Volume 4, Issue 12, December 2014 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Smartphone Based Aquatic Environment Monitoring Robot with Optimal Battery Charging

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Abstract*— Aquatic debris monitoring is of great interest to the marine life, ecosystems, human health, and water transport. This paper presents the design and implementation of Smartphone based aquatic robot a vision-based surveillance robot system that integrates an off-the-shelf Android smartphone and a gliding robotic fish for debris monitoring. It features real-time debris detection and coverage-based rotation scheduling algorithms. The image processing algorithms for debris detection are specifically designed to address the unique challenges in aquatic environments. This paper also focuses on the design and construction of an optimization charging system for Li–Po batteries by means of tracked solar panels. Thus, the implementation of a complete energy management system applied to a robotic exploration vehicle is put forward. The rotation scheduling algorithm provides effective coverage of sporadic debris arrivals despite camera's limited angular view. Moreover, it is able to dynamically offload computation intensive processing tasks to the cloud for battery power conservation.

***Keywords*—Aquatic debris; smartphone; computer vision; object detection, Li–Po battery; robotic vehicle**

I. Introduction

Aquatic debris is nothing but the human-created waste found in water environments has emerged to be a grave environmental issue. The 2011 Japan tsunami released about one million tons of debris that heads toward North America, and some has drifted to U.S. West Coast . Inland waters also face severe threats from debris. Over 15 scenic lakes in New Jersey still suffer debris resulted from Hurricane Sandy after one year of cleaning. The debris fields pose numerous potential risks to aquatic ecosystems, marine life, human health, and water transport. For instance, the debris has led to a loss of up to 4 to 10 million crabs a year in Louisiana, and caused damages like propeller entanglement to 58% fishing boats in an Oregon port . It is thus imperative to monitor the debris arrivals and alarm the authorities to take preventive actions for the potential risks. For optimal battery charging paper introduces the concept of intelligent power management applied to the robotic vehicle. Which present the control of the battery-charging system by means of tracked solar panels, which is one of the aim of this paper [11].

Opportunistic spotting by beach-goers or fishermen is often the only viable solution for small-scale debris monitoring. However, this approach is labor-intensive and unreliable. An alternative approach is in situ visual survey by using patrol boats. However, it is costly and can only cover a limited period of time. More advanced methods involve remote sensing technologies, e.g., balloon-board camera and satellite imaging . The former is only effective for one-off and short-term monitoring of highly concentrated debris fields that have been already detected, and the latter often has high operational cost and falls short of monitoring resolution. Recently, autonomous underwater vehicles (AUVs) [14] have been used to for various underwater sensing tasks. However, AUV platforms often have high manufacturing costs (over $50,000 per unit). The limitations of these remote sensing and AUV-based approaches make them cost prohibitive for monitoring spatially and temporally scattered debris fields with small-sized objects. For instance, the debris from the 2011 Japan tsunami is expected to arrive dispersedly along U.S. West Coast over two years starting from spring of 2012 to late 2014 [1].

This paper presents Smartphone-based Aquatic Robot, a low-cost, vision-based surveillance robot system that integrates an off-the-shelf smartphone and a robotic fish platform. Various salient advantages of smartphone and gliding robotic fish make the integration of them a promising platform for debris monitoring. First, recent smartphones are powerful enough to execute advanced computer vision (CV) algorithms to process the images captured by the camera to detect debris objects [1]. Meanwhile, the price of smartphones has been dropping drastically in the last five years. Second, besides visual sensing, various built- in sensing modalities such as GPS and accelerometer can be used to facilitate the navigation and control of the robot and enable situation awareness to improve the debris detection performance. Third, the long-range communication capability (3G/4G) of smartphone makes it possible to leverage the cloud to increase robot's intelligence and reduce energy consumption by offloading intensive computation. Lastly, as a commercial off-the-shelf platform, smartphone provides an integrated sensing system and diverse system configurations, which can meet the requirements of a wide spectrum of embedded applications. Moreover, it offers user-friendly programming environments and extensive library support, which greatly accelerates the development process. The gliding robotic fish, which is a low- cost aquatic mobile platform with high maneuverability in rotation and orientation maintenance, provides robot the mobility to adapt to the dynamics of debris and water environments. Owing to these features, it represents an unprecedented vision-based, cloud- enabled, low-cost, yet intelligent aquatic mobile sensing platform for debris monitoring.

However, the design of Robot still faces several unique challenges associated with aquatic debris monitoring. First, due to the impact of waves, it cannot acquire a stable camera view, thereby making it highly difficult to reliably recognize the debris objects. A possible solution is image registration that aligns multiple images into a common coordinate system. However, water environments often lack detectable 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

This paper also explain the platform uses a control algorithm of maximum power point (MPP) aimed at maximizing system-supplied power for five PV modules designed as a cube. Finally, there are some noteworthy projects which main achievement is the optimal selection of solar energy and different power sources according to the operation conditions of a robot. A typical power management design consists of smart batteries integrating both communication devices and electronics able to control the charge. However, when an economical system is required, the concept of intelligence should be applied to software design for simple batteries

II. RELATED WORK

Yu Wang, Rui Tan etal presents SOAR a new vision-based robotic sensor system designed for aquatic debris monitoring. SOAR integrates an off-the-shelf Android smartphone and a gliding robotic fish. The vision-based debris detection algorithms of SOAR effectively deal with various dynamics such as camera shaking and reflection. A rotation scheduling algorithm adaptively guides the rotation of SOAR to capture the images of arriving debris objects. Moreover, SOAR dynamically offloads the entire/partial image processing to the cloud for energy conservation. Testbed experiments and extensive simulations based on a prototype system show that SOAR provides robust debris detection performance, meets the real-time requirement on smartphone platforms, and efficiently covers the sporadic debris arrivals [1].

Stuart A. Bowye et.al. proposes 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 anisotropically regulates the motion to provide assistance. The type of assistance offered by active constraints can vary ,but they are typically used to either guide the user along a task-specific pathway or limit the user to within a "safe" region. There are several diverse methods described within the literature for applying active constraints, and these are surveyed within this paper. The active constraint research is described and compared using a simple generalized framework, which consists of three primary processes: 1) constraint definition, 2) constraint evaluation, and 3) constraint enforcement. All relevant research approaches for each of these processes, found using search terms associated to "virtual fixture," "active constraint" and "motion constraint," are presented. [2]

CHEN Shi-Feng et.al. propose an algorithm combining the Meanshift algorithm with the bump characteristic of the ring contour to eliminate the mirror image effects and background interference. Eventually a bio-inspired Central Pattern Generator control method is adopted to smoothly drive the robotic fish to swim towards the ring. All proposed algorithms are implemented in real time with a hybrid control system consisting of two embedded microprocessors (TI DM3730 and STMicroelectronics STM32F407). Preliminary aquatic experiments demonstrate that a fairly good exploration effect is resulted and the interference caused by mirror image effect and background is largely eliminated. The proposed robotic fish-based scheme offers an alternative to cave exploration in complex aquatic environments.[3]

Chao Wang et.al. presents 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. Considering the pros and cons of the hill-climbing search and spiral coverage scanning algorithm, this paper provides C-SpiralHill algorithm and the simulation in A.B.KAPAYMEB model of water pollution diffusion was set up. The result proves that the new fusion algorithm could avoid getting trapped into local optimal point. On the basis of guaranteeing the high accuracy of searching and locating, the global search and location is guaranteed at the same time, and the energy efficiency is improved. If the robot-fish is applied to the investigation of pollution incidents in the reservoir based on the C-SpiralHill algorithm, it can locate the pollution sources quickly and report timely, and the water resources can be protected effectively. [4]

Ernesto Olgu´ın-D´ıazetal et.al. proposed a passivity-based model-free control scheme for an underwater fully actuated vehicle-manipulator system (UVMS) in contact tasks is proposed. Orthogonalized motion and force second-order sliding modes are enforced for all time for the re- dundant noninertial robotic UVMS, including when it is subject to a class of fluid disturbances and presented a passivity-based force–motion control scheme for redundant noninertial robots subject to hydrodynamic disturbances within the context of submarine missions. The control scheme does not depend explicitly on knowledge of the dynamic parameters of the system. The power transmission principle allowed us to formally introduce the conditions under which the Lagrangian UVMS preserves passivity during contact tasks when its end-effector is moving on a rigidly smooth surface. This result opens the possibility of applying a wide variety of passivity-based controllers. [5]

Mahdi Jadaliha et.al. presents a brief practical solution to the problem of monitoring an environmental process in a large region by a small number of robotic sensors. Optimal sampling strategies are developed, taking into account the quality of the estimated environmental field and the lifetime of the sensors also present experimental results for monitoring a temperature field of an outdoor swimming pool sampled by an autonomous aquatic surface robot. Simulation and experimental results are provided to validate the proposed scheme. [6]

Yuichiro Toda et.al. this paper proposes a localization method using multiresolution maps for the navigation of multiple mobile robots based on formation behaviours. The remote control of multiple mobile robots is one the most important tasks in robotics to realize distributed remote monitoring in unknown and/or dynamic environments. [7]

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. The developed system has autonomous navigation ability and the water quality monitoring capability. Sensors and related signal processing systems are integrated to the developed system for achieving its abilities. [8]

Steven Floyd et.al. describes the design and development of a novel robot,which attempts to emulate the basilisk lizard's ability to run on the surface of water. The design of a biomimetic robot utilizing similar principles is discussed, modeled, and prototyped. Functionally, the robot uses a pair of identical four bar mechanisms, with a 180◦ phase shift to achieve locomotion on the water's surface. Simulations for deter- mining robot lift and power requirements are presented [9]

C.W.Yuo et.al.propose study in designs a driving safety alert system that can detect dangerous driving behaviors using both front- and rear-facing cameras of a smartphone. [10]

Tom´as de J. Mateo Sanguino et.al. presents the design and construction of an optimization charging system for Li–Po batteries by means of tracked solar panels. Thus, the implementation of a complete energy management system applied to a robotic exploration vehicle is put forward. The proposed system was tested on the VANTER robotic platform—an autonomous unmanned exploration vehicle specialized in recognition. The interest of this robotic system lies in the design concept, based on a smart host microcontroller. [11]

Chamnan Ratsame presents an intelligent control method for the maximum power point tracking(MPPT) of a photovoltaic powered water pump system for long tailed boat in Thailand by using DC-DC boost converter as switching charger, this system consisted of a solar array, a switching battery charger based on boost DC-DC converter, a battery and small water pump.[12]

Ling-Feng Shi et.al. presents a mode-selectable synchronous buck DC–DC converter with high efficiency and low quiescent current is proposed, which is suitable particularly for use as an Li-ion battery charger. The high efficiency is obtained by applying dynamic power management technology under light load, which makes some modules of the chip enter into sleep state and the quiescent current of the whole chip down to 45 μA. At the same time, power metal–oxide semiconductor (MOS) devices are also shut down to decrease the dissipation of the system. A simple loop compensa- tion method is also proposed, which can eliminate the influence brought by the high equivalent resistance of the output's capacitor on the stability of the system loop. The converter has been made with a 0.5-μm complementary MOS process. Experimental results show that the peak efficiency is 94% at an output current of 100 mA when the supply voltage is 2.7 V. Moreover, the output voltage can recover within 14 μs at 400-mA load step. [26]

III. PROPOSED METHODOLOGY

Robotic unit is consisting of PIR sensor 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 internet. MAX232IC is used for communication between Microcontroller and Raspberry Pi(ARM Processor).

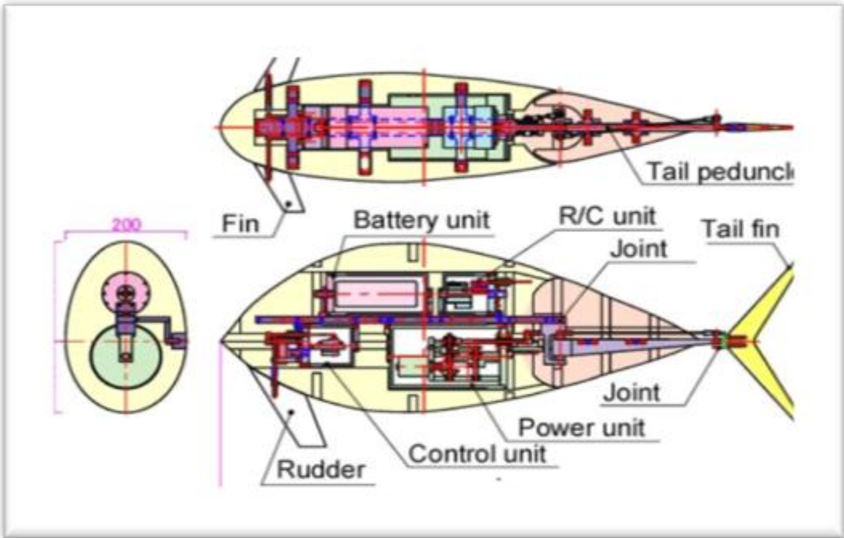

Fig1.Internal structure of robotic fish

Motor driving circuits are used for operating motors. The gliding robotic fish is capable of moving in water by beating its tail that is driven by a servo 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 ZigBee or GPS.

Batteries Switching System

The switching system consists of two MAX1538EVKIT selectors with break-before-make operation logic. Their function is connecting electrically the charge and discharge paths between the batteries, the charger module, and the load system (see Fig. 2). That is, selector 1 is inserted between the charger and the dual-battery pack. Its function is routing the current from the PV panels to the input of the charger and, from there, to the battery selected in each moment. Selector 2 is used to connect the selected battery to the load system. Therefore, the dynamic connections of the electric circuit are carried out according to the SHM-defined logical operation mode.

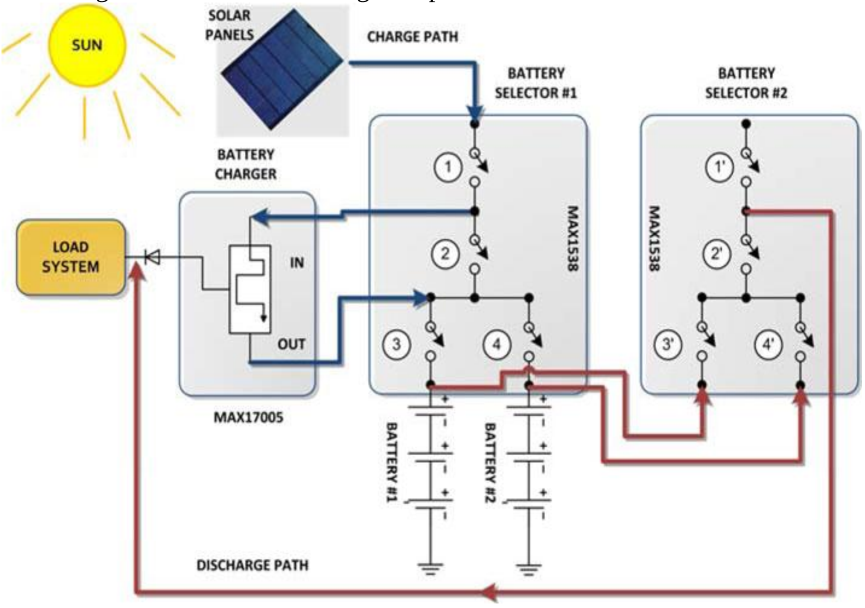

Fig2.Overall connection diagram for batteries selectors. The logical operation for charging and discharging modes is shown in Table I.

Table I Logical Operation Mode of the Battery Selectors

Battery Selector	1	2	3	4	1'	2'	3'	4'
#1 Charging & #2 Discharging	C	O	C	O	X	C	O	C
#1 Discharging & #2 Charging	C	O	O	C	X	C	C	O

C = Closed, O = Open, X = No Connected

Table I shows an example of battery selector operation. In the first row, selector 1 was programmed to charge battery 1 while selector 2 is preset to discharge battery 2. Charge current obtained from the PV panels is routed to the charger through selector 1 and, from the charger, to the selected battery. Likewise, the discharge current of battery 2 is routed to the load system through selector 2. The main advantage of the dual selector system is that it allows hot swapping of separated power supplies. In addition, in case both batteries were fully discharged, a working mode was programmed in selector 1 to supply the load system directly from the PV panels.

ACKNOWLEDGMENT

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 would like to sincerely thank our guides, Prof.Mrs.S.M.Ansari & Prof.Mr.S.V.Shelar for their significant support, guidance, inspiration and constant motivation during our studies. 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.

REFERENCES

[1] Yu Wang, Rui Tan, Guoliang Xing, Jianxun Wang, Xiaobo Tan, Xiaoming Liu, and Xiangmao Chang, "Aquatic Debris Monitoring Using Smartphone-Based Robotic Sensors" IEEE CONFERENCE PUBLICATION, APRIL 2014.

[2] Stuart A. Bowyer, Student Member, IEEE, Brian L. Davies, and Ferdinando Rodriguez y Baena, Member, "Active Constraints/Virtual Fixtures: A Survey," IEEE TRANSACTIONS ON ROBOTICS, VOL. 30, NO. 1, FEBRUARY 2014.

[3] CHEN Shi-Feng, YU Jun-Zhi, "Underwater Cave Search and Entry Using a Robotic Fish With Embedded Vision," Proceedings of the 33rd Chinese Control Conference July 2014.

[4] Chao Wang, Yaping Dai, "A Cruise Route Design of Robot-fish for the Pollution Source Location," Proceedings of the 33rd Chinese Control Conference July 2014.

[5] Ernesto Olgu´ın-D´ıaz, Member, IEEE, Gustavo Arechavaleta, Member, IEEE, Gerardo Jarqu´ın, and Vicente Parra-Vega, Member, IEEE, "A Passivity-Based Model-Free Force–Motion Control of Underwater Vehicle-Manipulator Systems" IEEE TRANSACTIONS ON ROBOTICS, VOL. 29, NO. 6, DECEMBER 2013.

[6] Mahdi Jadaliha and Jongeun Choi, "Environmental Monitoring Using Autonomous Aquatic Robots: Sampling Algorithms and Experiments", IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY, VOL. 21, NO. 3, MAY 2013.

[7] Yuichiro Toda, Student Member, IEEE, and Naoyuki Kubota, Member, IEEE, "Self-Localization Based on Multiresolution Map for Remote Control of Multiple Mobile Robots," IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 9, NO. 3, AUGUST 2013.

[8] Gi-Hun Yang and Youngsun Ryuh, "Design of High Speed Robotic Fish 'ICHTHUS VS.6'," 13th International Conference on Control, Automation and Systems Oct. 2013.

[9] Per Henrik Borgstrom, Brett L. Jordan, Bengt J. Borgstrom, Member, IEEE, Michael J. Stealey, Gaurav S. Sukhatme, Senior Member, IEEE, "NIMS-PL: A Cable-Driven Robot With Self-Calibration Capabilities," IEEE TRANSACTIONS ON ROBOTICS, VOL. 25, NO. 5, OCTOBER 2009.

[10] C.-W. You, N. D. Lane, F. Chen, R. Wang, Z. Chen, , T. J. Bao, Y. Cheng, M. Lin, L. Torresani, and A. T. Campbell, "CarSafe app: alerting drowsy and distracted drivers using dual cameras on smart- phones," in Proceedings of the 11th International Conference on Mobile Systems, Applications, and Services (MobiSys), 2013, pp. 13–26.

[11] Tom´as de J. Mateo Sanguino and Justo E. Gonz´alez Ramos, "Smart Host Microcontroller for Optimal Battery Charging in a Solar-Powered Robotic Vehicle," IEEE/ASME TRANSACTIONS ON MECHATRONICS, VOL. 18, NO. 3, JUNE 2013

[12] Chamnan Ratsame, "A New Switching charger for Photovoltaic Power System By Soft-Switching," 2012 12th International Conference on Control, Automation and Systems Oct. 17-21, 2012 in ICC, Jeju Island, Korea.

[13] T. Hao, R. Zhou, and G. Xing, "COBRA: color barcode streaming for smartphone systems," in Proceedings of the 10th International Conference on Mobile Systems, Applications, and Services (MobiSys), 2012, pp. 85–98.

[14] T. Mace, "At-sea detection of marine debris: overview of technologies, processes, issues, and options," Marine Pollution Bulletin, vol. 65, no. 1, pp. 23–27, 2012.

[15] M. Rahimi, R. Baer, O. I. Iroezi, J. C. Garcia, J. Warrior, D. Estrin, and M. Srivastava, "Cyclops: in situ image sensing and interpretation in wireless sensor networks," in Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems (SenSys), 2005, pp. 192–204.

[16] S. Richardson and P. J. Green, "On Bayesian analysis of mixtures with an unknown number of components," Journal of the Royal Statistical Society, vol. 59, no. 4, pp. 731–792, 1997.

[17] D. L. Rudnick, R. E. Davis, C. C. Eriksen, D. M. Fratantoni, and M. J. Perry, "Underwater gliders for ocean research," Marine Technology Society Journal, vol. 38, no. 2, pp. 73–84, 2004.

[18] Y. Shen, W. Hu, J. Liu, M. Yang, B. Wei, and C. T. Chou, "Efficient background subtraction for real-time tracking in embedded camera network," in Proceedings of the 10th International Conference on Embedded Networked Sensor Systems (SenSys), 2012, pp. 295–308.

[19] H. Solomon, Geometric Probability. Society for industrial and applied mathematics, 1978, vol. 28.

[20] C. Song, Z. Qu, N. Blumm, and A.-L. Baraba´si, "Limits of predictability in human mobility," Science, vol. 327, no. 5968, pp. 1018–1021, 2010.

[21] C. Stauffer and W. E. L. Grimson, "Adaptive background mixture models for real-time tracking," in Proceedings of the 13th IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 1999, pp. 246–252.

[22] R. Tan, H. Huo, J. Qian, and T. Fang, "Traffic video segmentation using adaptive-k gaussian mixture model," in Advances in Machine Vision, Image Processing, and Pattern Analysis, 2006, pp. 125–134.

[23] T. Gandhi and M. M. Trivedi, "Pedestrian protection systems: issues, survey, and challenges," IEEE Transactions on Intelligent Transporta- tion Systems, vol. 8, no. 3, pp. 413–430, 2007

[24] I. Vasilescu, K. Kotay, D. Rus, M. Dunbabin, and P. Corke, "Data collection, storage, and retrieval with an underwater sensor network," in Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems (SenSys), 2005, pp. 154–165.

[25] Steven Floyd, Student Member, IEEE,and Metin Sitti, Senior Member, IEEE, "Design and Development of the Lifting and Propulsion Mechanism for a Biologically Inspired Water Runner Robot," IEEE TRANSACTIONS ON ROBOTICS, VOL. 24, NO. 3, JUNE 2008.

[26] Ling-Feng Shi and Wei-Gang Jia, "Mode-Selectable High-Efficiency Low-Quiescent-Current Synchronous Buck DC–DC Converter," IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 61, NO. 5, MAY 2014.

