MOTH MONITORING SYSTEM TO PREVENT DESTRUCTION OF MAIZE FROM FALL ARMYWORM LARVAE

JEROME PLANCHAIS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING
PROGRAM IN AGRICULTURAL MACHINERY ENGINEERING
FACULTY OF ENGINEERING
RAJAMANGALA UNIVERSITY OF TECHNOLOGY THANYABURI
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Thesis Title	Moth Monitoring System to Prevent Destruction of Maize from Fall Armyworm Larvae
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Program	Agricultural Machinery Engineering
Thesis Advisor	Assistant Professor Kiattisak Sangpradit, Ph.D.
Academic Year	2022

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หัวข้อวิทยานิพนธ์	ระบบเฝ้าติดตามผีเสื้อกลางคืนเพื่อป้องกันการทำลายข้าวโพดจากหนอนกระทู้ข้าวโพดลายจุด
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บทคัดย่อ

ปัจจุบันมีการเชื่อมโยงของอุปกรณ์อัจฉริยะทั้งหลายผ่านอินเทอร์เน็ต (IoT) ในด้านต่างๆ และพัฒนาคุณภาพชีวิตให้ดีขึ้น โดยเฉพาะอย่างยิ่ง IoT ได้ถูกนำมาใช้ในการเกษตรเพื่อให้มีความยั่งยืนของระบบนิเวศน์ ตัวอย่างเช่น กับดักอัจฉริยะ มีศักยภาพในการจับและควบคุมแนวโน้มจำนวนศัตรูพืชเพื่อลดการใช้สารกำจัดศัตรูพืช งานวิจัยนี้มีวัตถุประสงค์เพื่อ 1) สร้างระบบกับดักอัจฉริยะใหม่ 2) ทดสอบประสิทธิภาพของกับดักอัจฉริยะ และ 3) ทดสอบต้นแบบในพื้นที่จริง

ในบทความนี้ มีการเสนอกับดักอัจฉริยะพร้อมความสามารถ IoT ที่ใช้การประมวลผลภาพเพื่อระบุแมลงที่สนใจ วิธีการแก้ปัญหานี้ประกอบด้วย ระบบฝังตัวพร้อมกล้อง แผงโซลาร์เซลล์ และเว็บแอปพลิเคชันเพื่อนำเสนอข้อมูล พื้นที่การศึกษาตั้งอยู่ที่ KSP Equipment Co. Ltd. ในลำไทร อำเภอวังน้อย จังหวัดพระนครศรีอยุธยา ประเทศไทย การเพาะปลูกข้าวโพดเลี้ยงสัตว์ในพื้นที่ดังกล่าวเริ่มตั้งแต่เดือนมิถุนายนถึงพฤศจิกายน พ.ศ. 2564

กับดักอัจฉริยะที่พัฒนาขึ้นในโครงการนี้ทำงานอัตโนมัติอย่างสมบูรณ์ด้วยแหล่งจ่ายไฟผ่านแผงโซลาร์เซลล์ และอุปกรณ์ออนบอร์ดอิเล็กทรอนิกส์ ต้นทุนและขนาดของระบบไม่สูงมาก กับดักอัจฉริยะมีความแม่นยำสูงมาก ข้อมูลที่เก็บรวบรวมได้มีความชัดเจนโดยไม่ต้องไปสถานที่ของการเพาะปลูก กับดักอัจฉริยะที่พัฒนาขึ้นมีความแม่นยำมากกว่า 97% ในการทดสอบครั้งเดียวบนพื้นที่จริง โดยแสงมีบทบาทสำคัญในการตรวจจับศัตรูพืช และมีข้อจำกัดในการตรวจจับ เช่น มีศัตรูพืชที่จับได้จำนวนมาก

คำสำคัญ : กับดักอัจฉริยะ การประมวลผลภาพ อิเล็กทรอนิกส์ หนอนกระทู้ข้าวโพด ข้าวโพด

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ABSTRACT

The Internet of Things (IoT) is now used in many different fields and improves the quality of life. In particular, IoT has been applied in agriculture to make it more ecologically sustainable. For example, smart traps have the potential to capture and control pest population trends for reducing pesticide use. This research aimed to: 1) create a new smart trap system, 2) test smart trap effectiveness, and 3) test prototype on site.

In this paper, a smart trap with IoT capabilities using image processing to identify the insects of interest was proposed. The solution included an embedded system with camera, a solar panel and a web application to present data. The location of the study area was at KSP Equipment Co. Ltd., in Lam Sai, Wang Noi District, Phra Nakhon Sri Ayutthaya Province, Thailand. Cultivation of fodder corn on the aforementioned areas started from June to November 2021.

The smart trap developed in this project was completely automatic with power supply via solar panel and on-board electronics. The cost and the size of the system were not very high. The smart trap was highly accurate. The collected data could be visualized without going to the cultivation areas. The developed smart trap had more than 97% accuracy for one test on site. Light played a very important role in detecting pests and there were limitations to detection such as large numbers of captured pests were trapped.

Keywords: smart trap, image processing, electronic, corn armyworm, maize

Acknowledgements

Joining the Ph.D. Program at Rajamangala University of Technology Thanyaburi enables me to grow in so many directions, as an academic and a person. I have been blessed with friends and professors who have supported and provided guidance.

I have benefited greatly from the guidance and advice of my committee members. I am indebted to Assistant Professor Doctor Kiattisak Sangpradit who has been an outstanding advisor. Other committee members, namely Associate Professor Doctor Roongruang Kalsirisilp, Associate Professor Doctor Grianggai Samseemoung, and Assistant Professor Doctor Pansa Liplap, have provided me tremendous suggestions and motivation to think carefully on the research ideas and methodology throughout the dissertation duration process. Furthermore, I would like to thank department of agricultural machinery engineering, Faculty of engineering, Rajamangala University of Technology Thanyaburi and KSP Equipment Co. Ltd., for cooperation and support for this research.

I am most thankful for my family who always supports and encourages me in every endeavour in my life. Without their love, patience and encouragement, I will not be who I am today.

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CHAPITRE 1
INTRODUCTION

1.1 Background and Statement of the Problems

One of the five major crops in Thailand is maize. Maize occupies about 33% of Thailand's agricultural land. The other crops are rice, cassava, sugar cane and rubber. 12.4 million rai (nearly 2 million ha) were planted with maize in 1984-85, just behind rice (59 million rai or 9.5 million ha). In 1984, 3.0 to 3.7 million tons of maize were exported by Thailand and enabled it to earn nearly 10,000 million baht (400 million dollars). The area under maize cultivation began to decrease in area thereafter and occupied only 7.3 million rai (nearly 1.2 million hectares) in 2002-03. Production was only about 4.5 million tons, Benchaphun Ekasingh, (2004).

In 1950, for the first time in Thailand, a corn plantation was established in Thailand. At that time, maize grew in the highlands of Thailand. These highlands were only used for domestic consumption and the feeding of domestic animals. Maize later became an export product like rice. This change in status took place thanks to the first national economic and social plan in 1961. From the 1960s to the 1980s, the crops of corn, cassava and sugar cane became important field crops in Thailand. Government-sponsored crop diversification, increased population growth, improved transportation networks, international trade, and the expansion of upland agricultural areas have enabled this change. Mountain cultures have spread into forest areas. A simultaneous decrease in forest areas has therefore appeared at the same time as the increase in the production of maize, rice, cassava and sugar cane. In these newly cleared forest lands, the cultivation of maize had become very productive but soil erosion by tractors and deforestation then increased drastically and worsened throughout the 1980s.

Thailand was a major maize exporter in the 1980s. But in the 1990s, these exports fell dramatically as domestic demand for grain increased. The cause was the increase in the national livestock industry, which in turn transformed its production into various exportable products. Maize production in Thailand has not been sufficient to meet national needs and small amounts of grain have been imported in recent years. Variations in climatic and rainfall conditions and occasional droughts have greatly impacted national maize production. The production has decreased enormously with the losses caused. When grain prices are low, competing crops, such as sugar cane, cassava and sunflower, sometimes replace maize. All of this has led to a stagnation or decline in maize production in Thailand over the past two decades.

The agriculture for humanity is very important, indeed it provides food and medical products. However, crop productivity is reduced due to certain types of insects (called pests). The consequences are a loss of production and an increase in costs. Mildew, rust, rats and stem borers are the main diseases and pests identified. Maize is somewhat more resistant to these pests than other crops.

For reasons of efficacy and practicability, chemical control is the most widely applied. But the toxicity of insecticides on the market are extreme. Health in humans can be widely impacted and cause problems. Life in the wild can also suffer damage. The cost of these insecticides is also very high and needs to be used several times in the plantations during the year, Romano Andrade (2000).

IoT, cloud computing, electronic traps and advanced insect identification techniques are new solutions that have emerged through the evolution of new technologies. These technologies provide opportunities for agriculture. Technologies are helping to deal with problems related to cultivation and farms and digital agriculture is emerging, Connolly (2018). Human health and natural life is at the heart of the motivation for the arrival of these technologies. The reduction of economic costs due to pests and diseases, the possibility of monitoring the trapping operation is also an objective.

1.2 Purpose of the Study

This study was conducted to:

1.2.1 Create a new model of Smart Trap system.

1.2.2 Test smart trap effectiveness.

1.2.3 Test prototype on site.

1.3 Research, Question and Hypothesis

We are interested in seeing to bring a new model of Smart Trap system which can reduce the pest and disease problems in the crop.

In this study, we introduce the Smart Trap system which will be designed and created to function in crop of maize.

1.4 Theoretical Perspective

In this study, we use many theories. The concerned theories are:

1.4.1 The basic of the Smart Trap system theory.

1.4.2 The image processing theory.

1.5 Delimitations and Limitation of the Study

1.5.1 The box will be designed.

1.5.2 The box will be constructed based on the design concept.

1.5.3 The software will be designed and developed

1.5.4 The secondary functions such as alimentation of electronic board will be studied and created.

1.5.5 The Smart Trap will be tested in a crop of maize.

1.5.6 The monitoring and communication for the data collected will be developed and tested.

1.5.7 Results are then compiled and analysed.

1.6 Signification of this Study

The advantage of this studying in this project, we can improve and develop the previous concepts and knowledge in the Smart Trap system which can be used in the future to help the farmer to limit the pest problems in their crop.

CHAPITRE 2
REVIEW OF THE LITERATURE

2.1 Corn Plant

2.1.1 History of corn

The history of corn begins 9,000 years ago, in a high valley in Mexico, where the Rio Balsas river flows. A local plant, teosinte, was cultivated on the slopes of this valley by the first Amerindian civilizations, at an altitude of 1,500 m. Teosinte is a plant adapted to the tropical climate and the humid summers of this valley. The plant has many ears, each consisting of only a few seeds. The harvested grains were then ground to obtain a flour consumed by the local populations.

The evolution of teosinte, the ancestor of corn, took place both naturally through genetic mutations, but above all by humans through mass selection which selected favorable mutations. Indeed, this historic period is part of the domestication of plants: Native American farmers choose the seeds of the best plants to save them and sow them the following year. Thus, the characteristics facilitating the cultivation and harvesting of grains, such as the size of the ears and the number of grains per ear, are gradually selected by the farmers.

Maize will acquire a central place in the diet of the peoples of Central America (Olmecs, Mayas, Aztecs) and the Andes (Mochicas, Nazcas, Incas) and will also be at the center of religion and rites. From the 5th millennium BC, corn would then quickly spread throughout the tropics and equatorial regions of Central and South America, with varieties that are still present today. Then the varieties of corn adapted to temperate zones and will be cultivated from the first millennium of our era on the territories of the current United States and as far as Canada.

Corn was first discovered by Europeans in 1492 by Christopher Columbus and his crew in the Caribbean. On his return to Europe, he brought back many native plants including corn cobs: his cultivation began at the beginning of the 16th century on the Iberian Peninsula. Other explorers brought corn to Europe: Magellan on his trip to Brazil in 1520, as well as Jacques Cartier from Quebec in 1535.

Initially present in European gardens and botanical collections, maize cultivation developed more at the beginning of the 17th century over larger areas, and extended over the entire Mediterranean region, as well as in the European countries of the Where is.

The first hybrid varieties were cultivated in the United States from 1933 in Iowa. Ten years later, 100% of the corn grown in the United States is hybrid. These American hybrid varieties were introduced in France in 1947 to be tested in experimental stations. As early as 1957, INRA (National Institute for Agronomic Research - now INRAE, National Research Institute for Agriculture, Food and the Environment) created the first French hybrids from American varieties and popular varieties French. While the average yield of corn crops in France changed little until the middle of the 20th century, the new hybrid varieties made it possible to double the yield in about ten years. The average yield of 14 quintals per hectare in 1948 rose to 28 quintals in 1960.

2.1.2 Characteristic of corn

Corn is an annual herbaceous plant that varies in height and consists of a single, large-diameter stem made up of a stack of nodes and internodes. At each node are inserted a leaf and an axillary bud. Depending on the variety, each plant has between 15 and 20 leaves, large (up to 10 cm wide and 1 meter long) and distributed alternately on one side and the other of the stem.

The root system of maize is fasciculated: many so-called adventitious roots develop at the base of the stem and form a network of roots of equal size. They allow the plant to be mechanically anchored in the surface layers of the soil.

Maize is a monoecious plant: the male and female flowers are borne by the same plant but placed in different places:

- The female inflorescence (the ear) develops laterally from an axillary bud, inserted at the base of a leaf in the middle of the plant. The ear has 12 to 20 rows of ova topped with long styles, the bristles.
- The male inflorescence (the panicle) consists of spikelets made up of two flowers. Branched, it is located at the end of the stem.

Maize is an allogamous plant, that is to say that fertilization is predominantly crossed (in 90% of cases) and takes place between two distinct plants. The female flowers are pollinated by pollen from another plant, hybridization is natural in maize.

By its tropical origin, maize is a C4 plant, like sorghum or sugar cane. This particular metabolism is linked to the structure of the leaf, its chlorophyll cells and its veins. It leads to an increase of CO_2 in the cells of the sheath. It gives corn a better yield for photosynthesis - that is, for the conversion of light energy into organic matter - than cereals in our latitudes which are C3 plants. In hot climates, C4 plants can also limit their water loss through transpiration.

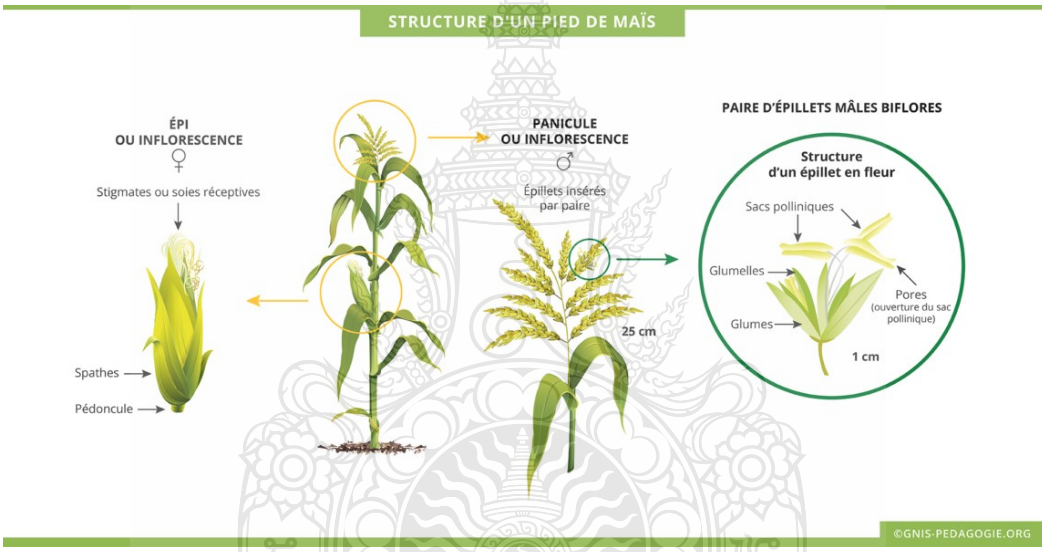

Figure 2.1 Maize development

2.1.3 Corn cultivation

Corn is an easy crop to grow and maintain. If there is an adequate water source, corn can be grown year round. Most farmers prefer to grow animal corn primarily from natural rainwater. Therefore, the optimum growing season for corn depends on the amount of rain and monthly rainfall.

2.1.3.1 1st generation corn or rainy season

1st corn crop of the year is mainly grown on the basis of seasonal rainwater. The planting period can be divided into 2 periods:

- sow at the beginning of the rainy season (April - June). Planting corn at this time can experience rain problems during the months of June to July, when the corn is blooming. If it rains regularly, maize yields 20-25% better than late rainy season crops due to longer light periods. But may encounter problems during the harvest period in August - September, which is a period of heavy rains. This can make harvesting difficult. At the same time, the pod or kernels of corn harvested in this version often have high humidity and therefore are vulnerable to the destruction of fungi.
- Most farmers prefer to sow maize at the end of the rainy season (July-August) as they rarely encounter the problem of rains during the period. Because it is harvested at a time when the air is low. But the problem that is often found in this version of corn is the risk of late blight infestation. So farmers who grow this version of corn choose a mold resistant variety of corn.

2.1.3.2 2nd generation corn for breeding farm animals

The second generation of maize is the cultivation of maize during the dry season. They are mainly planted in the months of November to February and harvested from February to May. Farmers prefer to plant corn using an irrigation water source or natural water sources. The advantage of this version of corn is that it is more resistant to mold problems than corn grown at the start of the rainy season. The best period is from November to December because the flowering period does not correspond to the too high temperature. In addition, during the dry season, the sky is not cloudy. Corn plants have a chance of getting full sun, resulting in a high yield.

2.1.3.3 Preparing the soil for growing corn

If corn is planted in the fields, the land is uneven. It is necessary to prepare the soil during the agricultural season, that is, plowing to get rid of weeds. And adjust the area to be evenly smooth to facilitate water and drainage of the plot. The paddy field should have a surface depth of at least 30cm so that the roots of the corn can grow and absorb water and food from the soil well. In case the soil is acidic or very acidic, the soil should be modified before planting corn by adding lime or marl at an appropriate ratio.

For fields where rice has been harvested, there may be thick rice straw and stubble, which is an obstacle to using the maize planter Farmers have to ferment the rice straw to decompose it during the harvest. soil preparation. After that, the water is pumped to cover the soil for 7 days before draining the water and drying the soil for about 2 weeks before preparing the soil. However, one should avoid burning rice straw in the fields. Corn prefers aerated, well-drained soil. In general, the following method of soil preparation for growing corn is used: the field is to plow first. After the rice harvest then the plots are dried for at least 5-7 days to destroy the weeds first.

2.1.3.4 Plantation management

In general, there are 2 types of planting arrangements :

- Single row planting Row spacing 75cm and planting at a distance of 20-25cm, lay 1-2 corn kernels / hole (number of plants per row is about 8500-10600 plants, will use approximately 3.0 to 3.5 kg of corn kernels per spoke).
- Two-row planting There is a raised groove. Spaced 120 centimeters per groove, planted in two rows. Next to the groove, spaced 30 centimeters apart, planted 20-25 centimeters per plant. The number of plants is around 8,500-10,600 plants per spoke and using corn kernels about 3.0-3.5 kilograms per spoke).

2.2 Disease and Pest

Major diseases and pests identified included downy mildew, rust, rats, and stem borers, although maize is more tolerant to diseases than other up landcrops.

2.2.1 downy mildew

Downy mildew is a leaf disease caused by fungus-like organisms (oomycetes). It spreads from plant to plant via airborne spores. It is a wet weather disease because prolonged leaf wetness favors infection.

A range of common edible and ornamental plants may be affected including crucifers, carrots, pigeons, foxgloves, geum, vines, whiteflowers, impatiens, lettuce, onions, pansies, parsnips , peas, poppy, rhubarb, rose, spinach and tobacco plants.

Downy mildews affects only a few hosts in general. Plants affected by downy mildew are not numerous. For example, the downy mildew affecting brassicas is not the same species as one infecting pansies.

The Plants affected by downy mildew recognition is not easy. The symptoms are :

- The upper leaf surface starts to have Discoloured blotches. The colour may vary depending on the plant affected. It can vary between pale green, yellow, purple or brown. If the blotches are bordered by the leaf veins, it can have straight edges.
- On the underside of the leaf where a spot is visible, an outgrowth forms. It can be of different colour depending on the species of mildew. This growth may be white, grey or purple.
- The growth can be detected with the naked eye in some cases (e.g. pea, pansy) but it can be difficult to see even with a hand lens in others cases(e.g. foxglove, rose).
- If the leaves are seriously affected, then they may shrivel and turn brown like tobacco plant. They may also turn yellow and fall off as with roses.
- It happens that other parts of the plant can be infected with mildew as cauliflower curds, buds, pea pods.
- Severely affected plants are often stunted and lack vigour. In some cases as columbine and tobacco plant. The plant may sometimes die.

2.2.2 Rust diseases

The upper parts of the plants can be infected by a group of diseases: the rusts. Rusts most often affect the leaves but it can also settle on the stems and even on the flowers and fruits, but less frequently.

The colour of the spore pustules produced by the rusts varies. Indeed, depending on the species, the type of spore is different. Their life cycles are complex. There can be two infected plants and up to five types of spores can be produced.

The symptoms are :

- Pale leaf spots eventually develop into spore-producing structures called pustules.

- The underside of the leaves are often the target of pustules. They then produce many more microscopic spores.
- The pustules can be different colours. They can vary from white to black through orange, yellow or brown. The name of the disease is in reference to the rusty brown of some pustules.
- Leaves usually turn yellow if seriously infected and drop.
- Leaf petioles and stems are also sometimes infected. Pustules form more rarely on flowers and fruits.
- The infected plant may lose vigour if the infection is large. The plant may die in extreme cases.

2.2.3 Rats

Rats are rodents. They are widely used around the world and common in Thailand. They can be in urban areas as well as in the countryside. Their adaptability is very great and can feed on a wide variety of foods. Their homes can be anywhere. both underground and in compost heaps, buildings, greenhouses or sheds.

Adaptability is very high in these rodents. They can eat a wide variety of food. They can feed on corn, pumpkins or squash and various vegetables such as carrots, beets or potato tubers in the fields. Rats feed during crop growth or storage. Fruits are also the target of these rodents. Apples, for example, can be damaged because of this. Rats can also eat the seeds when sowing.

The rat usually leaves visible parallel grooves on its food. Indeed, that's where his incisors bit. Rats make tunnels in the ground. These tunnels generally have a diameter of 30 to 40 millimeters. They leave behind visible feces where they feed. excrement has a cylindrical shape. Their extremities are rounded and measure about 15 millimeters long and 5 wide when fresh. Adult rats can be about 21 centimeters long- Adult rats are about 21 cm long. Their fairly long tails can add 18 centimeters to their length.

Rats are pests. damage to food is done during growth or after harvest and storage. They can also scavenge their food by taking food provided to wild birds, poultry and pets. Leptospirosis or Weil's disease is a disease that can be transmitted to humans through rats. Indeed, they are often carriers of bacteria. The urine of rats is the cause of the spread of this bacterium. It can persist for a long time in damp places. It infects people through cuts or through ingestion.

Compost piles are an environment that rats love. Digging into it is relatively easy due to its crumbly nature. Compost can be used in the fields. But if it comes from a garbage can or a heap in which rats have lived, its use is not recommended on fruits or vegetables. Indeed, if they are eaten raw, this can cause problems. Edible parts that may come into contact with the compost.

2.2.4 Stem borers

The stem borer, Ostrinia nubilalis, is one of the main pests of maize: by parasitizing the entire plant, the larvae cause significant damage which leads to yield losses of up to 20 q / ha. This larva, which burrows in the stems and can attack the ears, also contributes to the development of fungi such as those of the genus Fusarium, responsible for the production of mycotoxins.

The adult moth is a butterfly with thin, broad, triangular, ocher-beige wings, a narrow body with thin, cylindrical antennae. The male measures 20 to 25 mm in wingspan and is darker than the female, with often black-gray forewings marked with pits and dirty yellowish bands. His abdomen usually protrudes from the wings when at rest. The larger female measures 25-30mm in wingspan and is pale yellow in color with a thin zigzag stripe on the last third of the forewings.

The larva is a caterpillar of 2 to 20 mm depending on the stage: it is gray-yellow with a dark head, a dark gray dorsal line and dark spots on each segment, distributed on both sides of this line.

(A) (B)

Figure 2.2 The Corn Armyworm (A) and his larva (B)

2.3 Smart Trap

2.3.1 Pheromone

A pheromone is a chemical substance comparable to hormones, emitted by most animals and certain plants, and which acts as a message between individuals of the same species (intraspecific communication, as opposed to ectomones involved in interspecies communication). This semiochemical compound transmits information to other organisms that influences physiology and behavior (sexual, maternal, aggression, aggregation, tracking, etc.).

Very active, some pheromones act even in small quantities, and they can be transported and detected several kilometers away. In mammals and reptiles, pheromones are primarily detected by the vomeronasal organ, while insects typically use their antennae.

Unlike classic hormones (insulin, adrenaline, etc.) produced by the endocrine glands and which circulate only inside the body by participating in its metabolism, pheromones are generally produced by exocrine glands, or secreted with urine, and serve as chemical messengers between individuals. They can be volatile (perceived by smell), or act by contact (skin compounds of insects for example, perceived by taste receptors). They play an essential role during mating periods, and in certain social insects, such as ants or bees. These pheromones are essential for the proper functioning of the group. Insect sex pheromones contribute to the reproductive isolation between species thanks to their specificity.

Thanks to biochemical techniques, it is possible to produce synthetic pheromones. They are used by the cosmetics industry, often in perfumes, with commercial presentations that suggest sexual and emotional effects, despite the absence of valid experimental data5,4. Synthetic pheromones can also be used in crop protection, as an environmentally friendly alternative to traditional insecticides, Romano Andrade (2000).

Figure 2.3 Pheromone effect

Different pheromones can be used as biocontrol agents to protect certain crop plants from damage caused by insect pests27. Two levels of action are possible:

- indirectly for agricultural warnings and monitoring populations within crops.
- directly for the control of certain insects by mass trapping or by causing mating disruption. For example, a company such as M2i Life Sciences produces pheromones against the codling moth of apples and pears, the boxwood moth, the red palm weevil, the pink cotton worm, the pine processionary or even eudemis or worm. cluster, which attacks the vine.

2.3.2 Pest count

The image processing aims to obtain an improved image and to be able to extract important information from this image. This involves operations on the image. The input of the function is therefore an image. The output can be an image or data linked to this image. It is a type of signal processing. Currently, new technologies make extensive use of this process. The disciplines of engineering and computer science make it a central area for research, Michele Preti (2020).

Image processing takes place in three steps:

- The image is imported using acquisition tools;
- The image is analysed and manipulated;
- The result is the output, It can be a modified image or data related to the image.

For example, the number of targeted object.

Two types of methods exist and are used for image processing. These two types are analog and digital processing. Hard copies such as prints or photographs, for example, are made using analog processing. The use of these visual techniques utilize fundamental principles of interpretation. The manipulation of digital images is when it was dealt with using computers. There are three phases for processing all types of data. The preprocessing is the first phase, then comes the display and finally the extraction of information. These three phases then allow the use of digital data.

Pre-processing is almost always mandatory for images taken with conventional sensors. Indeed they may contain too much noise or be poorly focused. two of the most used methods for this pre-processing are filtering and edge detection.

The input image is filtered to improve and modify it. The filters thus make it possible to accentuate or suppress certain characteristics of the image. For example, reduce image noise. Linear filtering, median filtering and Wiener filtering are the most popular filtering techniques.

Edge detection uses filters for image segmentation and data extraction are used for edge detection. Luminosity discontinuities are detected for this method. Significant edges of objects in the processed images are then found. The most popular edge detection techniques are Canny edge detection, Sobel edge detection, and Roberts edge detection.

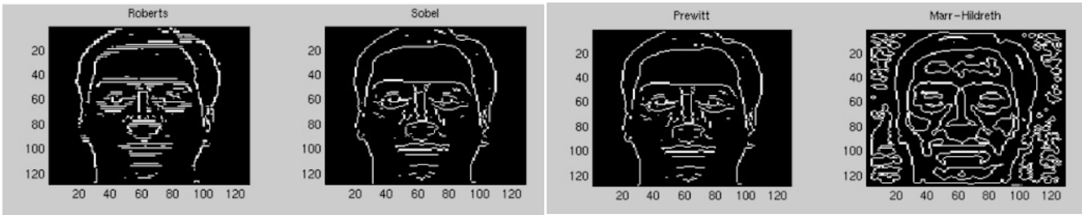

Figure 2.4 Examples of edge detection

Other popular techniques exist to handle image processing tasks. They are many. Image compression, for example, is carried out using the wavelet technique. It can also be used for denoising.

The augmentation is also the result of some filters. This helps to increase the size of targeted objects. For example, in some projects, edge detection is used to discover the physical sizes of objects in digital image data.

The use of specific libraries and frameworks makes it easier to handle these techniques but also to facilitate the implementation of these functions of image processing in systems. The various image processing tasks are executed with the help of algorithms thanks to libraries. Some are open source and very popular and easy access. These libraries are presented below.

Common image processing functions and algorithms are incorporated into computer vision libraries. When developing image processing and computer vision functionality, there are ready-to-use open source libraries:

- OpenCV
- Visualization Library
- VGG Image Annotator

The r, g, b receptors of our retinas perceive colors in the same way as the RGB color model. Television or any other medium that projects color with light uses the RGB model. it uses additive color mixing. Computers and Web Graphics uses this basic model. On the other hand, print production cannot be carried out with it. The secondary colors of RGB are cyan, magenta and yellow. They are formed by mixing two of the primary colors among the colors red, green and blue and excluding the third color. Red and green combine to make yellow, green and blue to make cyan, and blue and red to make magenta.

The combination of the three primary colors in full intensity makes white. The RGB model is the best known and most used color model.

In Photoshop, the intensities mix according to the additive color mixing model if one uses the "screen" mode for the different layers of an image. In this way, it amounts to layering images on top of each other and shining light through them.

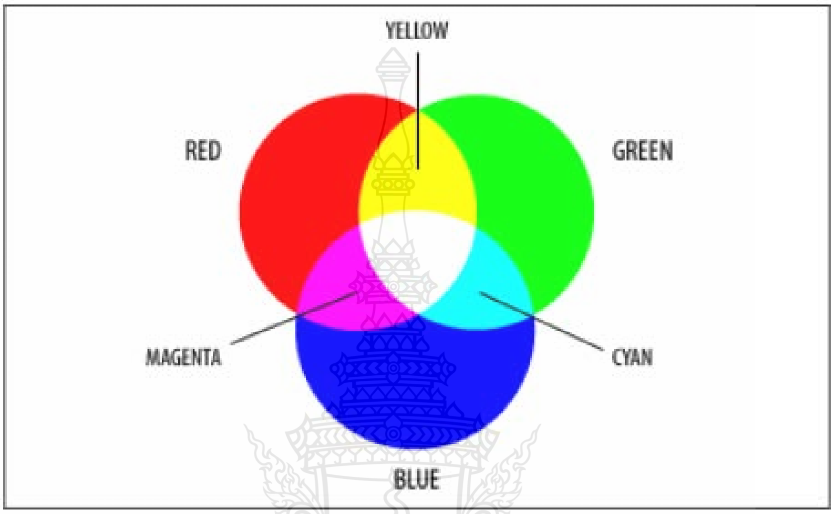

Figure 2.5 RGB system

2.4 Monitoring (responsive site)

Responsive design revolves around modifying the appearance of the website to suit the device from which the page is visited. In this way, the user experience improves considerably and it is one of the SEO optimization resources that Google strongly emphasizes. Taking into account that since 2015, it has changed its algorithm to reward websites that have done so.

But the responsive design is more than just displaying each device. It offers us the possibility of modifying the design (without doing it) and truly adapting it to each device. To improve our SEO, and that our website is not relegated by others who integrate it. In the end, it all adds up, and today we're going to be talking about responsive designs.

2.5 Study Guidelines and Related Research

2.5.1 A Proposed IoT Smart Trap using Computer Vision for Sustainable Pest Control in Coffee Culture

The aim of the study is to propose a solution against pests for agriculture. this solution includes an embedded system with a camera, a GPS sensor and motor actuators. The internet of things can be adapted for any type of domain. Here, an IoT middleware allows to retrieve the data and a web application allows to present the data in the form of a map. The demonstration of proposed solution is exposed and the main conclusions are the perception about pest concentration at the plantation and the viability as alternative pest control against traditional control based on pesticides. (Vitor Alexandre Campos Figueiredo, 2020)

2.5.2 Managing social insects of urban importance.

Social insects have significant social and economic impacts on urban communities. The rapid urbanization of the world has greatly increased the incidence of urban pests. Human trade has led to the spread of urban invasive species around the world, so much so that different species are now common in many major urban centers. Our goal was to highlight social behaviors that could be exploited to control these pests with minimal use of pesticides. Their confusing behavior often prohibits direct treatment of colonies. However, foraging and recruitment are essential aspects of their social behavior and expose workers to traps, baits and pesticide applications. The advent of new chemical technologies has revolutionized the pest management strategies used to control them. In recent years, environmental awareness has increased, especially in urban communities. Advances in molecular and microbiological agents promise additional tools for the development of integrated control programs against social insects. (Michael K Rust, 2011)

2.5.3 Optimization of a Pheromone Lure for Spodoptera frugiperda (Smith) in Central America Braz.

Mass trapping of Spodoptera frugiperda (Smith) in Central America required a high performance lure with consistent catch rates. S. frugiperda lures from North America and England gave inconsistent catch rates under field conditions. A new investigation of four acetate attractants for S. frugiperda present in Costa Rica revealed that Z7-12Ac and Z9-12Ac were highly attractive to S. frugiperda when presented alone. The binary combination of Z7-12Ac with Z9-14Ac significantly increased attraction and was at least 10 times more attractive to S. frugiperda in Costa Rica than North American or English lures. Addition of Z11-16Ac to binary combinations of Z9-14Ac and Z7-12Ac slightly increased capture rates. If the concentration of Z7-12Ac is increased to 5% in lures containing Z9-14Ac, the capture rates of Z11-16Ac and Z7-12Ac decrease significantly. The optimized lure contains Z7-12Ac which is a previously unreported component in S. frugiperda from the Caribbean region. (Romano Andrade, 2000)

2.5.4 A “Smart” Trap Device for Detection of Crawling Insects and Other Arthropods in Urban Environments.

The author are introducing a device that automatically detects and reports crawling insects in urban areas. It is an urban pest monitoring device suitable for the context of smart home, smart city and compatible with the emerging discipline of Internet of Things (IoT). We think it can find its place in all rooms of hotels, hospitals, military camps and residences. This box-like device attracts targeted pests, detects incoming insects, and automatically takes a spatial image of the inside of the box. The images are transmitted via Wi-Fi commonly found in these facilities to the authorized person/stakeholder receiving the images to take appropriate action. Electronic traps include strong attractants (pheromones and/or food) to increase their effectiveness. Insects are trapped on the sticky floor of the device. The device has the necessary optoelectronic sensors to protect all entrances from traps. When insects enter, it cuts off the infrared light source. This triggers a detection event; a photo is taken and timestamped before reporting the event via Wi-Fi. The device can be integrated seamlessly into urban environments and operates unobtrusively for human activities. We report results on different insect pests and, depending on the insect species, we can achieve a detection accuracy of 96-99%. (Panagiotis Eliopoulos, 2018)

2.5.5 Insect pest monitoring with camera-equipped traps: strengths and limitations.

The infestation threshold to trigger an action to counter it and to choose the appropriate control method allows integrated integrated control. Pest monitoring is very important. Placing a series of traps in infested areas is the classic approach to monitoring insect pests. These traps are controlled by operators on a time basis. This classical method generates a high labor cost and does not give a satisfactory result for the spatial and temporal resolution achievable by single operators. The use of cameras and video sensors has several advantages. This study summarizes the various advances on automatic traps. Systems equipped with cameras are particularly targeted. Embedded image recognition software and algorithms allow automatic use of these traps. pest identification is done automatically on the image. Nowadays, it is possible to use cameras with high image resolution. And thanks to wireless communication technologies, it is possible to have remote control of insect captures. the possibility of measuring insect population dynamics continuously and simultaneously in a large number of traps with a limited need for human labor is opened up by the availability of real-time and online pest monitoring systems at from a remote location. This limits field visits. But some prototypes have the real limits of high cost, low energy autonomy and poor image quality. The automatic detection of insects is to be greatly improved in many cases. With a view to the future development of technology-driven insect pest monitoring and management, the limitations and benefits from several studies are reviewed and discussed. (Michele Preti, 2021)

2.5.6 Field optimization of pheromone traps for monitoring and controlling cocoa mirids.

In Cameroon, pheromone traps seem interesting for monitoring or even controlling populations of Sahlbergella singularis in cocoa plantations. The effectiveness of pheromone bait traps depends on a good knowledge of the visual and olfactory stimuli that attract cocoa trees and how to deploy the trap appropriately in the cocoa field. The purpose of this preliminary study was to first compare the attractiveness of traps of different colors and primed with different mixtures of pheromones. For this, we followed a total of 90 traps of 3 different colors (30 red, 30 yellow and 30 white) and primed with

2 different mixtures of pheromones, deployed on 10 plots of 1 hectare (100 x 100 m). The PVC siphons are monitored weekly starting in March. At the same time, tunnel flight experiments were carried out in the laboratory to confirm the trends observed in the field. Second, to better understand how trap deployment affects mirid capture rates, we tested 3 trap densities in a total of 21 1-hectare (100 x 100 m) plots receiving different treatments, 7 plots with high density of traps (16 traps ha-1), 7 medium trap density plots (9 traps ha-1) and 7 low trap density plots (4 traps ha-1). Traps are monitored weekly. In addition, populations and damage were assessed in each plot twice a year. Seven untrapped plantations were sprayed with pesticides according to spray recommendations and were also monitored to assess yield gain or loss between the two controls. Understanding the factors involved in directed movements of small groups in the field will allow you to make relevant recommendations to improve the integrated management of S. singularis and potentially reduce the economic costs of control strategies. (Bagny-Beilhe Leila, 2012)

2.5.7 A review of the biology and control of the coffee berry borer.

The coffee berry borer, Hypothenemus hampei Ferrari, is a serious problem for the majority of coffee growers around the world and has proven to be one of the most difficult pests to deal with today. Despite extensive research, control still relies largely on the application of environmentally harmful organochlorine insecticides or a variety of cultural and biological control methods with variable and unpredictable results. This review summarizes the most important aspects of the biology and ecology of H. hampei and its control and identifies the weak points of knowledge about this pest. Emphasis is placed on analysing available chemical-free control methods and making recommendations on new ecological and environmental factors meriting further study, in search of sustainable and feasible control methods. (Anne Damon, 2001)

2.5.8 Maize in Thailand: Production Systems, Constraints, and Research Priorities.

This study discusses maize production systems in Asia. there was a series of seven national studies and this is one of them. The studies are funded by the International Maize and Wheat Improvement Center (CIMMYT) and the International Fund for Agricultural Development (IFAD). The goal is to promote a sustainable increase in maize production systems. This requires equitable income growth and improved food security. This focuses in particular on poor families dependent on maize. The social and biophysical environment of maize production in Thailand was studied and characterized. The response to the increase in demand was reviewed. constraints determined to Future productivity growth has constraints that have been determined. the study also addresses the potential consequences on the environment and indicates them. a review of the options available to promote sustainable growth in maize production has been completed. (Benchaphun Ekasingh, 2004)

CHAPITRE 3
METHODOLOGY

3.1 Materials for Construction of the Smart Trap

The smart trap concept in this section is divided into three main systems :

1. Box with pheromone
2. Camera with electronic board
3. Monitoring on Internet

The box with pheromone allow to capture pests. Then, the camera will give images in the box. Images captured are analysed to determine the number of pest in the smart trap. The electronic board allow to calculate that. Humidity and temperature sensors can be added to get more information of environment. The purpose is to recover the data on a responsive site to supervise the problem in the culture.

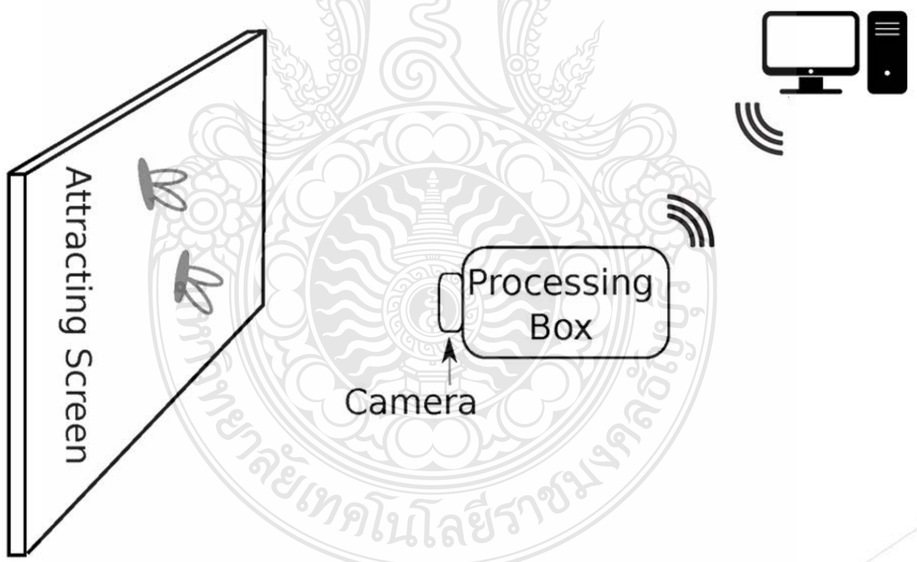

Figure 3.1 Principle of the system

A specific attractive substance must be used to attract the Corn Armyworm. The female-produced sex pheromone of *S. frugiperda* is often used to monitor populations to time insecticide application. Pheromones enable mating disruption and mass trapping.

3.2 Materials for Construction of the Smart Trap

The mainly components for construct the smart trap are as below :

3.2.1 Pheromone

3.2.2 Electronic board

3.2.3 Camera

3.2.4 Box

3.2.5 Battery

3.2.6 Solar panel

3.2.7 Sensors

3.2.8 PC / tablet

3.2.9 4G key

3.2.10 IDE (Informatic Environment Development)

3.2.11 Programming cable

3.2.12 Structural materials

As shown in Figure 3-2, the system consists of several elements with a control part, a power part and the elements allowing screen capture and the transfer of collected information. A solar panel is used to power the various elements of the system. This allows battery life in the field. The embedded system is composed of a Raspberry Pi 4, a Pi camera, an SD card, a 4G key and optionally a GPS. The Raspberry Pi integrates an ARM Cortex-A72 processor and image acquisition and analysis software. This electronic card is connected by DCMI to a pi camera which captures images on a regular basis and stored in the SD card. The 4-BIT SPI interface allow the communication of the processor with the SD card. Subsequently, 4G key allows internet access and data transfer on Line and Grafana. The software is written in Python language and OpenCV library is used to image processing.

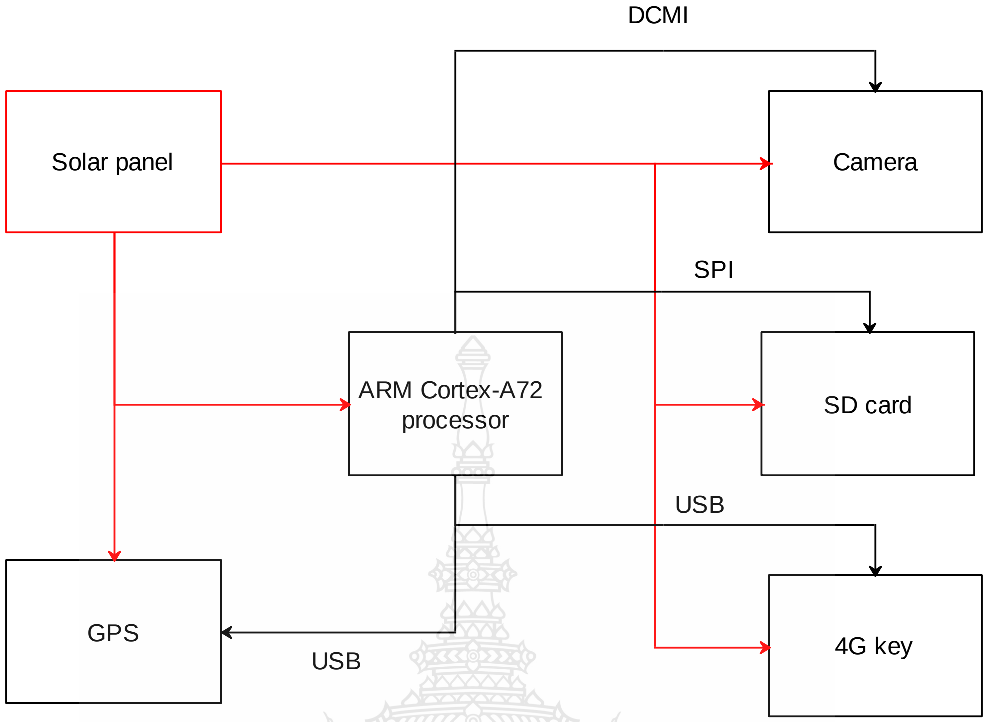

Figure 3.2 System diagram of smart trap

Raspberry Pi 4 have a 1.5 GHz 64-bit quad core ARM Cortex-A72 processor, on-board 802.11ac Wi-Fi, Bluetooth 5, full gigabit Ethernet (throughput not limited), two USB 2.0 ports, two USB 3.0 ports, 2–8 GB of RAM, and dual-monitor support via a pair of micro HDMI ports for up to 4K resolution. The version with 1 GB RAM has been abandoned and the prices of the 2 GB version have been reduced. The 8 GB version has a revised circuit board.

The Raspberry Pi Camera Board is a custom designed add-on module for Raspberry Pi hardware. It attaches to Raspberry Pi hardware through a custom CSI interface. The sensor has 5 megapixel native resolution in still capture mode. In video mode it supports capture resolutions up to 1080p at 30 frames per second.

As shown in Figure 3.2, the system consists of several elements with a control part, a power part and the elements allowing screen capture and the transfer of collected information. A solar panel is used to power the various elements of the system. This allows battery life in the field. The embedded system is composed of a Raspberry Pi 4, a Pi camera, an SD card, a 4G key and optionally a GPS. The Raspberry Pi integrates an ARM Cortex-A72 processor and image acquisition and analysis software. This electronic card is connected by DCMI to a pi camera which captures images on a regular basis and stored in the SD card. The 4-BIT SPI interface allow the communication of the processor with the SD card. Subsequently, 4G key allows internet access and data transfer on Line and Grafana. The software is written in Python language and OpenCV library is used to image processing.

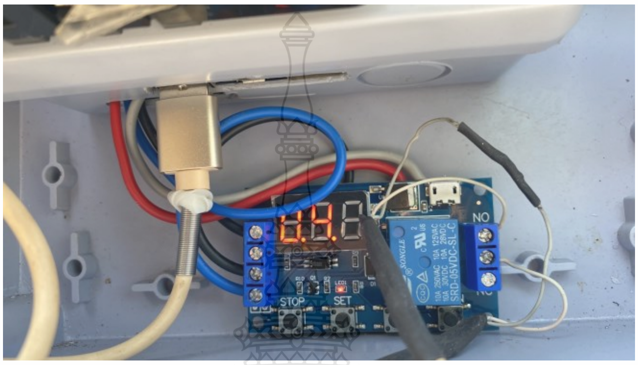

Figure 3.3 Counter for power supply activation

A meter is used to save the energy. It engages when the brightness increases and feeds the card for 45 minutes. The system can take pictures for image processing at this time. The system therefore works in the morning when the brightness allows a good picture to be taken. Photos are taken every 20 minutes to ensure adequate light. The capacity of the solar panel allows the system to operate at least once a day even if there is very little sun per day. The capacity is overestimated in case of lack of sun.

(A) (B)

Figure 3.4 Camera location

The camera is positioned facing the bottom of the trap to allow an overview of the pests inside, showed in Figure 4 and a color photo with 640x480 resolution is taken at a specific time during the day. The photography is on RGB (*Red Green Blue*) channels model. Several positions have been tested but this one is the best. The bottom of the box must be visible as a whole in the photo. The yellow part of the box must not be in the field of vision of the camera because it interferes with the detection of pests afterwards. A piece has been cut to clear the vision. There were no problems with vision obstruction at this location, such as an insect landing in front of the lens.

Finally the height of the box is set to wheat height and therefore evolves during the growth of the maize. This allows for better dispersal of pheromones and better accessibility to the moth.

Figure 3.5 Example of image captured witch pests count

The images taken are then converted into the HSV (or HSL) color space. This model is based on a (human) perception of color. The hue is commonly called colour (mainly red, yellow, green, cyan, blue or magenta). We often represent the hue in a circle and give her value in degrees (over 360 degrees). For example, yellow color corresponds to 120°. Saturation refers to the intensity of the colour between grey (low saturation or desaturation) and pure colour (high saturation). The saturation is usually expressed as a percentage or between 0 and 1. The value corresponds to the brightness of the colour, between black (low value) and average saturation (maximum value). The value is usually expressed as a percentage or between 0 and 1.

The system filters with the parameters implemented to detect pests. A mask of the image is created then the shapes obtained are analyzed. The counting of the shapes corresponding to the insects is then carried out. In figure 5, we can see seven insects. Each identified insect is marked with a white dot. The blue dot corresponds to two insects. The system differentiates them because the two are glued together. The color difference depending on the case allows feedback to know how the software managed to identify this or that pest.

Figure 3.6 Example of image captured with her mask

In this figure 6, we can see the photo analyzed by the smart trap. a photo mask is created and saved on the Raspberry PI. This mask filters out all colors that are not within the ranges determined for the analysis parameters. The parameters are the values of the HSV format. The mask allows the detection of the contours of the pests thanks to the filtering of the selected color. This is all accomplished by doing a convolution between the kernel and the image. Convolution is the process of adding each element of the image to its immediate neighbors, weighted by the kernel elements.

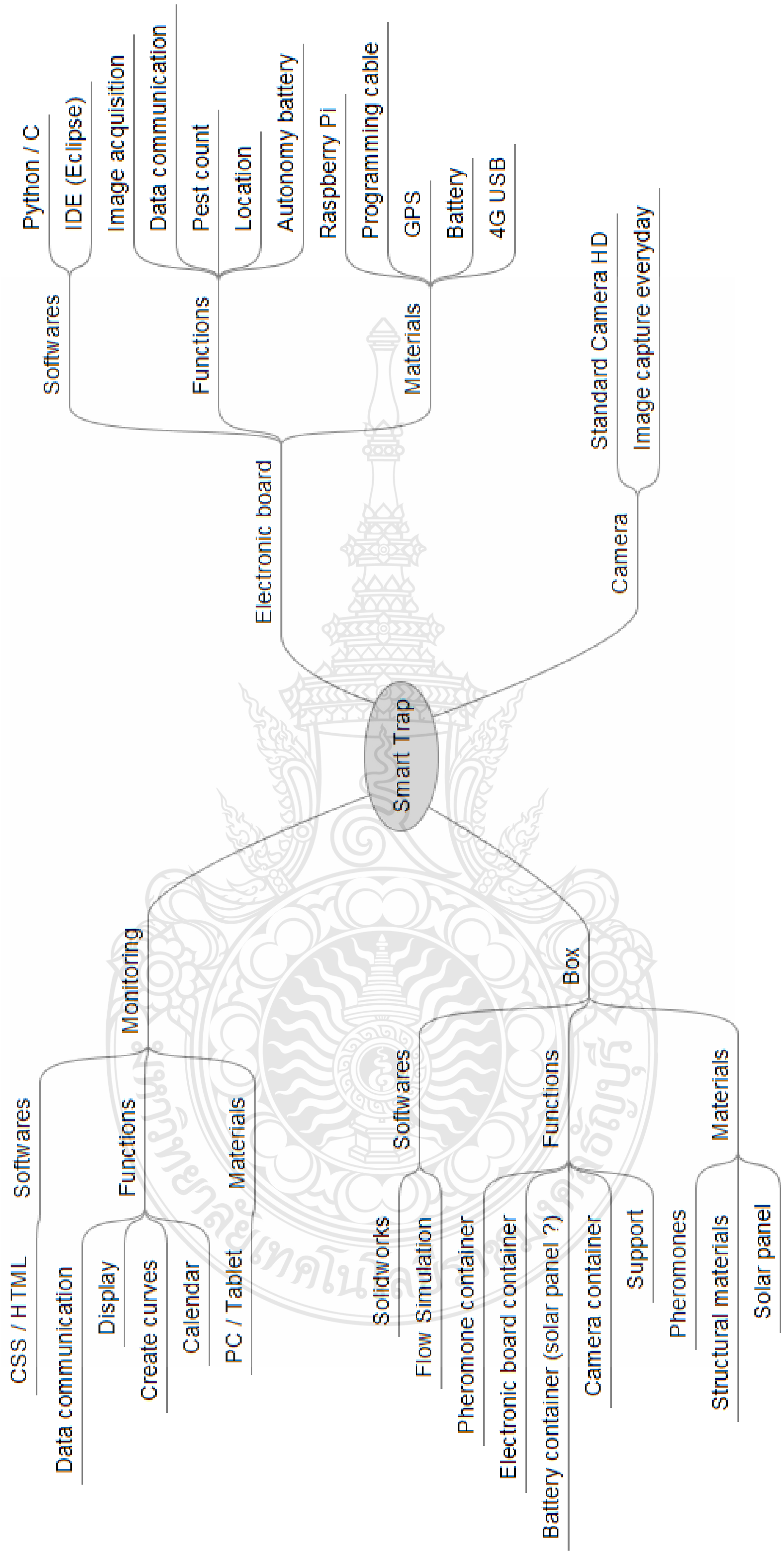

Figure 3.7 Mind map

3.3 Designing Procedure

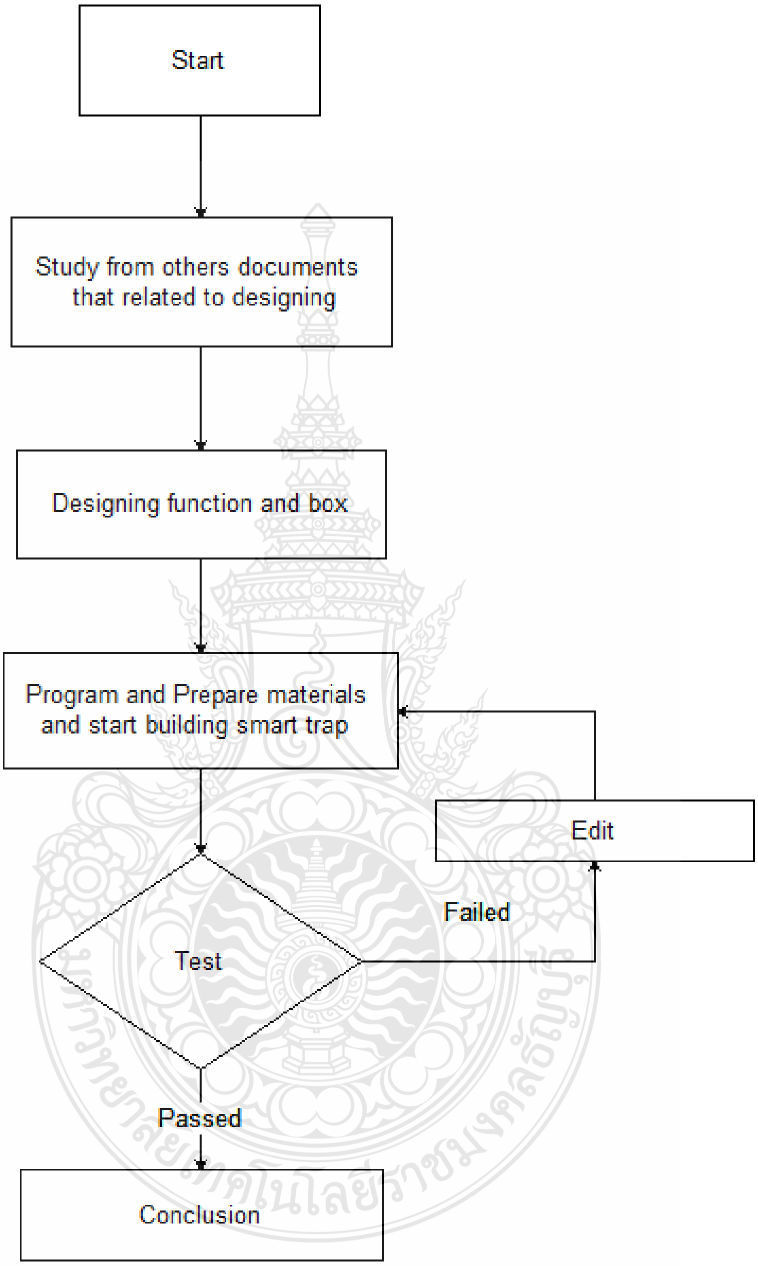

Figure 3.8 Experimental stages

Table 3.1 Project management chart

	2020	2021						2022				
details	11	1	3	5	7	9	11	1	3	5	7	9
Study relevant research data												
Smart trap design												
Prepare materials												
Create smart trap												
Test smart trap												
Analysis of collected data												

To develop the embedded software, a versioning software will be used to follow the evolution of the program.

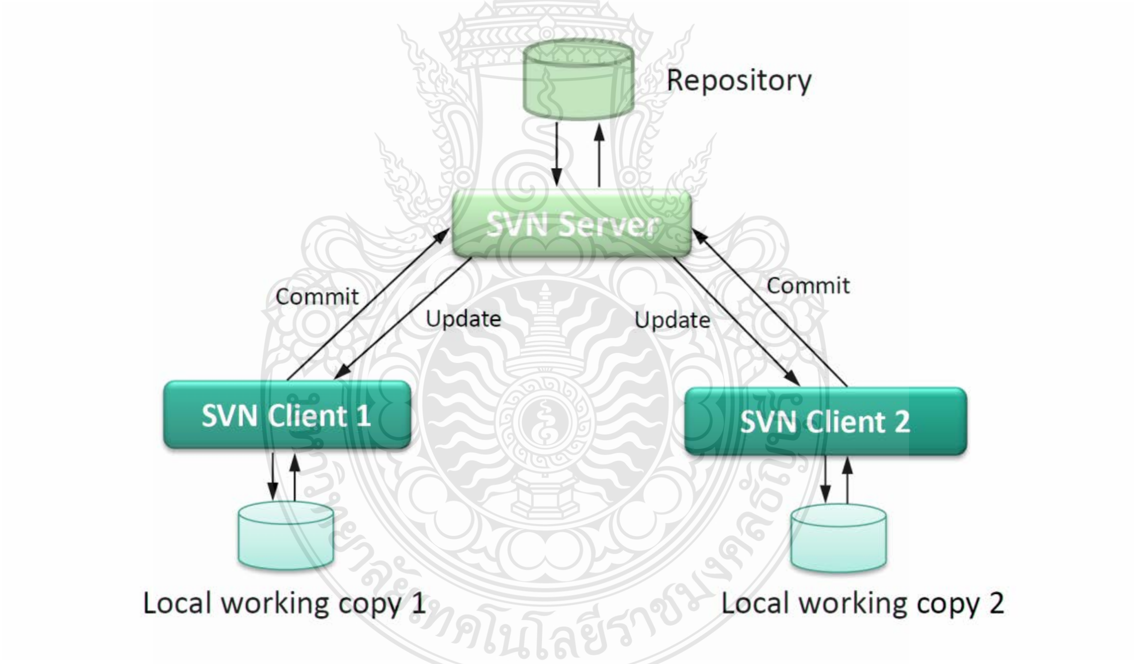

Figure 3.9 SVN principle

Subversion is version control software. This is software that records all the states of a tree over time (by tree I mean both the folder structure, but also the content of the files). This is where the term "version" comes from: the software monitors the different versions of a directory.

Subversion can be networked, which allows it to be used by people working on different computers. In a way, the ability for multiple people to edit and manage the same set of data from different locations promotes collaboration. Things move faster when you avoid having a single channel through which all changes must pass. And since the changes are tracked in versions, don't worry, the absence of such a channel does not have the counterpart of a loss of quality: if inappropriate changes are applied to the data, it is enough to undo them. Some version control systems are also software configuration management system. These systems are specially designed to manage source code trees and have many features unique to software development.

3.4 Experimental Method

3.4.1 Simulation test

3.4.1.1 Solidworks

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) application owned by Dassault Systèmes. KSP develop one structure for the smart trap.

3.4.1.2 Unit test

The unit test is a procedure making it possible to verify the correct functioning of a specific part of a software or of a portion of a program.

We write a test to compare a realization to its specification. The test defines a stop criterion (state or outputs at the end of the execution) and makes it possible to rule on the success or failure of a check. Thanks to the specification, one is able to match a given input state to a result or an output. The test makes it possible to verify that the input / output relation given by the specification is indeed carried out.

The XP method recommends writing the tests at the same time, or even before the function to be tested (Test Driven Development). This makes it possible to precisely define the interface of the module to be developed. Tests are run throughout development, making it possible to see if the freshly written code matches the requirement.

When a program is modified, unit tests report any regressions. Indeed, certain tests can fail following a modification, it is thus necessary either to rewrite the test to make it correspond to the new expectations, or to correct the error in the code.

Unit tests can be used as a complement to the API, it is very useful to read the tests to understand how a method is used. In addition, it is possible that the documentation is no longer up to date, but the tests themselves correspond to the reality of the application.

We generally define 4 phases in the execution of a unit test:

1) Initialization (setUp function): definition of a completely reproducible test environment (a fixture).
2) Exercise: the module to be tested is executed.
3) Verification (use of assert functions): comparison of the results obtained with a defined result vector. These tests define the test result: SUCCESS or FAILURE. You can also define other results like EVITE (SKIPPED).
4) Deactivation (tearDown function): uninstallation of fixtures to restore the initial state of the system, in order not to pollute the following tests. All tests must be independent and reproducible individually (when performed alone).

3.4.2 Real test

A prototype must be created in 4 months to be able to carry out tests in a corn field of the CP company. This will make it possible to determine whether the functions developed are functional and adapted to the environment in which the smart trap will be installed. For example, for the shape of the box, is it better to put it on the ground or hang it.

Figure 3.10 Smart trap system

3.4.3 Area study

The location of the study area is at KSP Equipment Co. Ltd., in Lam Sai, Wang Noi District, Phra Nakhon Sri Ayutthaya Province, Thailand. Cultivation of fodder corn on the aforementioned areas started from June to November 2021. Areas used for experiments in the size of 12,467 square meters, which is equally divided in two, into Plot A and Plot B. The maize used for the test was cultivar CP303 with a harvest of 105 days and 115 days for fresh harvest and dry harvest respectively. The average yield should be expected at 1,500-2,000 kg/rai at 25-30% humidity (CPP). The smart trap was installed in the middle of the field between Plot A and Plot B, so that the pheromones are the maximum range. A smart trap with a sachet of pheromone is enough to cover the whole field. The installation took place after sowing corn in the field. The pesticide was not used at the beginning of the plantation to be able to see the pest problems appear. There is no internet access at this location, which is why the system is equipped with a 4G key

3.4.4 Smart trap and pheromone

The box with pheromone allows to capture pests. Then, the camera will give images in the box. Images captured are analyzed to determine the number of pest in the smart trap. The electronic board allow to calculate that. Humidity and temperature sensors can be added to get more information of environment. The purpose is to recover the data on a responsive site to supervise the problem in the culture. A specific attractive substance must be used to attract the Corn Armyworm. The female-produced sex pheromone of *S.*

frugiperda is often used to monitor populations to time insecticide application. Pheromones enable mating disruption and mass trapping. The propagation capacity of this type of pheromone is 1 km².

3.4.5 Image processing

The camera is positioned facing the bottom of the trap to allow an overview of the pests inside, showed in Figure 4 and a color photo with 640x480 resolution is taken at a specific time during the day. The photography is on RGB (Red Green Blue) channels model.

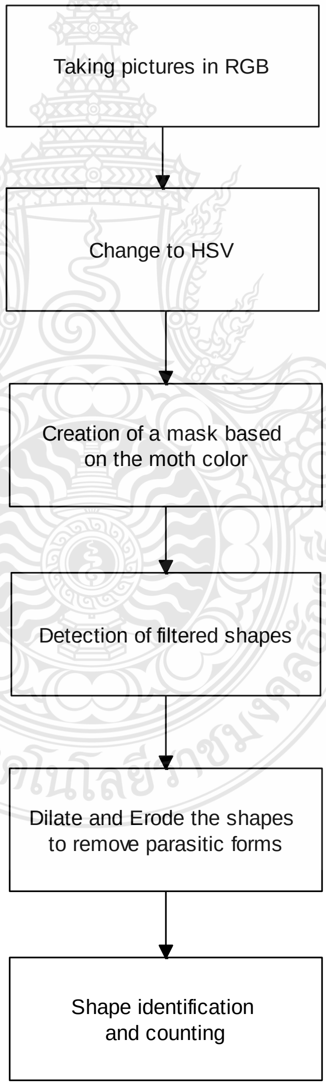

Figure 3.11 Image processing steps

The image processing steps are shown in Figure 3.11. First, the photos are taken in the RGB format. They are then converted into the HSV format. A mask from the photo is created, based on the color of the moths. This color is determined upstream and is translated into HSV. Then, a detection of the filtered forms is made. The image obtained is cleaned of parasitic shapes with the functions "Dilate()" and "Erode()". Finally, the program identifies the remaining shapes thanks to their size and counts.

3.4.6 IoT

Two functions are performed by an Internet of Things (IoT) middleware: 1) it is used to store the data coming from the analysis of the smart trap; and 2) it transports and provides data to the user application. This project send data on Line application for the test. In this project data is sent over Line and Grafana.

CHAPITRE 4
RESULT AND DISCUSSION

4.1 Efficiency

The results of the prototype trap evaluation are shown in Figure 6. We relate the system count to the manual count. The slope of the regression line indicates the association between the manual count and the system count. r represents the fraction of the total variance of the system count. Manual count variation explains this variance. We can see from these results that r is very high. Automatic counting is very close to manual counting.

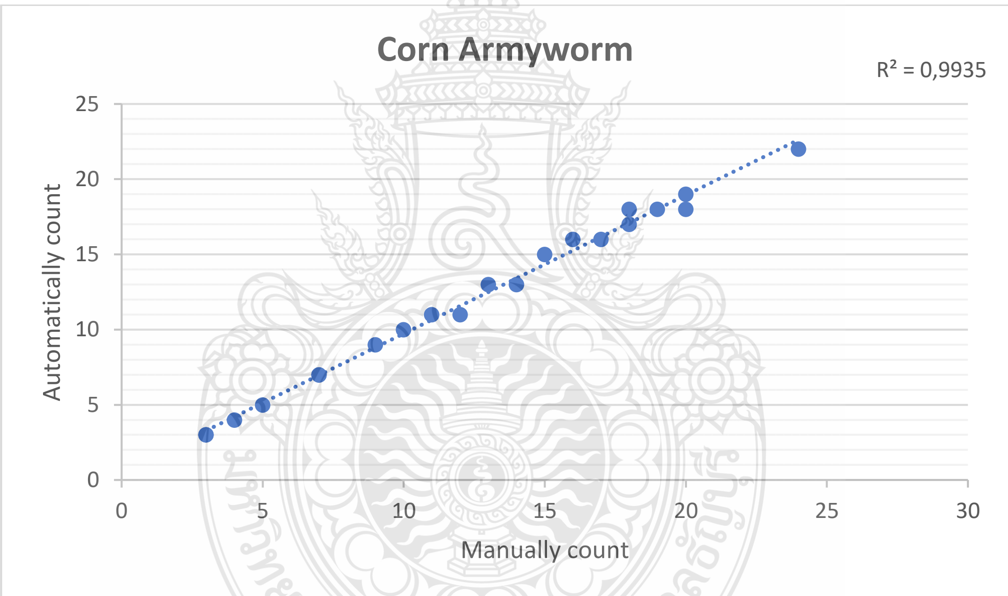

Figure 4.1 Accuracy of the automatic counting in comparison with actual detection

A comparison between the captures measured by the system and those counted manually was made. This comparison allows to determine the accuracy of the developed system. The error between manual counting and counting by image processing allows to define the inaccuracy of the system. The accuracy of the system is calculated with an equation (1), which is shown as follows:

$$a = 1 - \frac{|Mc - Ma|}{Mc} \qquad (1)$$

where a is the counting accuracy of the system, Mc is the number of manual counting pests, and Ma is the number of the automatically counted pests. The results are shown in Table 1.

Table 4.1 The counting accuracy of the proposed smart trap.

Automatically count	Manually count	Accuracy % (a)
1	1	100.00%
3	3	100.00%
3	3	100.00%
4	4	100.00%
5	5	100.00%
7	7	100.00%
7	7	100.00%
9	9	100.00%
10	10	100.00%
11	11	100.00%
12	11	91.67%
13	13	100.00%
14	13	92.86%
15	15	100.00%
16	16	100.00%
17	16	94.12%
18	18	100.00%
18	17	94.44%
19	18	94.74%
24	22	91.67%
20	18	90.00%
20	19	95.00%
Mean accuracy		97.48%

Preliminary tests were done on a single day on site. As shown above, accuracy of our smart trap is very accurate, achieving about 97% accuracy. This accuracy is determined by comparing the number of insects counted manually and the number counted automatically. Our system's pest detection has a high accuracy. Indeed, the very high correlation (r > 0.99 in all cases) between the automatic detection and the pests present in the box show this accuracy.

4.2 Effect of Brightness

The brightness is modified on the original photographs to test its influence on the effectiveness of image processing. We can see, in Figure 2, the difference in processing due to brightness. On image A, the luminosity has been lowered by 50. There is a counting error compared to the original photograph. In fact, the decrease in luminosity affects the counting. Pests are less distinguishable by analysis. The insects stuck together have more difficulty in being differentiated. The more the brightness is increased, the more the detection will have difficulty counting. On image A, the luminosity has been increased by 50. We can see that the brightness helps in the detection of insects. Pests are much sharper on photography masks. Image capture during the tests was done early in the morning. But taking an image when the brightness is greater would increase the efficiency of the system. Image capture should be done when the light is adequate to maximize brightness. This would reduce errors when counting pests.

(A) (B)

Figure 4.2 Brightness influence

A timer switch is used to save the energy. It engages when the brightness increases and feeds the card for 45 minutes. The system can take pictures for image processing at this time. The system therefore works in the morning when the brightness allows a good picture to be taken. This system allows to manage the problem of light and energy.

Figure 4.3 Example of brightness effect on site

As shown in the figure 3, photos are taken at 10 minute intervals in the morning on site. The start of the power supply is done when the luminosity begins to increase. We can see that the brightness is changing very quickly. The detection is practically not done on the example when the luminosity is very high.

The brightness must be adequate: neither too high nor too low. In both cases, detection will be impacted. the power meter allows the smart trap to start at a fixed brightness in the morning. It is therefore necessary to determine the best interval to take a photo. After 20 minutes of power, the brightness seems the best to work with.

4.3 Limitation of Image Processing

4.3.1 Pest cluster

Figure 4.4 Example of pest cluster

When there are a lot of pests, they tend to stick together. The erode() function makes it possible to dissociate them to facilitate counting. But in the case of the figure above, dissociating the insects is impossible. The method used is therefore to estimate the number of insects on a certain surface. The estimate is made on all the photos recovered to be as close as possible to reality. This scenario shows the limits of image processing for the smart trap. The tests carried out for this system were relatively good but the estimate must be improved. The surface is counted in pixels on the photos.

To avoid having this kind of problem, the smart trap must be maintained. Thanks to the monitoring of the evolution of the population of pests, we can determine a threshold where pesticides must be used. Emptying the smart trap at this time resets the evolution curve from the use of pesticides. Another solution is to increase the size of the box.

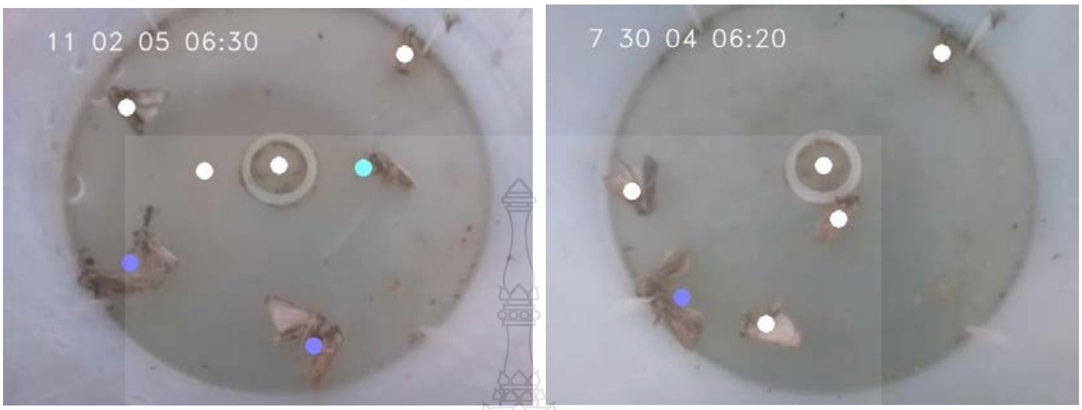

Figure 4. 5 Image processing for cluster

For the tests, different colors were used to mark the counted pests. In the figure, we can see that the blue dots denote two pests. The turquoise point is for three pests but here there is an error. The colors are taken arbitrarily and can be modified easily for the understanding of pest counting. Nine categories have been defined to count the pests. Beyond 10 stuck, it is considered that it is no longer useful to count. Indeed this means that the box is full and that it must be emptied.

Table 4.2 Categories of pixel surface

number of pixel	number of pest	Colour code	Colour
11 -77	1	(255, 255, 255)	White
78 - 144	2	(97, 51, 255)	blue
145 - 211	3	(255, 51, 70)	Red
212 - 278	4	(255, 51, 224)	Pink
279 - 345	5	(190, 51, 255)	Purple
346 - 412	6	(51, 252, 255)	Turquoise
413 - 479	7	(51,255, 100)	Green
480 - 546	8	(252, 255, 51)	Yellow
> 547	> 9	(255, 165, 51)	Orange

The table 2 shows the different pixel area categories determined. The colors used are obtained thanks to their RGB code. Each surface has a number of related positions. As said above, the number of categories is nine. This has been determined after various tests but this is not reliable.

4.3.2 Unwanted objects

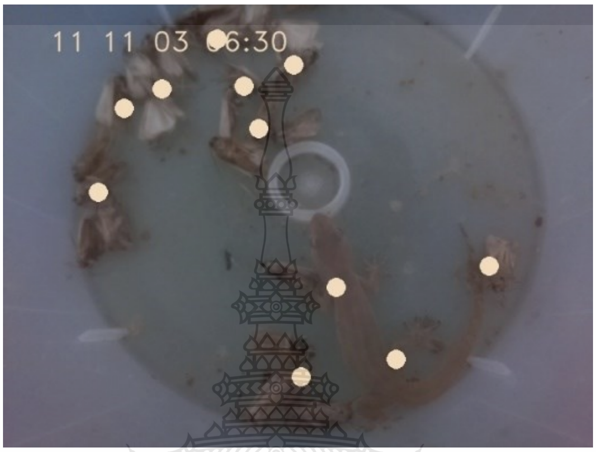

Figure 4.6 Lizard in the box

The functions "dilate()" and "erode()" allow you to refine the vision and remove small objects such as stains or leaves. "Erode()" makes them disappear, then "dilate()" makes the remaining objects bigger for detection. These functions are available thanks to the OpenCV library.

This method works for small objects but it does not work when they are large objects. Indeed, a lizard entered the box and was the same color as the pests. The smart trap can't tell if it's a bunch of pests or something else. The case has only occurred once and is therefore very rare. The pheromones used only work on fall armyworm and the lizard didn't come in for that reason.

This photo was taken with low light. With better brightness, the smart trap could have differentiated the color tone between the pests and the lizard. But we couldn't do any further tests with the lizard.

4.4 IOT in Smart trap

4.4.1 Line application

The original photo and the analyzed photo are both sent to the Line application. This makes it possible to compare the photo taken with the result obtained for the counting of pests. The Line application has a tool that allows you to send notifications and data on a conversation. The Python language on Raspberry provides functions aimed at sending character strings for messages and variables used in software. Here we even send complete images. the image before processing and after processing are both sent.

The header has evolved to designate the time of the test to be able to sort the recovered photos. The number counted by the smart trap is indicated in the header to avoid having to look at the analyzed photo. This system allowed us to collect a lot of data to make image processing more reliable. Being able to recover the original photo without having to go to the site to recover it on a USB key saved a lot of time. The photos could be reused for new tests in order to make the smart trap more reliable.

Figure 4. 7 Notification in Line application

4.4.2 Grafana platform

Node-RED is a powerful tool for building Internet of Things (IoT) applications with a focus on simplifying programming which is done through predefined blocks of code, called “nodes” to perform tasks . It uses a visual programming approach that allows developers to connect blocks of code together. Connected nodes, usually a combination of input nodes, processing nodes, and output nodes, when wired together constitute a "flow".

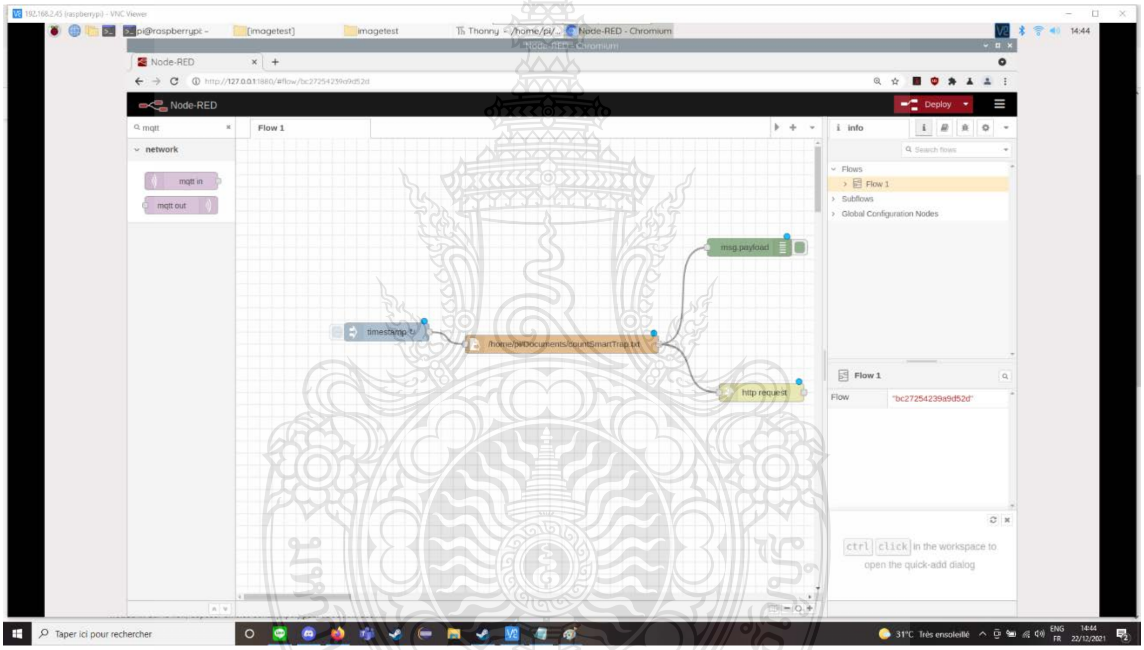

Figure 4.8 Diagram in Node Red

A diagram on Node Red was created to ensure a connection between the smart trap and Grafana. Currently the feature has not been tested as Grafana is not running in the global KSP system. The information needed to be sent is stored in a text file. This information is the date and time and the number of insects detected. Other data can be sent. In a larger system with multiple smart traps, an ID number for each system can be sent with the data.

CHAPITRE 5
CONCLUSION

Thanks to the Internet of Things, it has become possible to provide supervision in different fields of application. Agriculture is an important field where automation and data analysis can be very useful. Pests are a major problem for plantations. They decrease production and increase costs with the use of pesticides. The smart trap is a system that captures these pests using pheromones and provides valuable information to growers.

The smart trap developed in this project is completely autonomous with power supply via a solar panel and on-board electronics. The cost and the size of the system are not very high. the software is free of charge and allows the development of image processing at no cost. Compared to other systems on the market, this smart trap does not cost much to make. The smart trap has very good accuracy. The collected data can be visualized without having to go to the place of culture. This allows a better knowledge of pests in the field and therefore better management of pesticides. The developed smart trap has a high accuracy (>97%) on one test on site. But light plays a very important role in detecting pests. Image capture should be done around noon to maximize brightness. Unwanted objects can also interfere with image processing. Stains on the bottom of the box or even other animals like lizards can be the cause. To correct these errors, the OpenCV library provides functions such as “dilate()” or “erode()”.

For future developments, a GPS can be added to locate an installed smart trap. On a large field, a single smart trap is not enough to map the pest population. Indeed, pheromones only disperse in a limited area. With several smart traps equipped with a GPS and installed in a field, a map can be created to determine the areas where the problems appear. The treatment of the field with pesticides would then be adapted to the population of pests.

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APPENDICES

APPENDIX A
Application Code

Import

```
import cv2
import numpy as np
import picamera
import picamera.array
Import request
```

Color Configuration

```
lo=np.array([0, 22, 0])#([2, 18, 40])
hi=np.array([75, 255, 255])#([100, 120, 255])
color_infos=(183, 217, 241)
color_infos_2=(150, 100, 100)
myDate = '12_00_00'
WIDTH=640
HEIGHT=480
```

Image Manipulation

```
camera.capture(stream, 'bgr', use_video_port=True)
image=cv2.cvtColor(stream.array, cv2.COLOR_BGR2HSV)
mask=cv2.inRange(image, lo, hi)
image=cv2.blur(image, (7, 7))
mask=cv2.erode(mask, None, iterations=4)
mask=cv2.dilate(mask, None, iterations=4)
image2=cv2.bitwise_and(stream.array, stream.array, mask=mask)
```

Image Saving

```
date_today = datetime.now()
date_image = date_today.strftime('%d_%m_%H_%M')
cv2.imwrite('/home/pi/Documents/smart trap/imagetest/Camera'+date_image+'.jpg',
stream.array)
cv2.imwrite('/home/pi/Documents/smart trap/imagetest/image2'+date_image+'.jpg',
image2)
cv2.imwrite('/home/pi/Documents/smart trap/imagetest/Mask'+date_image+'.jpg', mask)
```

Example Image Processing

```
elements=cv2.findContours(mask, cv2.RETR_EXTERNAL,
cv2.CHAIN_APPROX_SIMPLE)[-2]
    #image processing
    if len(elements) > 0:
        for e in elements:
            x, y, w, h= cv2.boundingRect(e)
            ((x, y), rayon)=cv2.minEnclosingCircle(e)
            if rayon>10 and rayon < 78:
                nbre = nbre+1
                cv2.circle(image2, (int(x), int(y)), int(rayon), color_infos, 2)
                cv2.circle(image, (int(x), int(y)), 5, color_infos, 10)
            if rayon>77 and rayon < 200:
                nbre = nbre+2
                cv2.circle(image2, (int(x), int(y)), int(rayon), color_infos_2, 2)
                cv2.circle(image, (int(x), int(y)), 5, color_infos_2, 10)
```

Line

```
url = 'https://notify-api.line.me/api/notify'
token = 'lrdXlVXmjPAjkf25hYYZtmMC13dfUuYaaPkGA3uncoh'
headers = { 'content-type': 'application/x-www-form-urlencoded', 'Authorization':'Bearer
'+token}
while True:
msg = input("Enter your name:")
r = requests.post(url, headers=headers , data = {'message':msg})
print(r.text)
```

APENDIX B
Publication of Works


RMUTCON
E - PROCEEDINGS
11th RMUTIC
The 11th Rajamangala University of Technology
International Conference
Collaboration
Prachachuen Research Network
The Materials Research Society of Thailand
18 - 20 May, 2022
Royal Cliff Grand Hotel, Pattaya, Thailand

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Session 8: Food Innovation and Smart Farm

A Smart Trap Device for Detection of Corn Armyworm in Maize Harvest

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Abstract

Maize is one of five major crops in Thailand. Maize produced approximately 4.5 million tonnes of total national yield in the 2019/20 crop year. In recent years, Thailand's domestic maize production has not been adequate to meet domestic requirements, and small quantities of grain have been imported. Moreover, some types of insects (called pests) are undesirable in agriculture as they decrease productivity as well as cause considerable financial losses. Chemical control is the most widely applied for efficiency and practicality reasons. However, all insecticides available in the market are extremely toxic and may cause health problems in humans and damage in nature life. These insecticides are also expensive and require several applications in the plantations during the year. Use of technology can reduce production losses, including the use of resources in production cost-effectively and environmentally friendly. New solutions have been attempted motivated by the evolution of a series of technologies such IoT, cloud computing, electronic traps, and advanced insect's identification techniques. Digital Agriculture is emerging as a trend offering technological artifacts to face the problems related to plantations on farms. The key objective is protecting human health and natural life. Secondary objectives are to decrease the economic cost of pest control, the possibility to monitor the trapping operation and to receive the effectiveness feedback in real-time. The smart trap with pheromone allows it to capture corn armyworm, *Mythimna separata* Walker, a pest that infests corn from 20 days of age to the pod stage. Then, the camera will give images in the box. Images captured are analysed to determine the number of pests in the smart trap. The electronic board allows us to calculate that. The purpose is to recover the data on a monitoring platform to supervise the problem in the culture. We report results on insect pests that can reach a detection accuracy ranging from 97%.

Keywords: Smart Trap, Image Processing, Electronic, Corn Armyworm, Maize

Introduction

Maize is one of the 5 largest agricultural production in Thailand. Indeed, Thailand has a lot of maize fields. Farms make up 33% of agricultural land in addition to rice, cassava, sugarcane, and rubber. In 1984/85, 12.4 million rai (nearly 2 million ha) were planted to maize, ranking second only to rice of 9.5 million ha. In 1984, Thailand exported 3.0-3.7 million tons of maize and earned nearly 10,000 million baht (US$ 400 million), but thereafter maize area began to decline and occupied only 7.3 million rai (nearly 1.2 million ha) by 2002-03, with a production of around 4.5 million tons (Benchaphun Ekasingh).

Agriculture provides food and medical products, so this area is very important for humanity. However, some types of pests are undesirable in agriculture. They decrease productivity as well as cause considerable financial losses. Major diseases and pests identified included downy mildew, rust, rats, and stem borers, although maize is more tolerant to diseases than other up land crops (Benchaphun Ekasingh). In Figure 1, we can see a corn armyworm in photograph A and its larva in photograph B. The larva is the pest that destroys maize plantations. It is a major pest in Thailand for maize. Large amounts of leaf tissue are consumed by larger fall armyworm larvae. This results in a ragged appearance to the leaves similar to grasshopper damage. The larvae are less impacted by pesticides, it is therefore necessary to trap and detect the adults upstream.

The chemical control is the most widely applied for efficiency and practicability reasons (Bustillo). However, all insecticides available to use in agriculture are extremely toxic. This is the cause of health problem in humans and damage in nature life. During the year, it is necessary to apply pesticides several time in the plantations. These insecticides increase the budget of farmer. A more measured use of pesticides and adapted to the importance of the problems detected in the fields would allow to reduce the costs.

New technologies are beginning to be mass-produced. The use of techniques such as Internet of Things (IoT) and image processing are emerging in agriculture to find solutions to the problems encountered (Martineau). All these new technologies provide task automation and better management of information such as the arrival of pests in a field. The smart trap is used in areas other than agriculture, for example in urban areas (Panagiotis Eliopoulos). The purpose of a smart trap in agriculture is to reduce the use of pesticides and therefore to protect human health. This also results in lower costs.

The purpose of this study is to develop a smart trap. The target is the Corn Armyworm. The function of this trap is to capture and count the number of pests in a field to monitor problems and adjust pesticide use accordingly. This paper is organized as follows. First of all, material and method describe the location and hardware and software used. Then results and discussion presents and analyses the obtained results. Finally, we conclude the paper and suggests future works.

(A) (B)

Figure 10 The Corn Armyworm (A) and his larva (B)

Material and Method

Study area

The location of the study area is at KSP Equipment Co. Ltd., in Lam Sai, Wang Noi District, Phra Nakhon Sri Ayutthaya Province, Thailand. Cultivation of fodder corn on the aforementioned areas started from June to November 2021. Areas used for experiments in the size of 12,467 square meters, which is equally divided in two, into Plot A and Plot B. The maize used for the test was cultivar CP303 with a harvest of 105 days and 115 days for fresh harvest and dry harvest respectively. The average yield should be expected at 1,500-2,000 kg/rai at 25-30% humidity (CPP). The smart trap was installed in the middle of the field between Plot A and Plot B, so that the pheromones are the maximum range. A smart trap with a sachet of pheromone is enough to cover the whole field. The installation took place after sowing corn in the field. The pesticide was not used at the beginning of the plantation to be able to see the pest problems appear. There is no internet access at this location, which is why the system is equipped with a 4G key

Smart trap and Pheromone

The box with pheromone allows to capture pests. Then, the camera will give images in the box. Images captured are analyzed to determine the number of pests in the smart trap. The electronic board allow to calculate that. Humidity and temperature sensors can be added to get more information of environment. The purpose is to recover the data on a responsive site to supervise the problem in the culture.

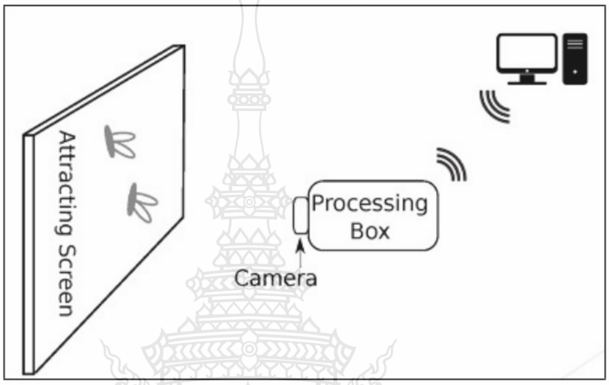

Figure 11 Illustration of Smart Trap System

A specific attractive substance must be used to attract the Corn Armyworm. The female-produced sex pheromone of *S. frugiperda* is often used to monitor populations to time insecticide application. Pheromones enable mating disruption and mass trapping.

Hardware

As shown in Figure 3, the system consists of several elements with a control part, a power part and the elements allowing screen capture and the transfer of collected information. A solar panel is used to power the various elements of the system. This allows battery life in the field. The embedded system is composed of a Raspberry Pi 4, a Pi camera, an SD card, a 4G key and optionally a GPS. The Raspberry Pi integrates an ARM Cortex-A72 processor and image acquisition and analysis software. This electronic card is connected by DCMI to a pi camera which captures images on a regular basis and stored in the SD card. The 4-BIT SPI interface allow the communication of the processor with the SD card. Subsequently, 4G key allows internet access and data transfer on Line and Grafana. The software is written in Python language and OpenCV library is used to image processing.

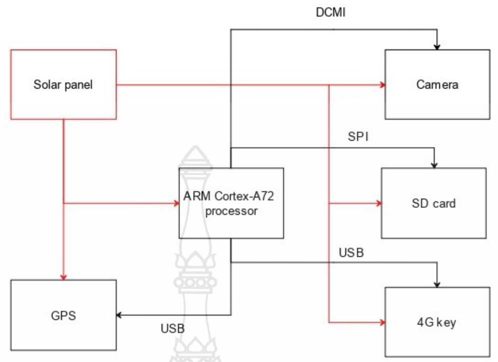

Figure 12 System diagram of smart trap

Image Processing

The camera is positioned facing the bottom of the trap to allow an overview of the pests inside, showed in Figure 4 and a color photo with 640x480 resolution is taken at a specific time during the day. The photography is on RGB (*Red Green Blue*) channels model.

(A) (B)

Figure 13 Hardware setup

The images taken are then converted into the HSV (or HSL) color space. This model is based on a human perception of color. The hue is commonly called color mainly red, yellow, green, cyan, blue or magenta. We often represent the hue in a circle and give her value in degrees over 360 degrees. For example, yellow color corresponds to 120°. Saturation refers to the intensity of the color between gray (low saturation or desaturation) and pure color (high saturation). The saturation is usually expressed as a percentage or between 0 and 1. The value corresponds to the brightness of the color, between black (low value) and average saturation (maximum value). The value is usually expressed as a percentage or between 0 and 1.

The system filters with the parameters implemented to detect pests. A mask of the image is created then the shapes obtained are analyzed. The counting of the shapes corresponding to the insects is then carried out. In figure 5, we can see seven insects. Each identified insect is marked with a white dot. The blue dot corresponds to two insects. The system differentiates them because the two are glued together. The color difference depending on the case allows feedback to know how the software managed to identify this or that pest.

Figure 14 Example of image captured with pest count

IoT

An Internet of Things IoT middleware has two main roles: 1) it stores data pushed from the smart trap software component; and 2) it provides data to the Web application component. This project send data on Line application for the test. In this project data is sent over Line and Grafana.

Results and Discussion

Efficiency

The results of the prototype trap evaluation are shown in Figure 6. We relate the system count to the manual count. The slope of the regression line indicates the association between the manual count and the system count. R^2 represents the fraction of the total variance of the system count. Manual count variation explains this variance. We can see from these results that R^2 is very high. Automatic counting is very close to manual counting.

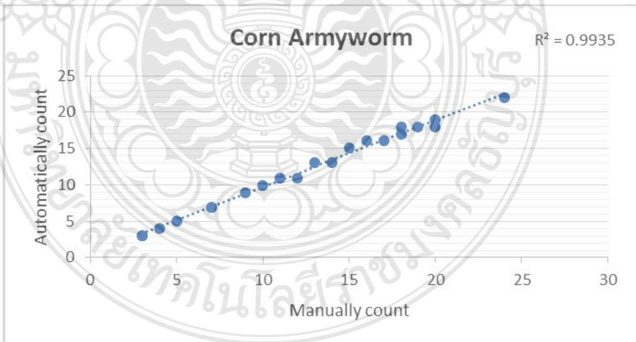

Figure 15 Accuracy of the automatic counting in comparison with actual detection

The numbers of the captures measured by the system were compared to those counted manually. This comparison allows to determine the accuracy of the developed system. The error between manual counting and counting by image processing allows to define the inaccuracy of the system. The accuracy of the system is calculated with an equation (1), which is shown as follows:

$$a = 1 - \frac{|Mc - Ma|}{Mc} \qquad (1)$$

where a is the counting accuracy of the system, Mc is the number of manual counting pests, and Ma is the number of the automatically counted pests. The results are shown in Table 1.

Preliminary tests were done on a single day on site. As it is clearly presented, our smart trap is very accurate, achieving about 97% accuracy on automatic counts compared with manually counted numbers of captured insects. The accuracy of our system in detecting insect presence is also shown by the very high correlation ($R^2 > 0.99$ in all cases) between the generated signals and actual numbers of insects caught in the trap.

Table 1 The counting accuracy of the proposed smart trap.

Automatically count	Manually count	Accuracy % (a)	Mean accuracy
1	1	100.00%	
3	3	100.00%	
3	3	100.00%	
4	4	100.00%	
5	5	100.00%	
7	7	100.00%	
7	7	100.00%	
9	9	100.00%	
10	10	100.00%	
11	11	100.00%	
12	11	91.67%	97.48%
13	13	100.00%	
14	13	92.86%	
15	15	100.00%	
16	16	100.00%	
17	16	94.12%	
18	18	100.00%	
18	17	94.44%	
19	18	94.74%	
24	22	91.67%	
20	18	90.00%	
20	19	95.00%	

Effect of brightness

The brightness is modified on the original photographs to test its influence on the effectiveness of image processing. We can see, in Figure 7, the difference in processing due to brightness. On image A, the luminosity has been lowered by 50. There is a counting error compared to the original photograph. In fact, the decrease in luminosity affects the counting. Pests are less distinguishable by analysis. The insects stuck together have more difficulty in being differentiated. The more the brightness is increased, the more the detection will have difficulty counting. On image A, the luminosity has been increased by 50. We can see that the brightness helps in the detection of insects. Pests are much sharper on photography masks. Image capture during the tests was done early in the morning. But taking an image when the brightness is greater would increase the efficiency of the system. Image capture should be done around noon to maximize brightness. This would reduce errors when counting pests.

(A) (B)

Figure 16 Brightness influence

A timer switch is used to save the energy. It engages when the light starts to appear and feeds the card for 45 minutes. The system can take pictures for image processing at this time. The system therefore works in the morning when the brightness allows a good picture to be taken. This system allows to manage the problem of light and energy.

Conclusion

Thanks to the Internet of Things, it has become possible to provide supervision in different fields of application. Agriculture is an important field where automation and data analysis can be very useful. Pests are a major problem for plantations. They decrease production and increase costs with the use of pesticides. The smart trap is a system that captures these pests using pheromones and provides valuable information to growers.

The smart trap developed in this project is completely autonomous with power supply via solar panel and on-board electronics. The cost and the size of the system are not very high. The smart trap has very good accuracy. The collected data can be visualized without having to go to the place of culture. This allows a better knowledge of pests in the field and therefore better management of pesticides. The developed smart trap has a high accuracy (>97%). But light plays a very important role in detecting pests. Image capture should be done around noon to maximize brightness.

For future developments, a GPS can be added to locate an installed smart trap. On a large field, a single smart trap is not enough to map the pest population. Indeed, pheromones only disperse in a limited area. With several smart traps equipped with a GPS and installed in a field, a map can be created to determine the areas where the problems appear. The treatment of the field with pesticides would then be adapted to the population of pests.

Acknowledgments

The authors would like to thank Department of agricultural machinery engineering, Faculty of engineering, Rajamangala University of Technology Thanyaburi and KSP Equipment Co. Ltd., for cooperation and support for this research.

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