Research Intent (MSc Mixed Mode)

Dear TDIT,

I am interested to supervise the following student for his 30 credit research component in fulfillment of MSc by Mixed Mode at our faculty. The student and I have worked many hours in finding suitable topic and prepared a brief research proposal for you to review. The student shows dedication and strong interest and fully agree to accord to my guidance during his research undertakings. I have expectation that the student completes his work in due time (12-15 months). I hope to receive full consideration for acceptance of this research intent.

Thank you.

Best regards,



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Title: Lake Surface Cleaning Robot with Autonomous Navigation

**1 – Introduction**

Cleaning of the water surface is a prevalent issue in Malaysia and the world, one which threatens the functioning of lake, pond and reservoir ecosystems. According to recent estimates, over 8 million tons of plastic enter the oceans every year (Jambeck et al. 2015). Apart from plastic and foam scraps, accumulation of tree leaves, particularly in tropic countries, can block water drainage and cause pollutions. The cleaning water surface is, therefore, an essential routine task.

Surface cleaning robots on the lake, pond or reservoirs gained interests from researchers in recent times. In general, the robot design is usually boat-like base equipped with cleaning components, mainly waste collector and waste container, then, a system for motion control and navigation strategy. The autonomous working of the robot is one of the areas need more research on. Since most robots are used in a manual manner, developing robots that will work automatically, will help reduce the routine in the process of cleaning the surface of the water. With automation, power consumption becomes an important design issue when energy-hungry sensors are considered on board. Researchers also discussed strategy of waste removal in large area where waste is assumed to be randomly distributed but waste position is known. On the other hand, the problem of waste removal where waste position is unknown is lacking investigation.

There are many theoretical and practical considerations in designing an appropriate water surface cleaning robot. Some of the important aspect being highlighted in recent works include the following:

1.1 Robot structure

Regarding structure, the floating waste removal robot is commonly a boat-like robot with waste collecting mechanism. The body is usually made of plastic or metal. The robots come in different sizes. Medium around 1-2-meter length or small ones about 56 centimeter Solar-BreezeNX2 (Solar Breeze n.d.) Used for cleaning swimming pools. The size is important to accommodate large waste container so the robot can consider larger cleaning area. However, for the purpose of cleaning smaller water bodies such as swimming pool, the robot-boat should not be too wide to improve access to narrow corners. The frame usually looks like a catamaran boat. However, others look like a pontoon boat. The usual weight for a medium-size robot is 10 to 40kg, that what helps the robot to be stable and collect a good amount of rubbish.

1.2 Waste collector and waste container design

Normally, the waste-collecting structure consists of two parts, collector and container. Some designs have both parts separately and others have both parts together. Net-like designs are common for collecting and containing the garbage at pools. There are some robots that use a conveyor belt to pick up the waste and put them in the container. Other designs opted for a waste picking arm or paddle wheels and a rudder for collecting the garbage. Since having extra parts on a mid-sized robot adds more weight, budget and more power to run, the robot with a simple net attachment can collect more garbage, move faster and smoother.

1.3 Control system

The popular control system for water surface cleaning robot is Arduino. There is also preference for Node MCU. The use of Arduino or Node MCU can be limited due to its memory size and processing power. This is undesirable for AI-based applications for example object detection. Raspberry Pi could then be a better option for it has Linux based operating system and has more RAM and storage space. Raspberry Pi also supports Google’s TensorFlow AI framework. Other advantageous of Raspberry Pi over Arduino and Node MCU include better live video streaming over network.

1.4 Navigation Strategy

Cleaning water surface is a routine process due to the abundance of surface water on the earth, it requires enormous machinery and manpower. Developing surface cleaning robots that work autonomously is a trending area for research. The most common approach is to utilize obstacle avoidance. For example, Su et al. (2009) uses bank following algorithm with ultrasonic sensors for obstacle avoidance. Sinha et al. (2014) uses two-axis gimbals camera to track pollutants with the help of either JSV color space or SURF as an object detection system to detect garbage position. Sumroengrit & Ruangpayoongsak (2017) on the other hand proposed laser-based waste detection system. Sensor preference and combination plays a major role in deciding navigation strategy. For instance, laser can be useful to detect waste from 4 to 10 meter in distance. The camera, richer in terms of input description, can detect in shorter distances. This means different combination of sensors can give different capacities to the robot. Therefore, having a navigation strategy that makes the robot more robust is a gap in water surface cleaning robot research. Technology such as sub-centimeter accurate GPS can also compliment robust navigation.

1.5 Power

The usual option for power is using batteries or, solar panels with batteries to power up the robot. Using solar panels raises the cost, however using a small solar panel might keep the cost low and be a good alternative for the battery charger. The solar system potentially make the robot less dependent and more autonomous. Using batteries to move a 10 to 20kg robot requires a powerful one. Lithium-ion batteries are more efficient than other kinds of batteries (Sears Auto n.d.), however, it is costly. Another potential option that is cheaper is lead-acid batteries. Though heavier, lead-acid weight can provide additional support to robot’s stability in the water, where payload is not an issue.

1.6 Waste removal strategy

There are also designs which consider waste detection using vision. In this type of design, a camera is fitted on the robot boat which oversees 180-degree view in front of the robot. The object detection algorithm is used to detect waste. Once the waste is detected and position of waste estimated, the target is locked, and the robot will move towards waste for collection. There is design using laser sensor that draws a 3D model of the surrounded area for detecting waste, or, tactile sensor (Agrawal & Bhattacharya, 2013). Using sensors are great for waste removal if the waste location is already known but for unknown areas, GPS system is a recommended addition for better waste removal performance.

With the health of water bodies deteriorating due to floating waste, the routine task to clean water surface becomes interesting with the application of robotics. In this proposal, I am interested to design a suitable floating waste removal robot for use at lake, pond or reservoirs. In my design, I will consider theoretical and practical considerations which cover robot structure, material, capacity of waste collector and container, waste collection technique as well as the robot navigation strategies for optimal floating waste removal.

**2 – Brief Literature Review**

For cleaning water surface many methods have been used since the pollution is coming from different sources. Some research has focused on cleaning algal and they designed robot specifically for that problem Jung et al. (2017) since it is a real issue in some countries. However, this section describes recent works in surface cleaning robot for lake, pond and water reservoirs.

Capturing waste on water surface and trap it, is a Strategy proposed by Dahlan et al. (2019) and Abrams (2018). Net is useful for waste capturing, with Dahlan et al. (2019) preferring nylon net for it is cheap in price and easy to replace while Abrams (2018) opted for metal net. Their robots were made from PVC pipes in similar shape to a catamaran boat. Dahlan et al. (2019) showed tele-operated robot controlled by user with additional function like water purification system. The system used two-stage filtering units. The first stage is a sediment filter which filters the contamination that can be seen by the naked eyes. The second stage is a carbon filter which remove heavy iron contained inside. In Abrams (2018), the robot can be remotely accessed through web-game-like website that allows contribution from any user in cleaning the water. In both designs, battery is used to power up the vehicle.

Sumroengrit & Ruangpayoongsak (2017) and Ruangpayoongsak et al. (2017) designed two paddle wheels and a rudder for movement for cleaning on calm water surface such as city canal, lake, pond, and pool. Both waste collection designs showed similarity in using two scoopers, one in the middle and another in the front, with a waste container in the center. Laser sensors is used for detecting garbage and the GPS, IMU and Tile sensors are also utilized. Ruangpayoongsak et al. (2017) upgraded the robot with a teleoperated camera.

The Blue Growth (yyyy) is a waste collection robot equipped with additional sensors that allows it to sense water temperature, pH, conductivity, Oxidation-Reduction Potential, and depth. Blue Growth weighs 39kg and is 1.5m in length. It is rectangular in shape that follows waste and contain them in the middle part of the robot’s body. The IADYS (yyyy) is another example of waste collection robot that is half in size and weight to the Blue Growth. However, the IADYS does not have the sampling sensing capacity. In terms of shape, the IADYS is square shape and similar to a catamaran boat. The IADYS has a cargo net on the back. The cargo net was able to capture and contain the waste. Both the Blue Growth and IADYS are remote-controlled. However, the Blue Growth has a level 1 automation that could find its way back from the harbor basin to a docking station, where it could deposit the collected trash and re-charge its batteries.

Sinha et al. (2014) proposed another design that used robotic arm and object detection with a camera, to detect and collect waste. The structure consisted of a twin-hull boat structure with two methods of propulsion. With extra two underwater propulsions they claimed that their design achieved very precise turning while the boat was stationary on water. The robot is able to pick up solid waste with two degree of freedom robotic arm and a gear operated mechanical gripper. In terms of power, solar panel with batteries are selected to power up the robot.

Conveyor belt is a popular mechanism for water surface waste collection robot (Rafique & Langde, 2017; Wang et al., 2008; Agrawal & Bhattacharya, 2013; Se et al., 2009). The conveyor belt is commonly placed at the front side of the robot with a collector at the back. Rafique & Langde (2017) proposed an RF radio to control the robot remotely. Wang et al. (2008) proposed obstacle detection on the robot block diagram that allows switching ‘on’ and ‘off’ of the conveyor belt automatically. Agrawal & Bhattacharya (2013) proposed tactile sensors for waste detection because it has been noted that majority of the range finding sensors such as the ultrasonic, infrared and etc. that work well on land are either unusable in water bodies or are unable to differentiate between hard rocks and leaves. Su et al. (2009) used a motion control strategy based on ultrasonic distance measurement. By analyzing the distribution characteristics of the floating waste on lakes, a method for cleaning up floating waste round the bank of the lake has been proposed. Su et al. (2009) also utilize two ultrasonic ranging system to obtain the positioning and the orientation of the cleaning robot for path planning.

**3 - Methodology**

Here are three (3) objectives for the proposed work:

1. To study appropriate discriminators in designing high performing robot for efficient surface water cleaning
2. To test the performance of the proposed prototype in real-time
3. To evaluate and compare the performance of the proposed prototype with existing solutions

Here are the proposed SMART objectives for the proposed work:

S - Specific, significant, stretching

M - Measurable, meaningful, motivational

A - Agreed upon, attainable, achievable, acceptable, action-oriented

R - Realistic, relevant, reasonable, rewarding, results-oriented

T - Time-based, time-bound, timely, tangible, trackable

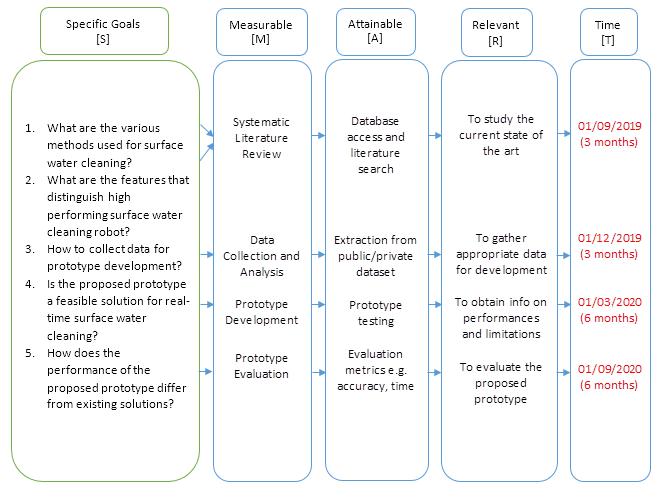


Fig. 1: The SMART objectives

Fig. 1 shows the mapping of research methodology. I will begin with a literature search and systematic review to identify discriminators before performing a conceptual design of the proposed prototype. I then perform prototype simulation. Once the desired parameters are confirmed, I will buy parts for the assembly. System integration is next followed by testing at the Tasik Varsity, UM and nearby lake in Petaling Jaya. I will compare results taken by prototype against existing works to see the performance of proposed prototype. Finally, I will write report and prepare manuscript for journal publication.

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