Autonomous Light-Seeking Robotic System Inspired by Dynamic Insect Vision

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Introduction

The purpose is to propose an approach that may lead to a solution to advance robotic vision, which still lacks the advanced perception and capabilities that many desire for it. Roboticists worldwide are actively working on better and different perceptual capabilities. Methods from insect visual processing may prove useful to machine vision algorithms that are implemented in systems that 'pursue' objects. Insects have high temporal resolutions. They've adopted very efficient methods for target tracking/identification and navigation in cluttered, complex environments. Their strategies could be informative towards light and motion tracking machines and robots. Biomimicry, a common and successful practice, is turning to nature's time-tested strategies to solve problems. In that vein, a mobile robot with insect-inspired vision, capable of adapting, understanding its environment, identifying higher luminance areas, and continuously following a moving light source against any background, was the goal.

Objectives

1. Identify potential benefits of studying insects for robotic vision.
2. Develop algorithm for a dynamic, fully autonomous, light-seeking, motion tracking, mobile robot that benefits from insect inspiration.

Methods and Materials

Simplified, the process involved studying literature, designing the body and circuit, writing appropriate programming, testing my work in various situations and lighting, recording useful data and trends, mostly qualitatively, and repeating for refinement. The process was divided into 3 stages.

1

Studying
- Literature review on possible solutions from insect vision for current challenges in robotic vision and light sensitive navigation.

2

Planning, Building and Designing
- Identifying all necessary and appropriate abilities in the algorithm
- Construction with Parallax/Arduino kit parts & the BASIC Stamp 2 module. Initial modulations.
- An identical pair of charge transfer circuits to measure ambient light and light intensity difference between left and right phototransistors. Utilized capacitor voltage decay time measurements to measure brightness of light incident.
- Programmed differentiating light intensities, directing towards the highest luminance areas in various tests., and the detection of environment changes.
- Acquired light sensitivity adaptability.

3

Testing and Refining
- Various tests for quality performance.
- Edits for flaws
- Add-ons

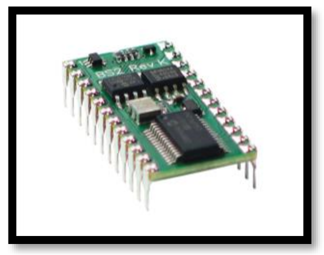

Figure 1. BASIC Stamp 2 is a programmable microcontroller. It can control and monitor timers, keypads, motors, sensors, switches, relays, lights, and more [1].

Figure 2. Trials configuring the right phototransistor sensitivity are critical to success.

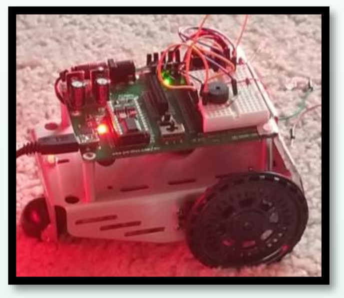

Figure 3. A closeup of the bot's features in progress during the trials.

Figure 4. Dragonflies can fly as fast as cars and theoretically see color better than humans. They have three ocelli or simple eyes and 2 large compound eyes which each have has about 30,000 tiny, six-sided lenses or facets. With thousands of different species, there are likely variations in the way they see. Dragonflies also see polarized light and ultraviolet light [2].

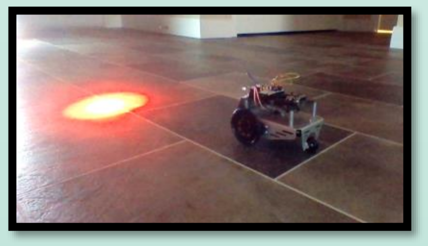

Figure 5. Robot following a moving light with good accuracy and reaction speed.

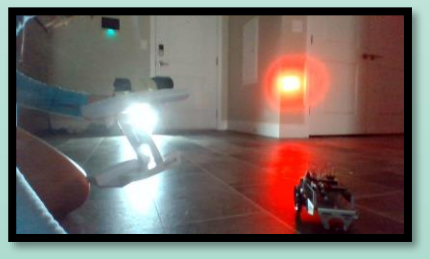

Figure 6. Robot is challenged to handle a complex scene with multiple light sources.

Figure 7. The final product. A look at its two phototransistor eyes.

Results of Objective 1

- Evolution has given insect eyes temporal gifts. However, this is coupled with spatial constraints.
- Overall visual acuity, making detailed images with shape and color, is worse than humans due to inferior neural processing, but they reign supreme in categories like speed, field of view, locking on a target, reflexes, and having multiple, different visual sensors at a time.
- Other information noted: insects are capable of distance perception, form perception, and stereoscopic sight. Masters of energy efficiency. Well-developed compound eyes have an extensive field of view. Some can even detect light polarization and magnetic field changes. Nocturnal insects adapt to see in low light levels at night may help low-light video technology. Some insects can see color, and most can also see ultraviolet light (whether as a color or as shades of grey).
- The structure of compound eyes seemed plausibly copiable with the right materials.

Results of Objective 2

- Completed robot: Turns away from shadows and seeks out light sources. Able to detect shadows and navigate in most classroom ambient light levels by adapting like insects do.
- Limitations: direct sunlight and rooms without any lights on will still exceed the system's ability to adjust and result in aimless roaming. Mechanical Power is weaker.. Module can't handle larger/more advanced AI programs..
- Design tries to maximum efficiency and precision like the way insects do. Pauses between signals minimized. Always moves at the top speed possible. Moves in subroutines of short adjustments to minimize unnecessary servo and energy usage. I had planned to add another servo motor to make create a head that turned independently of the body and therefore energy and time would be saved, but it wasn't completed.
- As a last touch, I added with whiskers to not run into walls or obstacles as it does its job. In the future, id like to add detection to avoid obstacles using infrared or UV sensors, which was an ability of many insects. This would follow the way insects often have more than one way to see too.

Conclusion

Discoveries from the anatomy and processing of insects that were included in the robot were minimal in amount due to time and resource constraints. However, theoretically, the comparison between current visual technology and the structural organization of the insect compound eyes was fruitful. Compound eyes may be creatable with more advanced, large scale photosensor circuits in this project's next steps. At the end of the project, the robot completed all its planned tasks and lots of potentially applicable knowledge from insect vision was gained, but satisfactory inclusion of the insect principles was not achieved. To go further than what was done; more literature needed to be read and more powerful mechanical and programmable parts needed to be had. Both problems could've been solved with more given time. Research is worth continuing because there is still potential in the proposal, despite this project's shortcomings.

Next Steps

1. Further inclusion of insect strategies. More research generally & in specific insects.
2. More efficient/powerful mechanical and electronic parts. More and different sensors.
3. Exploring artificial neural networks and deep learning AI inspired by insects

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References

[1] Parallax Inc (https://www.parallax.com/product/bs2-ic)
[2] Mitsuhiko Imamori/Minden Pictures