INNOVATION IN WATER SINGAPORE

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Water 4.0

Riding the digital wave in water research

Creating an Internet-of-Things for water monitoring through new smart water and adaptive technologies

Developing robotic intelligence and cost-effective sensors for big data collection on water quality

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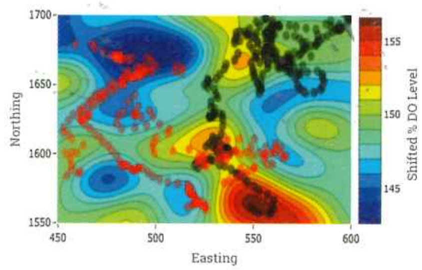
Water utilities need a good understanding of the environmental processes in freshwater bodies, such as reservoirs, in order to manage them efficiently. However, a common problem in environmental monitoring is that water bodies change over time, sometimes quickly, limiting the size of the area that can be surveyed accurately before the field changes significantly. These monitoring efforts are also labour and resource intensive.

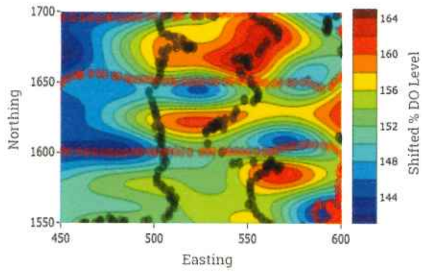
Hence, PUB collaborated with the National University of Singapore's (NUS) Environmental Research Institute (NERI) and Tropical Marine Science Institute (TMSI) in 2014 to fund the development of NUSwan (New Smart Water Assessment Network) - a fleet of cost-efficient and highly versatile robots that continuously monitor the water in our reservoirs. (Figure 1).

Figure 1. NUSwans in Pandan Reservoir, Singapore. Photo Credits: Jack Board, Channel News Asia.

Moving forward, NUS is now developing adaptive sampling algorithms that will improve accuracy of the spatial estimates using minimal survey time. It is also embarking on a joint project with commercial partners to put together a cost-effective sensor package that will make it economically viable to deploy a large number of nodes to collect big data on water quality.



a) Predicted field from data collected along the path planned adaptively. Time taken 1200s, Root Mean Square Error=3.9.



b) Predicted field from data collected along the standard lawnmower path. Time taken 1256s, Root Mean Square Error=6.6.

Figure 2: Comparisons on the performance of spatial estimations using data from the lawnmower and adaptive sampling path show the improved performance from the adaptive path. The RMSE is calculated using the independent data collected on the robots' return paths and its spatial estimates, assuming the field does not change during the period.

As planning the deployment of both mobile and static sensors to collect data efficiently and comprehensively is no trivial matter, NUS is working with Subnero Pte Ltd to create a web-based decision support system that will enable the scaleable collection, management and visualisation of data from the sensors.

NUS is testing Sparse Gaussian Processes (SGP) for field estimation and path planning to coordinate the NUSwan robots. With the adaptive sampling algorithms, the fleet will become smarter in planning sampling routes and collect more useful data. In preliminary field tests, the new algorithms provided reasonable improvements against standard lawnmower missions (Figure 2). The ongoing project will continue to improve and validate the algorithms' performance.

Furthermore, since each NUSwan robot can carry only one water sample, NUS is developing another algorithm with PUB's support, called Sampling and Adaptive Monitoring (SAM), which uses SGP to estimate the field and decision-making frameworks to determine the best sampling location.

The ongoing project will also extend NUSwan's existing web-based interactive mission control capability to include a scalable framework to support new robotic behaviours as well as interfaces for external data analytic modules and environmental models. This addition will allow for more integrated operation of PUB's assets to facilitate better decision-making.

If successful, the research partnership between NUS, PUB and Subnero will improve the accuracy and efficiency of spatiotemporal monitoring. It would also make it economically feasible to deploy a large number of water quality sensors, enhance the NUSwan's operational simplicity and improve the robots' sensing intelligence.

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