International Journal of Computer Applications (0975 – 8887)
Volume 117 – No. 17, May 2015

Design of Robotic Fish for Aquatic Environment Monitoring

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ABSTRACT
In this paper, smartphone based aquatic debris monitoring robot design is proposed and discussed. Regularly monitoring aquatic waste or debris is of more interest to the environments, aquatic life, human health, and water transport. This paper presents the design of a robotic fish system that integrates an Android smartphone and a robotic fish for debris monitoring. The smartphone based aquatic robot can accurately detect debris in the presence of various environments.

Keywords
Aquatic debris , raspberry pi, arduino, CV algorithm.

1. INTRODUCTION
Water resources and aquatic ecosystems have been facing various material, chemical, and natural threats from weather change, industrial contamination, and offensive waste disposal. The harmful diffusion processes like chemical leakages may also have dangerous impact on human health and sustainability of ecosystem.

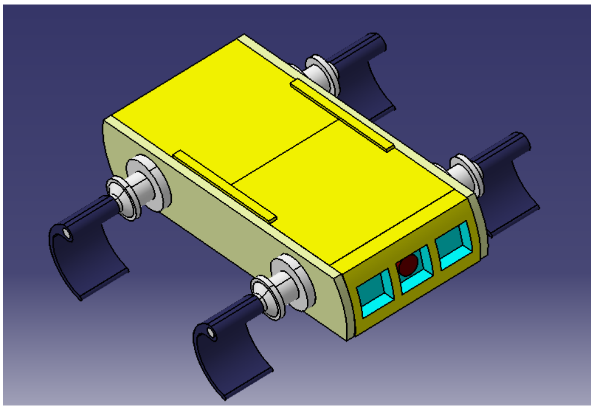

Fig 1.Aquatic Robot

Also, any kind of disturbances like obstacles coming in the way creates traffic. When such a conditions arises, an immediate requirement is to detect the characteristics of the diffusion process, including the location of source. Manual sampling, via boat/ship or with foothold devices, is still a general practice in the monitoring of aquatic diffusion processes. The past couple of years have seen significant progress in developing robotic technologies for aquatic sensing. This paper includes design of robotic fish and implementation of CV algorithm for image processing [1].

However, the design of smartphone based aquatic robot still faces several unique challenges associated with aquatic debris monitoring. First, due to the impact of waves, aquatic robot cannot acquire a stable camera view, thereby making it highly difficult to reliably recognize the debris objects. A possible solution is image registration that bring multiple images align into a common coordinate system [7]. However, water environments often not detect the features such as sharp corners that are commonly used for image registration. Second, it is powered by small batteries due to the constraints on the form factor and cost budget, while both aquatic movement of the robot and image processing on the smartphone incur high energy consumption. Lastly, debris entrances are often irregular in a large geographic region [1], making them highly difficult to be captured using smartphone cameras that typically have limited field of view. To address these challenges, in this paper we considered the following things:

To develop several lightweight CV algorithms to address the essential dynamics in aquatic debris or waste detection, which include an image registration algorithm for extracting the horizon line above water and use it to register the images to diminish the impact of camera shake. An adaptive background subtraction is for reliable detection of debris in water. The off-loading decisions are made to minimize the system energy consumption based on in situ measurements of wireless link speed and robot acceleration.

To analyze the coverage for sporadic and uncertain debris arrivals based on geometric models. Using the analytical debris arriving probability, here design of a robot rotation scheduling algorithm that minimizes the movement energy consumption while maintaining a desired level of debris coverage performance.

2. LITERATURE SURVEY
The literature survey carried out related to technology impact in the study of robotic fish with different algorithms. Yu Wang et.al. describes Smartphone based aquatic robot features real-time debris detection and coverage-based rotation scheduling algorithms. Gi-Hun Yang et.al. presents the development of robotic fish will be introduced from its design stage to the implementation of the Tchthus v5.6 [6]. The developed system has autonomous navigation ability and the water quality monitoring capability. The image processing algorithms for debris detection are specifically designed to address the unique challenges in aquatic environments. The rotation scheduling algorithm provides effective coverage of sporadic debris arrivals despite camera’s limited angular view [1]. An active constraints, also known as virtual fixtures, are high-level control algorithms which can be used to assist a human in man–machine collaborative manipulation tasks. The active constraint controller monitors the robotic manipulator with respect to the environment and task, and anisotropic ally regulates the motion to provide assistance [2].

An algorithm combines the Meanshift algorithm with the bump characteristic of the ring contour to eliminate the mirror image effects and background interference. [3]. the task of pollution source location in the use of environment monitoring robot-fish, there were two kinds of method to deal with the “cruise route”. One was discrete hill-climbing search method, and the other was spiral coverage scanning algorithm. [4] and [5] gives the practical solution to the problem of monitoring an environmental process in a large region by a small number of robotic sensors.

3. PROPOSED METHODOLOGY

3.1 Hardware Design

Robotic unit is consisting of array of sensors and camera which is movable around its axis and also vertically. Raspberry Pi is used for video processing and sending the video to the user through the Bluetooth is used for communication between Arduino and Raspberry Pi(ARM Processor).

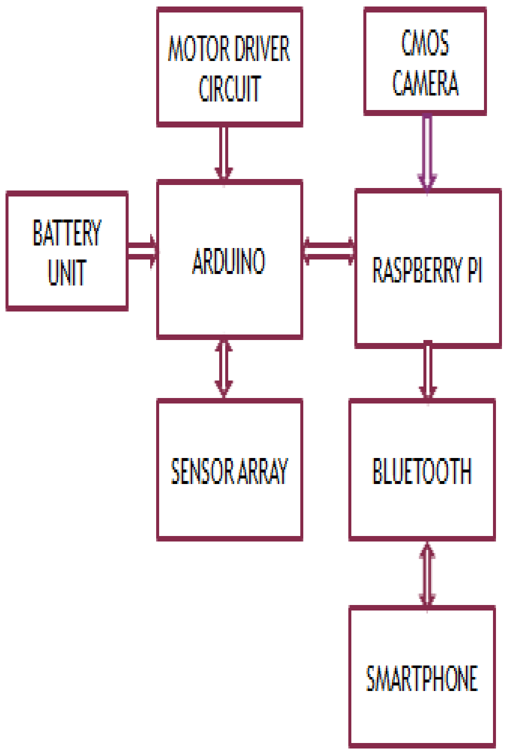

Fig 2.Block diagram for Robotic Unit

Motor driving circuits are used for operating motors. The gliding robotic fish is capable of moving in water by a DC motor. The motor is manipulated by a programmable control board, which can communicate with the smartphone through either a USB cable or short-range wireless links such as Bluetooth.

The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It is a capable little computer which can be used in electronics projects, and for many of the things that your desktop PC does, like spreadsheets, word-processing and games. It also plays high-definition video. Raspberry Pi has a strong processing capacity because of using the ARM11 architecture and Linux-based system. In terms of control and interface, it has 8 GPIO, 1 UART, 1 I2C and 1 SPI, which are basically meet the control requirement. There are simple and easy-used open source peripheral driver libraries.

Table 1.Technical data of Robot hardware design

Component	Specification
Raspberry pi (Model B+)	Chip Broadcom BCM2835 & ARM11 SoC Core architecture
Arduino	Microcontroller ATmega328
CMOS Camera	Resolution Support for:640 x 480 & 1600 x 1200
Bluetooth	HC-05
DC Motors	3-5V DC
Accelerometer	ADXL335 3-axis sensing
Ultrasonic distance sensor	HY-SRF05 2channel Logic Level converter
Gas sensor	MQ-3

3.2 Real Time Debris Detection

The image processing pipeline of Smartphone based aquatic robot is illustrated in Figure3 [1]. Although it is based on a collection of elementary CV algorithms, it is non-trivial to optimize these computation-demanding synergistic algorithms for smartphones given the limited resources and strict requirement on system lifetime. Specifically, it consists of the following image processing components. The image registration aligns successive frames to ease the impact of camera shaking caused by waves. In this paper, the focus on the aquatic environment is takes place.

3.2.1 Horizon-based Image Registration

Image registration is the process of aligning images taken at different time instants into one coordinate system. In aquatic debris detection, image registration is required to ease the impact of camera shaking caused by waves, such that consequent pixel-wise processing can be executed properly. Registration is performed by creating correspondence be-tween images based on their distinguishable features. However, a key challenge is that there are few detectable image features in typical water environments that can guide the image registration. A distinctiveness of our approach is to control the horizon line, which segments the sky and water areas, for image registration, as shown in Figure 3(a).

3.2.2 Background Subtraction

We adopt the background subtraction approach to reduce energy consumption in image processing and to detect the foreground debris object. Firstly we convert the representation of an image to HSV (Hue, Saturation, and Value) model. In HSV, hue represents the color, saturation is the domination of hue, and value specifies the lightness of the color. The HSV representation is strong to illumination changes and hence more effective in interpreting color features in the presence of reflection in water environments.

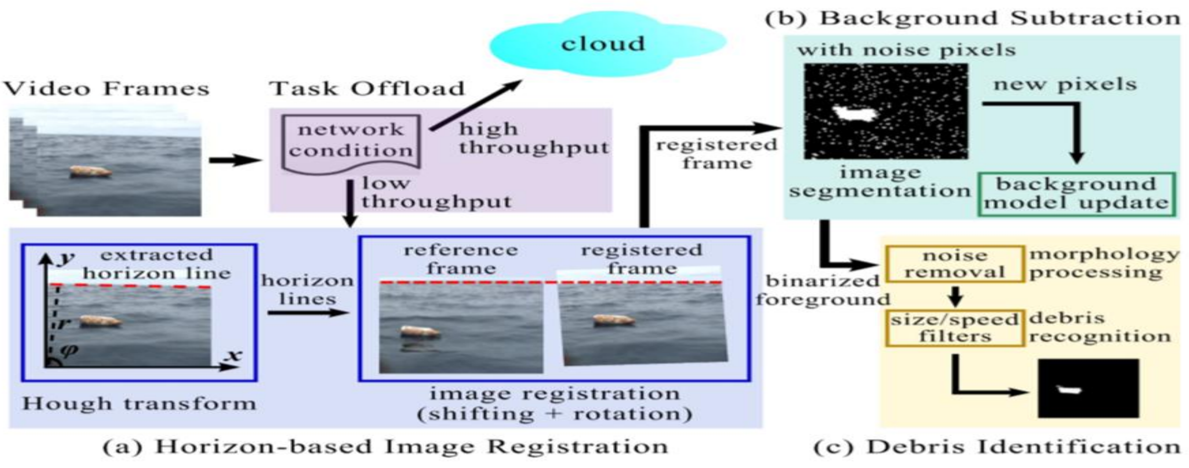

Fig 3: Real-time debris objects detection

3.2.3 Debris Identification

The binarized foreground image contains randomly distributed noise pixels, as depicted in Figure 3(c). Because the background subtraction is conducted in a pixel-wise manner, the labeling of foreground and background can be affected by camera noise, resulting in false foreground pixels. To deal with these noise pixels, we adopt the opening operation in image morphology. The opening operation, which consists of loss followed by enlargement, eliminates the noise pixels through loss while preserving the true foreground by enlargement. After the noise removal, we employ region growing to identify the debris objects from the foreground image. It uses the foreground pixels as the initial points and forms connected regions that represent the candidate debris objects by assimilating nearby foreground pixels.

4. IMPLEMENTATION

The robot is approximately 65 cm long, 50 cm wide (at the fins), and 13cm high. It is encased within an aluminum waterproof shell and displaces about 18 kg of water. The robot is powered by two onboard NiMH batteries providing over two hours of continuous operation. Camera, sensor and control signals are sent to a floating platform at the surface via fiber-optic tether. This information is used by the operator to control the robot via usage Bluetooth In this paper interfacing of all the sensors, DC motors, Bluetooth with Arduino (ATmema328) processor is explained. The interfacing diagram shown in fig.4.Ultrasonic sensor is used to calculate distance of obstacle from real position of robot. Accelerometer measures the three axial positions according to the movement or shaking of waves in water environment. Gas sensor MQ3 is used here to measure the amount of gases dissolve in water. If water body is contaminated with large number of harmful gases then gas sensor indicates its presence. The data collected by all the sensors are then sending to the smartphone via Bluetooth. The camera is interface with raspberry-pi. This makes the easy image processing with CV algorithm.

Real-time debris detection aims to extract debris objects from the taken images. It consists of three lightweight image processing modules, i.e., image registration, background subtraction, and debris identification, which can effectively deal with various environment and system dynamics such as shaking and internal noise of the camera. Specifically, first registers each frame by exploiting the unique features in aquatic environments, e.g., the coastline for inland waters and the horizon line for marine scenarios. Then, back- ground subtraction in HSV color space is performed on the registered frame to identify the foreground pixel candidates. Finally, the foreground is passed to debris identification for noise removal and debris recognition. At runtime, robotic fish minimizes the battery power consumption by determining if the above image processing tasks should be locally executed or entirely/partially offloaded to the cloud depending on the current network condition, e.g., the cellular network availability and link speed.

Coverage-based rotation scheduling is the completion of a monitoring round, smartphone based aquatic robot analyzes the debris coverage performance based on the estimated debris movement orientation and the surveillance history. It then adaptively configures the camera orientation and monitor time interval for the next round. Because of the limited energy supply and power- consuming movement in water environments, robotic fish must efficiently adjust its orientation while maintaining a desired level of debris coverage performance. To this end, we propose a scheduling algorithm that minimizes the rotation energy consumption in a round by dynamically configuring the rotation schedule, subject to a specified upper bound on miss coverage rate for debris arrivals.

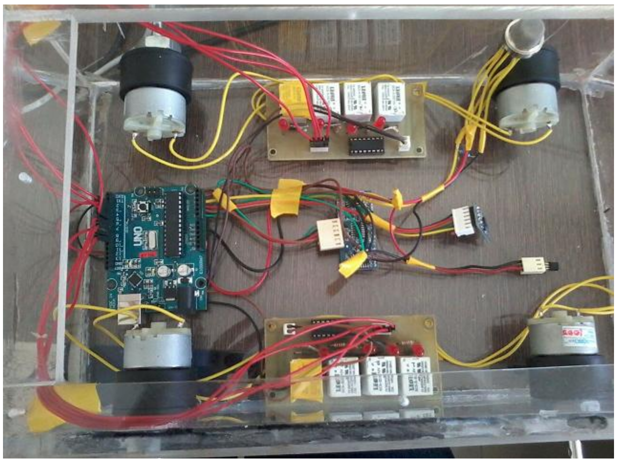

Fig 4: Implemented Hardware of Robotic Fish

The following diagram shows the flowchart of real time data monitoring by aquatic robot. The main purpose of ultrasonic sensor is to detect object in aquatic environment. If the object is detected then Accelerometer displays its XYZ co-ordinates. After confirmation of debris Microcontroller (ATmega328) decide movement (Left or Right) of robotic fish using DC Motors and display message "Remove aquatic waste".

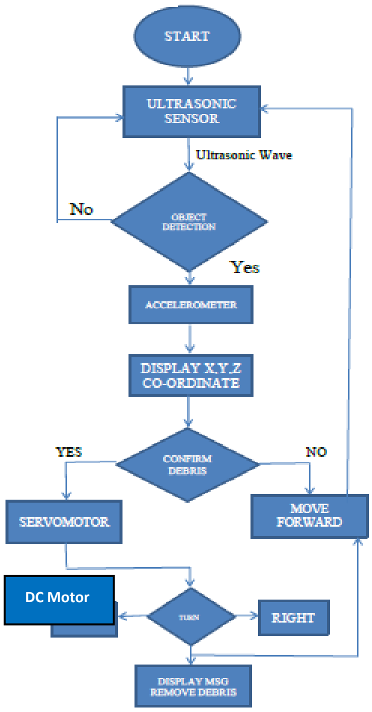

Fig 5: Flowchart Of Real Time Data Monitoring By Aquatic Robot

Fig.6 shows the simulation results of all the sensors implemented in hardware of aquatic robot.

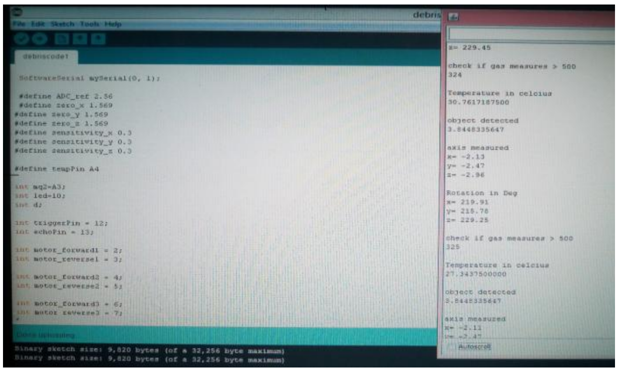

Fig 6: Simulation Result Of Implemented Hardware

5. CONCLUSION

This paper presents design of robotic fish for aquatic environment monitoring. The android smartphone is integrated with robotic fish to capture images and to acquire data of different sensors. The real time debris detection is done with the CV algorithm efficiently. In our future work, this can be extended to, use aquatic robot in an inland lake and evaluate it under various conditions such as debris flow speed and brightness/lightening.

6. ACKNOWLEDGMENTS

We take this opportunity to thank all the individuals for their guidance, help and timely support which made us to complete the research work in stipulated time. We also thank all teaching and non-teaching staff members for their patience and special consideration for the completion of our work. Lastly, we offer our regard for all those, in particular our parents and who supported us in any respect during this research work.

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