FPGA Implementation for Bio Inspired Visual Motor Control System Applied to Micro Aerial Vehicle

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Abstract: The Autonomous Navigation System (ANS) was a combat vehicle upgrade used to convert manned vehicles to autonomous unmanned capability or to upgrade already unmanned vehicles to be autonomous. Micro aerial vehicle is small aerial vehicle which is used for different application to extract the real time information in different weather condition. Therefore it needs a proper navigation system which can navigate the system in clutter environment. Proposed Visual motor control system will be helpful to navigate in cluttered environment with proper control signals for all the directions. For increasing the speed of the design efficient hardware architecture will be realized.

I. INTRODUCTION

In the last decade, technology applied to autonomous underwater vehicles (AUVs) has experienced a spectacular development. Scientific, industrial or security applications related to remote observation, object identification, wreck retrieval, mapping and rescuing, among others, have boosted such technological advances. AUVs are progressively becoming fundamental tools for underwater missions, minimizing human intervention in critical situations and automatizing as many procedures as possible.

Despite this increasing interest and the great number of vehicles developed far and wide, their cost, size, weight and depth rate are the main factors that mostly restrict their commercialization and extensive use worldwide. Compared to their larger counterparts, micro-AUVs are smaller, lighter and cheaper to acquire and maintain. These reasons make small AUVs a valuable tool for exploring and mapping shallow waters or cluttered aquatic environments, addressing a wide variety of applications. Conversely, the reduced size of these vehicles limits seriously the equipment that they can carry; thus, they have to be endowed with a reduced sensor set, which can meet, simultaneously, navigation and mission purposes.

The size and price of equipment have to be optimized when designing micro-AUVs. Low-cost sensors generally provide poor quality measures, so significant errors and drifts in position and orientation can compromise the mission achievement. In this case, software algorithms to infer accurately the vehicle pose and twist become a critical issue since small errors in orientation can cause important drifts in position after a certain time.

Nature provides us with many examples of ingenious sensors and systems at the service of animal behavior, which can be transferred into innovative systems for the control of Micro-Air Vehicles (MAVs). Winged insects demonstrate daunting behaviors in spite of the poor resolution of their visual system. For more than 100 million years, they have been navigating unfamiliar 3D environments by relying on optic flow (OF) cues. To sense and react to the flowing image of the environment, insects are equipped with smart sensors called Elementary Motion Detectors (EMDs) that can act as optic flow sensors.

II. LITERATURE SURVEY

The purpose of MAV is to provide an ultra-miniature aircraft which is able to perform ‘Vertical Take-off and Landing (VTOL)’ and maintaining altitude when the vehicle is moving or when the horizontal velocity of a vehicle is at 0 by getting life only from a single rotor's rotation, and without using separate stabilizers such as a tail-rotor or a gyro. To fulfill the above purpose, this invention comprises: several blades in airfoil shape that are placed in calculated angle and space; hubs that connect the blade to with a body of a vehicle; a rotor which gives lifting force with its spin; a spin-able axle which its vertical hem is bound to the hubs; a rotor drive that is needed to spin the rotor; a vehicle body that is placed right under the rotor in order to fly from the lift that is obtained by revolutions of the rotor; fixed-wings that are placed in certain angle and space around the outside of the vehicle body in order to reduce a reaction torque, which affects the body to turn the opposite direction of the rotor, from the rotor's movement; and a reaction-torque-counterbalance-system on each of the above fixed-wings that offsets the reaction torque aggressively.

Micro aerial vehicles (MAV) are a new type of remotely controlled aircrafts. Most MAVs today target a length of about six inches. The application of this device is mostly for observational purposes. Therefore, it can be used to unveil hazardous environments, new terrain or any areas
that aren’t easily assessible by ground. To be able to complete these tasks, the design of the micro aerial vehicle must be miniature aerodynamic, light and include a long ranged controls system. Due to time constraints and limited funding, the objective and specifications of the plane were modified. The purpose of the designed aircraft will be used as a transition to be a micro aerial vehicle in the future. Therefore, a larger platform will be designed and built so that future members of the MAV team will be able to modify the platform to fit the specifications of a micro aerial vehicle: The actual plane. As for the calculations for the platform, the concepts and calculations from the MAV project 08120 will be used as a benchmark to insure the accuracy of the current project. The calculations were also presented to a faculty advisor for thoroughness. The completed prototype of project 09123 will be semi-autonomous. Therefore, it will be controlled by a wireless remote control. Using the remote control, the user will be able to fly and control the aircraft without any external interference.

We have developed a visually based autopilot which is able to make a micro air vehicle (MAV) automatically take off, cruise and land, while reacting adequately to wind disturbances. We built a proof-of-concept, tethered rotorcraft that can travel indoors over an environment composed of contrasting features randomly arranged on the floor. Here we show the feasibility of a visuomotor control loop that acts upon the thrust so as to maintain the optic flow (OF) estimated in the downward direction to a reference value. The sensor involved in this OF regulator is an elementary motion detector (EMD). The functional structure of the EMD was inspired by that of the housefly, which was previously investigated at our laboratory by performing electrophysiological recordings while applying optical microstimuli to single photoreceptor cells of the compound eye. The vision based autopilot, which we have called OCTAVE (optic flow control system for aerospace vehicles) solves complex problems such as terrain following, controls risky maneuvers such as takeoff and landing and responds appropriately to wind disturbances. All these reputedly demanding tasks are performed with one and the same visuomotor control loop. The non-emissive sensor and simple processing system are particularly suitable for use with MAV, since the tolerated avionic payload of these micro-aircraft is only a few grams. OCTAVE autopilot could also contribute to relieve a remote operator from the lowly and difficult task of continuously piloting and guiding an UAV. It could also provide guiding assistance to pilots of manned aircraft.

Tomorrow’s Micro-Air-Vehicles (MAVs) could be used as scouts in many civil and military missions without any risk to human life. MAVs have to be equipped with sensors of several kinds for stabilization and guidance purposes. Many recent findings have shown, for example, that complex tasks such as 3-D navigation can be performed by insects using optic flow (OF) sensors although insects’ eyes have a rather poor spatial resolution. At our Laboratory, we have been performing electrophysiological, micro-optical, neuroanatomical and behavioral studies for several decades on the housefly’s visual system, with a view to understanding the neural principles underlying OF detection and establishing how OF sensors might contribute to performing basic navigational tasks. Based on these studies, we developed a functional model for an Elementary Motion Detector (EMD), which we first transcribed into electronic terms in 1986 and subsequently used onboard several terrestrial and aerial robots. Here we present a Field Programmable Gate Array (FPGA) implementation of an EMD array, which was designed for estimating the OF in various parts of the visual field of a MAV. FPGA technology is particularly suitable for applications of this kind, where a single Integrated Circuit (IC) can receive inputs from several photoreceptors of similar (or different) shapes and sizes located in various parts of the visual field. In addition, the remarkable characteristics of present-day FPGA applications (their high clock frequency, large number of system gates, embedded RAM blocks and Intellectual Property (IP) functions, small size, light weight, low cost, etc.) make for the flexible design of a multi-EMD visual system and its installation onboard MAVs with extremely low permissible avionic payloads.

II. PROJECT DEFINITION

MAV (Micro aerial vehicle)needs a proper navigation system in a clutter environment. Hence through proper navigation system it is made possible. Proposed system will be able to navigate the mav in corner condition by triggering proper signals. Develop a Object detection simulink model to detect and extract shape and size of an object. Develop a motion detection simulink model to detect motion and its location. Mat lab code for respective simulink model is generated. Object detection and motion detection in verilog. Motion controller using verilog (FSM). Hardware reference model has been taken to FPGA.

UML DIAGRAM

Fig.2. UML diagram
IMAGE ACQUISITION: Real time inputs are captured from camera i.e, still images and continuous image.

IMAGE PERCEPTION: Develop stimulant model for object and motion detection.

IMAGE EXTRACTION: Matlab codes are generated for both object and motion detection.

CONTROLLER DEVELOPMENT: Motor controller using verilog (FSM).

IV. ALGORITHM AND ARCHITECTURE DEVELOPMENT FLOW CHART FOR OBJECT DETECTION

- Reading input image (still images)
- Resizing of input image
- RGB to intensity conversion
- Thresholding (threshold scale factor 1.2 & 0.6)
- Subtraction
- Extraction of black spot
- Extraction of X & Y coordinates of respective black spot
- Identify shape of the object
- Store the shape & location of the object

**Fig. 3.** Flow chart for Object detection

Step 1: Reading still image as input.
Step 2: Input images are resized.
Step 3: RGB to intensity conversion is done
Step 4 & 5: Thresholding for scaling factor 1.2 and 0.6
Step 6: Threshold images are subtracted due to variation in intensity of images.
Step 7: Black spots are extracted from the subtracted image
Step 8 & 9: Object shape and size are determined from x and y coordinates obtained from object detection Mat lab code.
Step 10: Shape and location of the object is stored.

FLOW CHART FOR MOTION DETECTION

- Reading the continuous image
- Resizing of continuous image
- RGB to intensity conversion
- Thresholding (thresholding scale factor 1)
- Subtraction
- Extraction of motion X & Y coordinates
- Identify motion in 5 different locations in image
- Store the motion location

**Fig. 4.** Flow chart for motion detection

Step 1: Reading continuous image as input.
Step 2: Input images are resized.
Step 3: RGB to intensity conversion is done
Step 4 & 5: Thresholding for scaling factor 1
Step 6: Threshold images are subtracted due to variation in intensity of images.
Step 7: White spots are extracted from the subtracted image. Object motion is determined from x and y coordinates obtained from motion detection Mat lab code.
Step 8: Motion location of the object in five different quadrants is identified.
Step 9: store the motion location

**SIMULINK MODEL FOR OBJECT DETECTION**

The design flow is presented in Figure. This methodology requires design various stages as well as the linking framework. Firstly, we start to create a ‘simulink model’ as well as one or more simulated environment configurations for validating its principle. In this state, a functional approach involves dividing the system into elementary function blocks. Here the still image is fed as input. Secondly, these images are resized to get better processing. Next the resized image is converted from RGB to intensity followed by threshold scaling factor 1.2 and 0.6 (can be varied for different threshold values for proper identification). The output of these threshold blocks are subtracted to extract the black spots. Object shape and size are determined from x and y coordinates obtained from object detection Mat lab code. Finally shape and location of object is stored.

**V. RESULT AND DISCUSSION FOR OBJECT DETECTION**

Proposed design should be able to navigate the MAV in different direction. Processing speed of MAV navigation system should be faster for critical conditions. Proposed design should be flexible for different corner cases of navigation. Verilog simulation is shown in figure 7.
VI. IMPLEMENTATION

Visual control system has been realized using HDL and FPGA implementation has been carried out the input and output of visual control system has shown in above figure 8. The technology Schematic is shown in above figure 9. The technology schematics show the resources of FPGA have been used for design.

VII. CONCLUSION

Proposed design is able to navigate in cluttered environment. Proposed design is able to control the MAV in Corner case of navigation. Proposed design will be for low power and high speed application. Proposed design will be able to navigate the MAV in different direction. Processing speed of MAV navigation system will be faster for critical conditions. Proposed design will be flexible for different corner cases of navigation. The delay offer by the design is 3.597 ns.

REFERENCES


