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Automated Design of a Low-Cost Marine Sensor Network

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The Tasmanian Marine Analysis Network (TasMAN) project has focused on the development of low-cost sensor nodes [1] and the next stage is to develop techniques for deploying low-cost sensor networks. We are aiming towards a sensor network design method that is automated, scalable, efficient, relocatable, reproducible and cost efficient. We have identified contributing costs and benefits, and have developed methods for quantifying them.

The relevant costs we have identified costs are: maintenance, equipment, exposure, negotiation and communication. The benefits: interest to stakeholders, coverage and reduction in overall error. The costs and benefits for each potential location are then combined to give a cost versus benefit score. The location with the highest score is added and then the benefits are recalculated before we attempt to add another.

Sensors require regular maintenance and calibration. In marine sensor networks, this may need to be as often as monthly because of biofouling. In the case of our marine sensor network, we have the cost of boat hire; including fuel and crew. To quantify this, we use the distance by sea. At other locations it will be more efficient to drive to the water's edge and either launch a boat from there, or, in some cases, we may be able to reach the sensor from a jetty. We quantify this by the distance by land, which includes the distance to the nearest boat ramp. If we manufacture identical sensor nodes for each location than this will save on equipment costs. However, each time we have to customise a node this will incur costs in staff time and any additional parts. In TasMAN, we require greater than three metres of water to immerse the standard sensor string, so locations with less than three metres of depth are given a higher cost. There are some locations that will have increased risk of damaging, losing or destroying the sensor nodes. To derive a measure of exposure, we average the current velocity over nine months of hydrodynamic model data [2] for each of the potential locations. There are also locations that will attribute greater staff time costs through negotiations with authorities. The TasMAN project is required to keep the sensor nodes out of shipping channels and high traffic areas to limit the impact on mariners. We generate the shipping channels using the shortest path between boat ramps. In more compact sensor networks, we may be able to reduce costs by communicating between nodes via radio and only use communications that incur costs, such as satellite or mobile telephone, from one node. There are existing techniques for designing networks for efficient communication and these could be integrated at this stage.

In some locations the additional cost will be worthwhile when it produces significant scientific gain. Stakeholders (including marine scientists, government agencies and industry) highlight areas of high interest using a collaborative map. If the potential locations falls within one of these areas, this will increase the location's benefit score. The reduction in error and the coverage are calculated using temperature and salinity output from a hydrodynamic model [2]. We look at the difference in overall error after a node is placed at that location. The coverage is a footprint of influence of potential location; the number of grid points not yet covered that have a correlation with the potential location below a given threshold.

We have compared this technique to randomly and spatially distributed sensor node placement. The results suggest that using this automated cost-benefit analysis we can maintain equivalently accurate representation of an area whilst dramatically reducing the financial costs involved.

[1] Paulo A De Souza Jr, Greg Timms, Andrew Davie, Ben Howell, and Stephen Giugni, "Marine Monitoring using Fixed and Mobile Sensor Nodes", in IEEE Oceans, 2010, pp. 1–4.
[2] M Herzfeld, J Andrewartha, and P Sakov, "Modelling the physical oceanography of the D'Entrecasteaux Channel and the Huon Estuary, south-eastern Tasmania", Marine and Freshwater Research, vol. 61, no. 1996, pp. 568–586, 2010.