USING ULTRASONIC SONAR RANGERS: SOME PRACTICAL PROBLEMS AND HOW TO OVERCOME THEM

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Ultrasonic sonar rangers are ubiquitous in microcomputer-based measurement systems used in student mechanics laboratories and lecture demonstrations.

Ultrasonic rangers work by measuring the round-trip flight time of a reflected ultrasonic pulse train from a transducer to an object whose motion is monitored. Given the speed of sound in air, distance between the sensor and the object is calculated, and velocity, acceleration and net force transducer are inferred from distance data (1).

In practice, when using an ultrasonic ranger system, one is often faced with various kinds of difficulties. The most common problems encountered are:

- Measurement range appears narrower than expected.
- Data is more or less noisy, especially for velocity and acceleration.
- Data is grossly erratic.

Reasons for these errors, and ways to overcome them, are discussed below.

The blind spot and multiple reflections

The same transducer is used both for sending and receiving the ultrasonic signal. After sending the pulse train, the transducer foil must stop "ringing" before it can receive the returning signal. This problem is solved by not turning on the receiving circuitry until a delay interval has passed. This means that the ranger can not detect an object whose distance from the sensor is less than half the distance that sound travels during the delay interval. For the original Polaroid ranger, the "blind spot" is 40,5 cm. For a modernized version, it has been reduced to 15 cm.

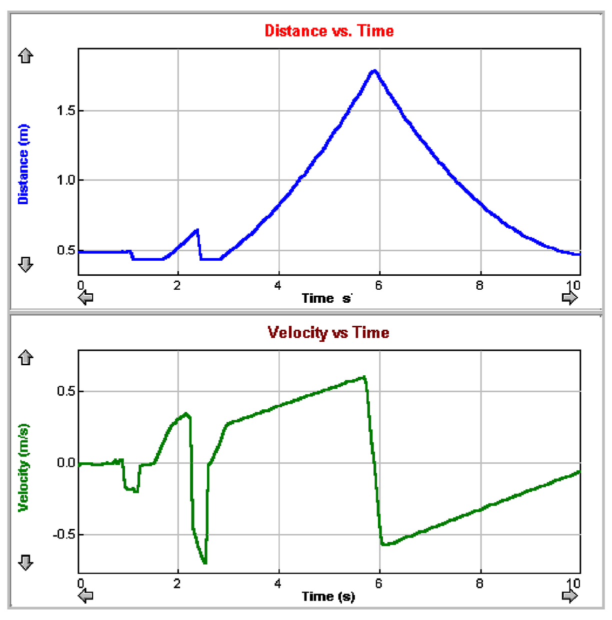
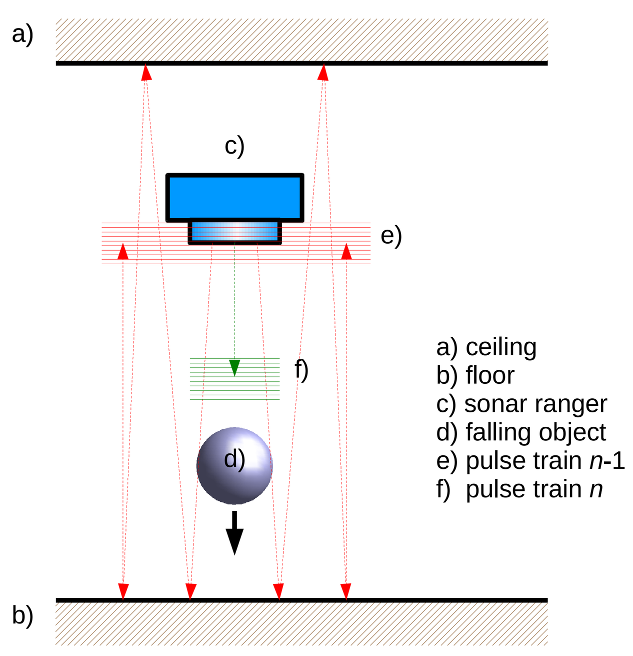


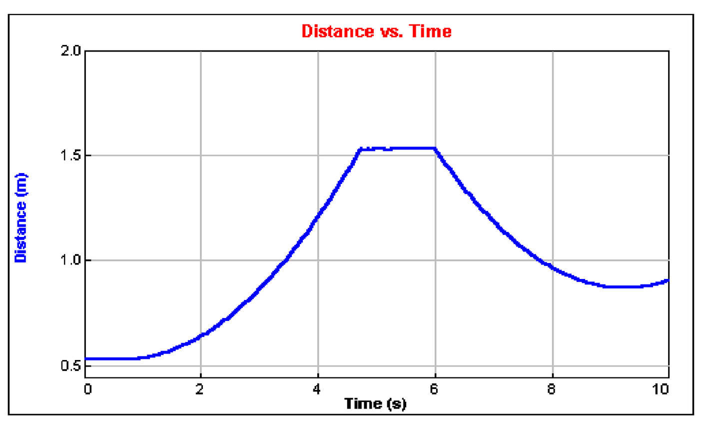
Figure shows uniformly accelerated motion of a reflector equipped PASCO glider on an air track. The glider was launched from within the blind spot, 20 cm from the sensor. Sensor data from 0.0 s - 0.3 s are distorted by the blind spot. In this plot, from 1.7 s - 2.3 s the sensor falsely reports distances that are exactly twice the actual separation between the sensor and the reflector due to a multiple reflection. In this region, the ultrasonic pulses reflect both from the reflector and the sensor, and travel the range distance four times before detection. Discontinuities in position plots result in the calculation of erratic velocity and acceleration data.

Multiple refection situations most commonly occur when measuring vertical free fall (measuring *g* or air resistance), when pulses bounce between floor and ceiling, or with an air track set up in a small room close and perpendicular to smooth walls. If pulse bouncing between surfaces is suspected, try the following:

- move the sensor and the object closer together
- move the sensor along the line of measurement
- relocate the line of measurement so that it is not perpendicular to the reflecting planes
- alter the data rate
- cover the surfaces with sound-absorbing cloth or other material



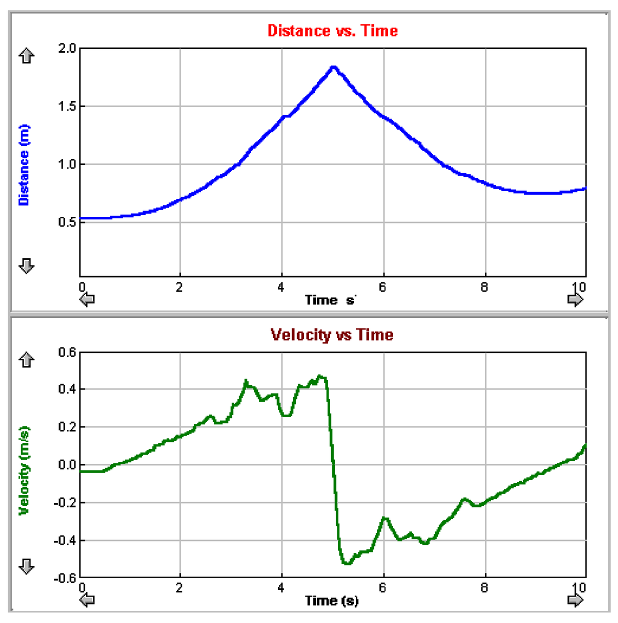
Obstructions and unwanted reflections



The sonar sensor detects the position of the first object that provides a reflection intense enough to trigger the receiver circuitry. If there is an obstacle within the cone of detection that is nearer the sensor than the moving object, then the sensor sees the obstacle, not the moving object. The result is that the sensor seems not to be able to measure beyond a certain distance. To correct this problem, clear unwanted objects from the beam, which is ca. 30º wide. Sometimes it is also possible to aim the ranger to exclude fixed obstructions from the cone of detection. Figure shows the effect of an air track support obstructing a sonar ranger just beyond 1.5 m.

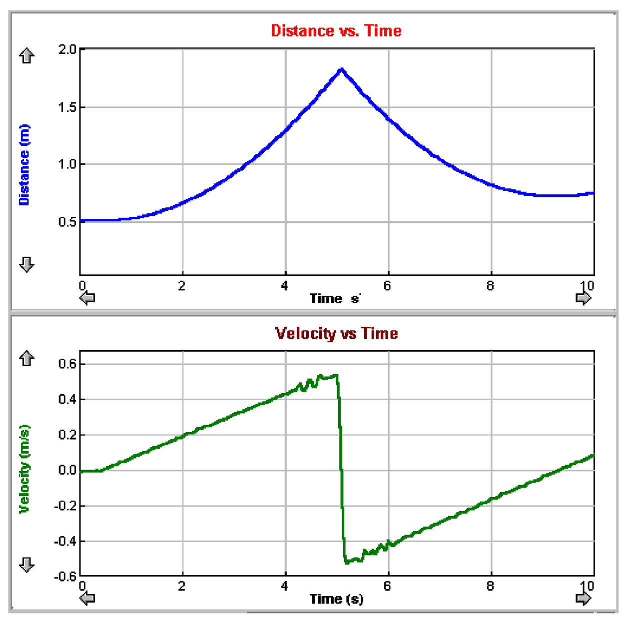
Getting a clear, consistent reflection

Frequently the target object does not produce a consistently clear, strong reflection from a single area. Objects that rotate, flutter or tilt as they move will provide reflections from different areas, yielding false data for the center of mass motion. A solution is to use a spherically symmetrical object for obtaining such data. Adding a 'sail' or 'flag' reflector to the transducer-facing end of an air track glider or wheeled cart greatly improves return signals, as shown below.

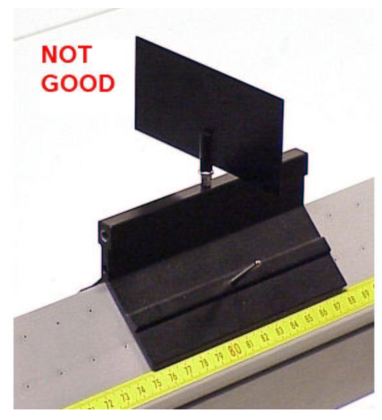


Left: distance and velocity data of an air track glider without a reflector.

Right: distance and velocity data of the same glider with a 5x6 cm reflector.

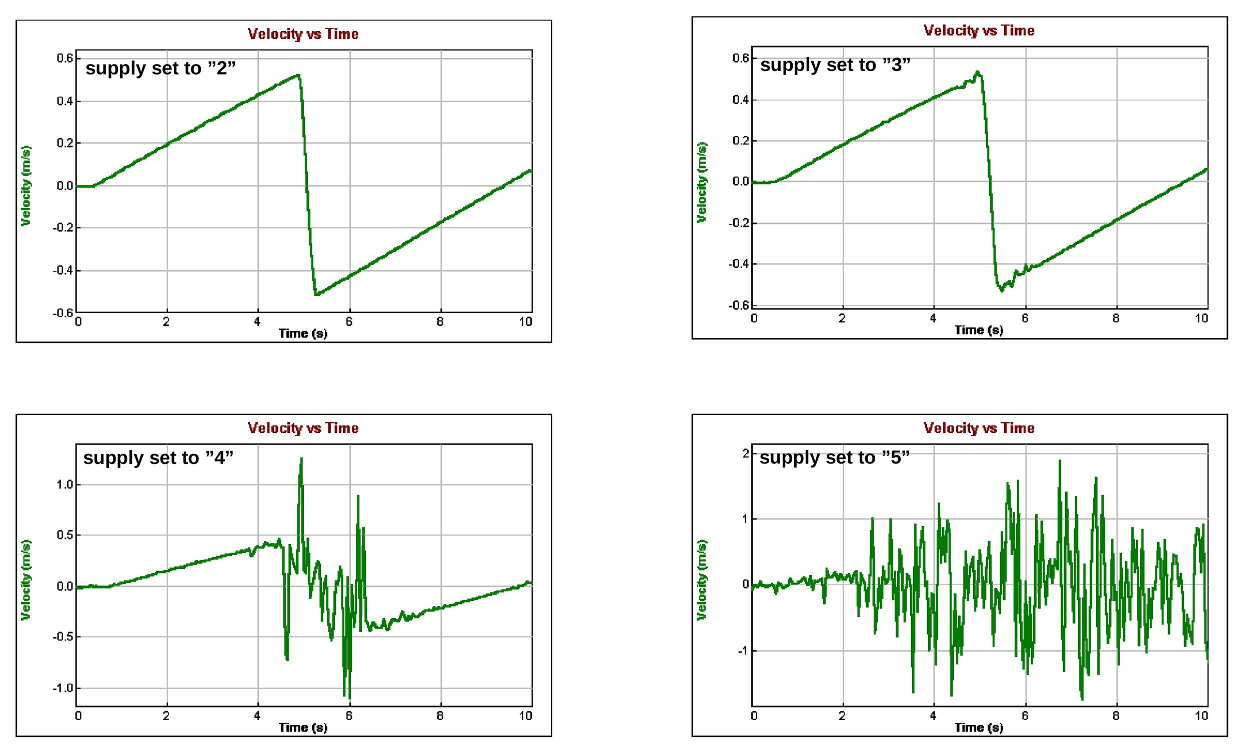


The reflector should be placed to transducer facing end of the glider or cart, so that the reflection always comes from the same area of the object.



External noise

External sound that is both loud enough and that contains transducer sensitive frequencies may cause the receiver circuit to be falsely triggered, and lead to noisy data. We have observed this with air tracks and their air supplies due to high pitched whistling. The presence of this noise can be confirmed by turning off the supply. To reduce it, turn down the supply or place it under the table or shield it. You can also shield the transducer from direct airflow from air track holes with a small piece of cardboard.



[1] D. MacIsaac and A. Hämäläinen, Phys. Teach. 40 (2002) 39.