PADI proposal

Needs: stated goals, plan for accomplishment, my credentials. (budget goes in a separate document)

Title: Development of an inexpensive echosounder for bathymetry measurements in coastal waters

Seafloor mapping with high spatial and temporal resolution is integral to understanding a hydrologic system. For instance, in coastal environments these measurements can show how sediment responds to high flow and wave conditions during storm events, which are important to predict the effects of storms on shoreline evolution. To obtain bathymetry data, instrumentation is needed that can collect a bathymetric record over a wide area during high wave conditions. Conventional methods of measuring bathymetry use stationary, towed, or autonomous sonar imaging devices which are capable of collecting data with high temporal resolution, albeit with a relatively small spatial footprint. Unfortunately, these instruments are expensive (at a cost greater than $6000 per device), and the risk of damaging or losing the device prohibits use in storm events. In addition, these devices are too expensive to deploy as an array in numbers sufficient to measure a wide area.

The objective of this project is to develop a low-cost bathymetric echosounder array for use in the nearshore through storm events. The prototype array will consist of twelve devices, each of which will cost less than $600, compared to the $6000 cost of a typical commercial sonar instrument. The planned approach consists of modifying off-the-shelf ultrasonic fish finders and depth finders (inexpensive instruments frequently used in the sport fishing hobby) in order to add the ability to log bathymetric measurements with sufficiently high temporal resolution. In collaboration with Delft University of Technology (TU Delft) in the Netherlands, the prototype devices will be thoroughly tested for mechanical, electrical, and waterproof durability to ensure that the devices can operate effectively within the harsh conditions of a storm event. Finally, the prototype devices will be deployed as a stationary array off the coast of the Netherlands, again in collaboration with TU Delft.

The cost of fish finders spans a range from $75 to over $700; however, the features required for construction of the sensor are common to devices at all price points. Thus, development of the prototype will begin with devices at the bottom of the price range. Three main approaches to modification will be explored: 1) Directly interfacing with the fish finder microcontroller to pull depth data (followed by logging the data using an external microcontroller equipped with storage), 2) Using only the sonar transmit and receive hardware of the fish finder (and then using an external microcontroller to process the signal and store the data), and 3) Using an external microcontroller to emulate keypresses and read the display of the fish finder (followed by using the same microcontroller to parse display signals and then log the data). Most likely, a successful approach will involve a combination of these strategies. Each potential design will be functionally tested and then calibrated for offset and range against a conventional sonar instrument provided by TU Delft’s Section of Hydraulic Engineering.

Once a working assembly has been developed, a waterproof and mechanical shockproof enclosure will be either fabricated or purchased and modified to field-harden the device. Power will be delivered to the device through a solar panel, battery, and power management system integrated with the enclosure. The device will undergo rigorous testing using TU Delft facilities (submersion tanks, testing pools, etc.) to ensure waterproofness, mechanical strength, and durability.

Finally, the devices will be deployed at a TU Delft nearshore field site, in a linear array with five meter spacing at four to ten meter depth. After each storm event, the data will be retrieved from the array and analyzed to develop time-resolved bathymetric maps.

The timeline for the project will involve developing the prototypes during the fall and winter of 2018, followed by testing in spring 2019, and finally deployment in summer 2019.

The design, fabrication, and calibration work will be carried out by me, Keiran Cantilina. I am currently finishing an MS in Bioproducts and Biosystems Engineering (concentration in Instrumentation) at the University of Minnesota. I have substantial experience conducting research across multiple disciplines, and I have been designing low-cost hydrological instrumentation for the last two years. I also speak and write Dutch at a basic level, and so am well-prepared to work with my collaborators at TU Delft. Please see my CV and project portfolio attached to this application for my full credentials.

Outline:

Intro: Background and objectives

* Bathymetry is important because
  + Sediment transport
  + Understanding/predicting storm events
* How things are normally done
  + Sonar instruments
    - Submerged stationary
    - Floating mobile
* Existing sensors are expensive
  + $6000 and up
* What we want to do
  + In collaboration with TU Delft
  + Look at wide area along the Netherlands coast
  + Storm events
* What we need
  + Arrays of sensors
  + Need to be cheap
    - To make a lot of them
    - To not be sad when they float into the sea never to be seen again
  + Acquire and log data without operator

Methodology

* Development of the instrument
  + Starting point is off the shelf fishfinders and depth finders
    - Cost ranges between $200 and up
    - A range of price points will be tried, starting with the cheapest
  + Fish finders will be modified; 3 approaches will be tried (in this order)
    - Directly interfacing with the device microcontroller to pull depth data, then log using external microcontroller with rtc and sd card
    - Hijack fishfinder transmit and receive hardware, but ignore device microcontroller and use own microcontroller to process signal, timestamp, and log
    - Use external microcontroller to control keypresses and read display, parsing display signals to get data, then logging
    - The successful approach might be some combination of these
  + Once working assembly is developed, waterproofing and enclosure design
    - Must be submergible, shockproof, etc.
  + Power budget?
  + Fabrication and modification work would be done by us, but using space allocated to us by TU Delft
* Testing/Deployment
  + Testing
    - Submersion testing in tanks at TU Delft
    - Functional testing in tanks
    - Adjustment of design
    - Compare to commercial model (borrowed from TU Delft section of hydraulic engineering)
    - Rinse and Repeat
    - Once optimized design is done, make more: Goal is
  + Deployment
    - Sensors will be deployed on fixed posts just off the shore, in 4-10 m water depth
    - Sensors will be deployed in a linear array parallel to the shoreline over a distance depending on the number of sensors.
      * Spacing: 5 meters apart
      * Location of each sensor will be recorded during deployment using handheld gps
  + Data analysis/collection
    - Data will be collected after about a week
    - Each data point will be timestamped and correlated to the coordinates of the sensor
    - Data points can be processed to develop time-resolved bathymetric maps

Budget

* Travel expenses
  + Flying there and back: $2000
  + Car rental: $1000
  + Misc. transit: $1000
* Material costs
  + Fishfinders: $4000
  + Microcontrollers, parts, supplies, etc.: $500
  + SD cards and loggers: $200
  + Deployment equipment
    - Solar panels: $1300
    - Charge controllers: $500
    - Enclosures: $200
    - Batteries: $1000
* Equipment costs
  + Digital Oscilloscope and logic analyzer: $700
  + High accuracy GPS unit: $500
  + Soldering station: $200
  + Multimeter: $300
  + Signal generator: $300
* Installation costs
  + Batteries: $1000
  + Sensor mounting post installation: $2000
* Testing costs: $3800
  + Pool testing
  + Mechanical stress testing
  + Electrical testing

My credentials

* Lots of experience with research
* Hydrology experience
* Experience building things (see portfolio)
* Masters relating to hydrological instrumentation