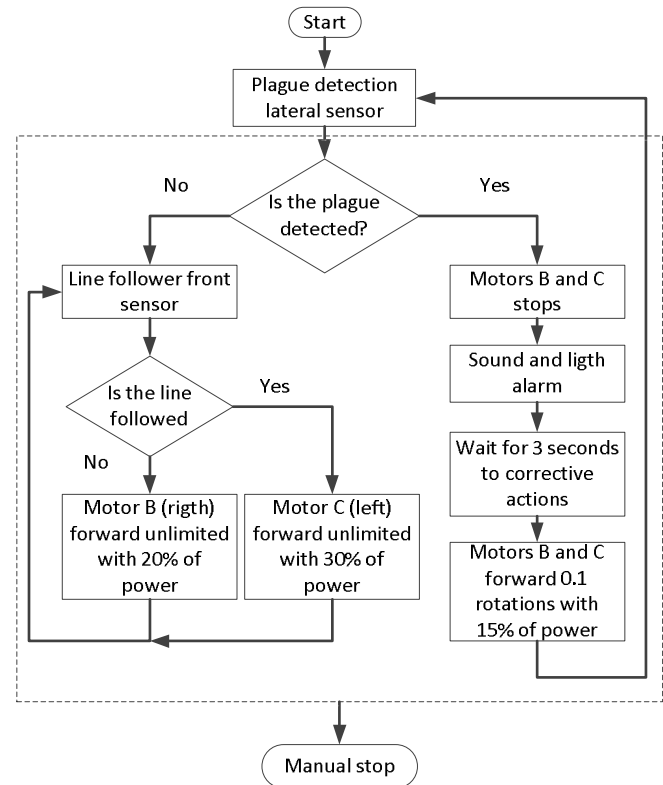

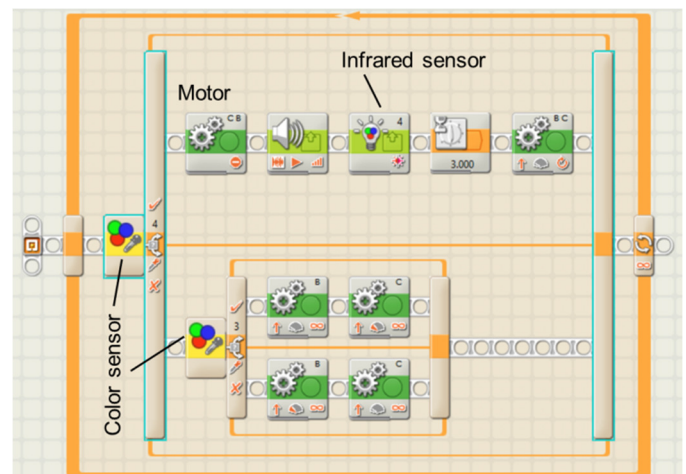Figure 3. Algorithm for coordinated plague detection and "crop path" following.

Figure 4. LEGO Mindstorms NXT graphical environment representation of the algorithm in Fig. 3.

The project required to recreate the crop scenario with artificial ornament or actual plants. Fig. 6 depicts some scenarios where the vehicles performed the detection routine.

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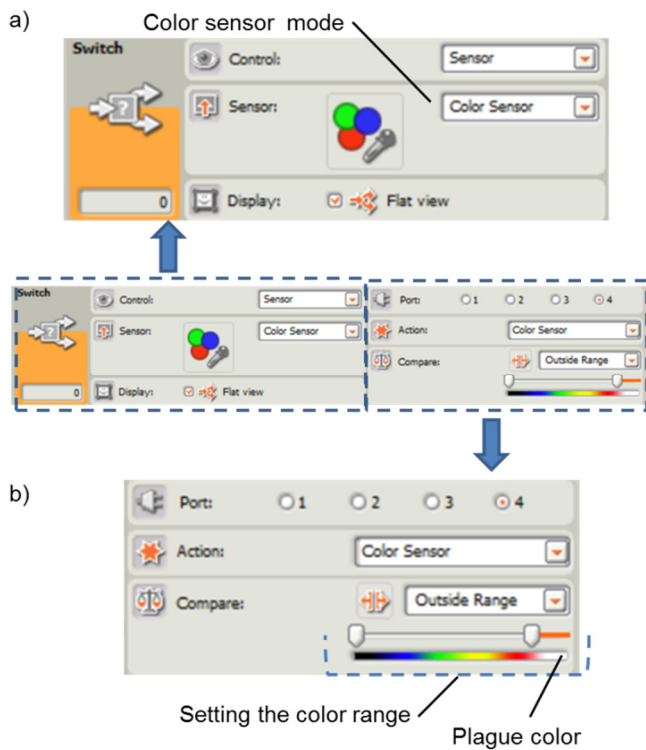
270

a)

Color sensor mode

Figure 5. Set-up of the plague color in the color sensor: (a) Sensor mode selection, (b) Setting the plague color range.
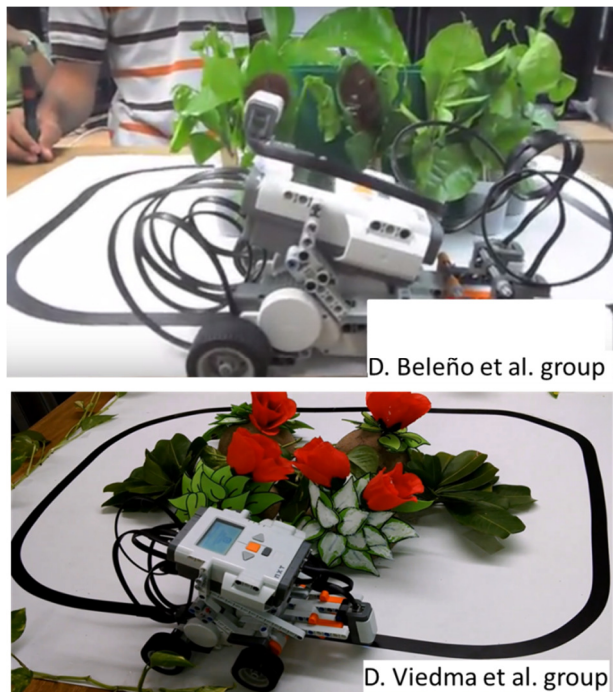

Figure 6. Some crops simulated scenarios for performing the detection routine.

IV. DERIVED FROM THIS PROJECT

Further research interests derived from this project are addressed to upscale the tested "friendly" system. First, a better understanding of the color is required if a camera or a commercial color sensor would be used. Color description through Red-Green-Blue three-element vector (RGB) is a very intuitive mode [18], where a value from 0 to 1 is used for each vector component with [0, 0, 0] corresponding to plain black and [1, 1, 1] for the plain white color. Fig. 7 presents the RGB space for zero-one colors.
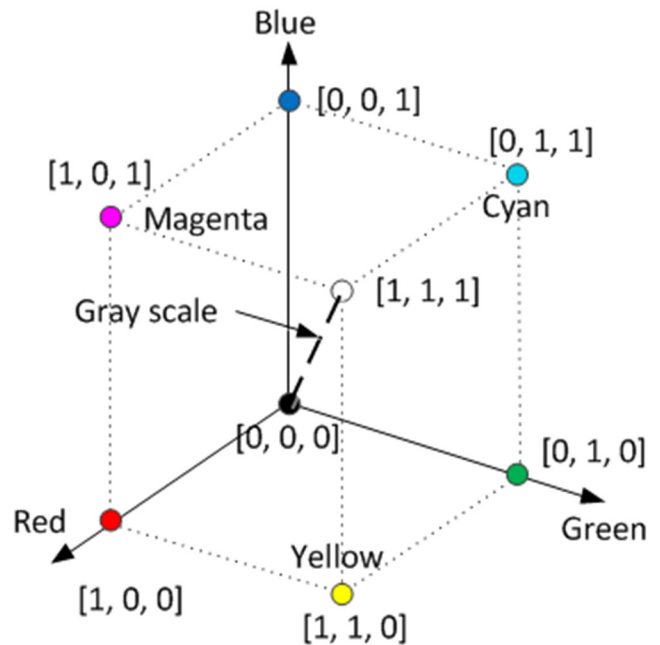

Figure 7. Color cube description or Red-Green-Blue space.

Software can be used to determine the color of actual plague from leaves pictures. Fig. 8.a depicts the color determination of the plague oidio on the grape plant and plague mildiu on the same plant [19] using the tool in the reference [20]. The color vectors depicted would be the pivot values for setting the color in a commercial sensor.
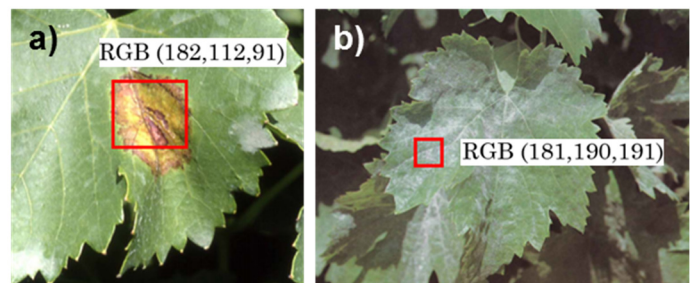

Figure 8. Color vector [R,G,B] determination for (a) Oidio plague, (b) Mildiu plague. [R,G,B]x1000.

Another concern from the activity is the shape of a vehicle that is suitable for an actual crop. After discussion, it is proposed a concept as illustrated in Fig. 9. It is presented a vehicle that carries a robotic arm with a camera (or color sensor) as its tool or end effector, Fig. 9.a. The ultrasound sensor, also in the end effector, would help in placing the camera at the right distance for taking the picture with the required resolution. The robotic arm would complement the vehicle mobility, by offering more dexterity inside a workspace where the sensors attached to the end effector can be closer to the leaves, and properly oriented to take the pictures of the leaves at the right inclination. Taking the pictures at the right inclination and distance from the leaf is important when the area or shape of the plague need to be known. A mechanism to vary the height of the robotic arm, Fig. 9.a, would increase the dexterity and scope of the sensors. Fig. 10.b depicts the arm extended, placing the end effector beyond the vehicle to avoid damage to the plant.
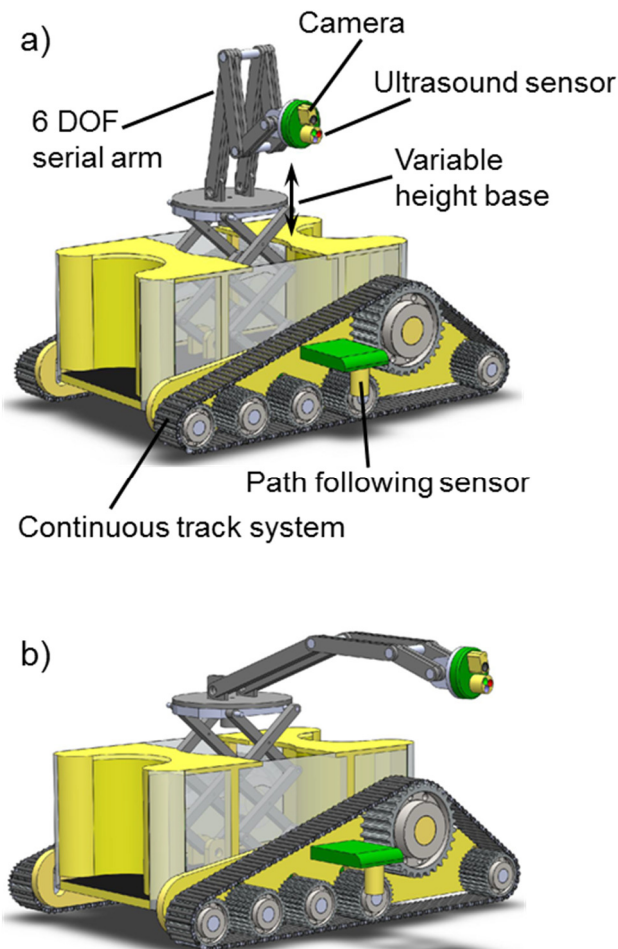

Figure 9. Mobile plague detector concept (a) Parts description, (b) Robotic arm extended to increase the scope of the sensors.

The continuous track wheel system is suitable for uneven terrains in the crop field. The path following infrared sensor (color sensor) placed on the side of the car would facilitate the tracking routine. A movable thick black wire, for example, can lay aside the crop path as the path to follow, as illustrated in Fig. 10.
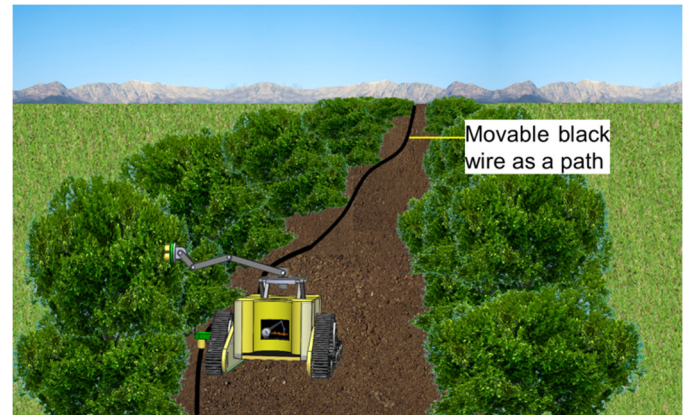

Figure 10. Recreated scene of the robot along the crop.

Projects to analyze the power need (battery), actuators, structural elements, transmission elements, DAQ and communication systems are being developed to have a full design and cost of the vehicle. A methodology for estimating the dimensions of the vehicle, based on the plants size and characteristics, orientation of the leaves and the field spaces, is also a possible future work derived from the proposed idea.

V.   CLOSING REMARKS

Development and results of a basics Mechatronics course project that was designed trying to engage students from various undergraduate Engineering disciplines are presented. LEGO NXT system allowed recreating at prototype scale a simplistic process of plague detection by color sensing, in a very friendly, almost ludic, manner. Sparked interest in the students for upscaling the LEGO model to the real scenario led to additional research in color definition and a vehicle concept for assisting the agriculture.

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