Diver dead reckoning system overview

Need:

A SCUBA diver would like to know his/her position underwater, relative to the dive start position. This requires a gyro system optimised for underwater use, utilising low cost hardware sensor inputs. GPS is not an option as the signals do not travel underwater. Transponder/pinger systems have already been developed, but require too much expense and configuration for the boat operator and the diver.

A simple standalone affordable dead-reckoning system is needed, but is inherently tricky to determine the diver's movements.

The system needs to be very cheap, so that price is not a barrier to its deployment.
The system needs to be small.

The hardware available include:

1. Depth transducer - 0.1m accuracy
2. Compass 1degreee accuracy
3. 3-axis $5 accelerometer - ie a cheap entry level device - 0.01g accuracy? See data sheets of typical devices.
4. Time resolution available: better than 1micro second if needed

These items are easily affordable. They can be installed on the diver, probably on the back adjacent to the gas tanks.

Problem:

Given the inherent uncertainty of:

1. tides and current
2. detection of movement in non depth related dimensions
3. subtle diver movement

what 3D accuracy can be obtained with currently affordable hardware?

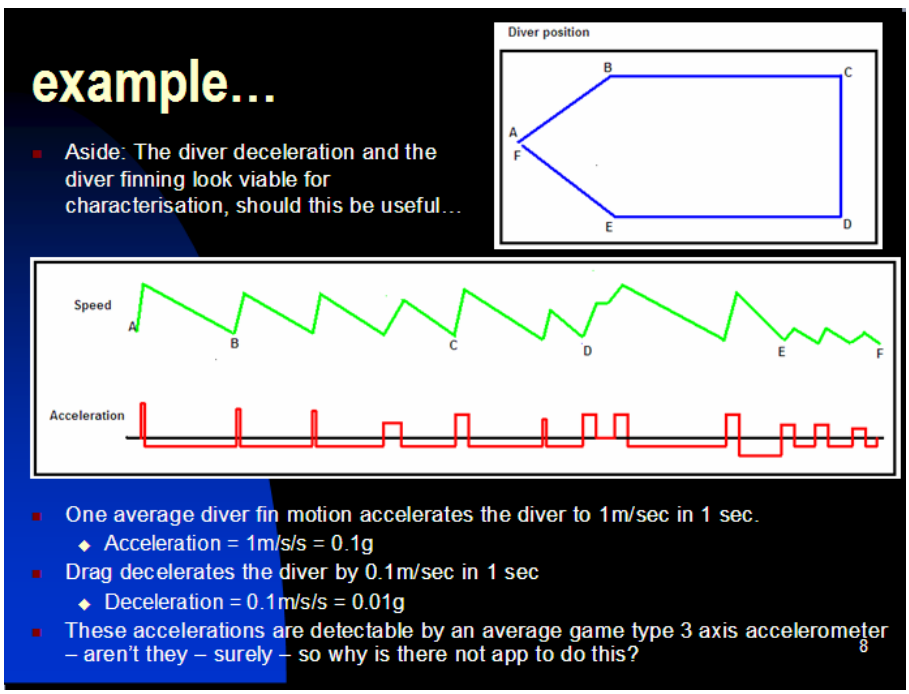
The diver swims with very subtle movement, and is subject to local changes in tide / current.

Kalman type filters would help achieve more certainty as to the position of the diver given a range of 3D inputs.

Depth can be measured very accurately using an ambient pressure sensor. Can this help determine, in conjunction with a compass, exactly how much the 3 axis acceleration components are acting in the non-depth directions?

What further mathematical techniques (rather than hardware) can be used to enhance the quality of the diver's position information given the specific modest quality of the hardware sensor data.

Are there any other characteristics of diver motion that could be used to obtain more certainty as to position? (Surface walking systems have used the 'detection' of steps in-conjunction with Kalman filters to produce a viable system for probable location what GPS is not available, eg in forests/jungle)



Practical deployment

To get the best out of the sensor input available, there is some practical deployment of equipment that has already been considered:

The 3 axis accelerometer and compass can be fitted to a fixed part of the diver, eg the air tank on the back of the diver. This back mounted system would also include a depth sensor, and all mathematical processing can be achieved in this fixed module. A wireless link can then display this data on a display on the diver's wrist. This configuration would reduce unwanted input from simple hand movements etc.

Thinking back over the problem as it has occurred to me over the last few years, there are methods that could get over some of the simple issues, but can the fundamental accuracy of 3 axis accelerometers at the entry level, give enough resolution.

I have used a 3 axis accelerometer in the product already, to give me some simple tilt options. These cost in the order of $5.

The practical issue for us is also making the unit cheap enough. So, non-perfect sensors are sort of part of the requirement. Just how much accuracy is needed to make a viable device? How much can clever signal processing maths improve the situation? To be commercially viable, the unit needs to be almost configuration free, cheap, and simple to use. You can buy one without the need to have extra equipment installed on the boat etc, as per current diver positioning systems.

Mathematical techniques

Given the cost and size limitations of the device, can the relative cheap cost of mathematical processing in modern micro-controllers, achieve clever processing of the available information and produce a viable diver dead reckoning navigation device?

1. What mathematical techniques would be best adopted to achieve maximum performance from simple accelerometer and depth sensors, given the complex underwater issues of tides/currents, human diving/finning techniques and other variables typical to underwater diving?

2. Depth can be measured very accurately using an ambient pressure sensor. Can this help determine, in conjunction with a compass, exactly how much of the 3 axis acceleration components are acting in the non-depth directions?

3. Given the best use of mathematical techniques, what sensitivity and time resolution would be required to give diving position with 1 metre using the simple sensor system?

4. Given the best use of mathematical techniques, what diver position accuracy could be expected from current sensor quality easily and cheaply available in the market place?

5. Are there any other characteristics of diver motion that could be used to obtain more certainty as to position? Surface walking systems have used the 'detection' of steps in-conjunction with Kalman filters to produce a viable system for probable location what GPS is not available, eg in forests/jungle.

Study group – practical aim

As a practical focus for the study group, can a modest land based solution be implemented in an android app by the end of the study group period. As accelerometers and compasses are standard in so many mo dels of phone/tablet, this would make a perfect test platform form some code.