A Real Time DSP Sonar Echo Processor[#]

by

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Introduction

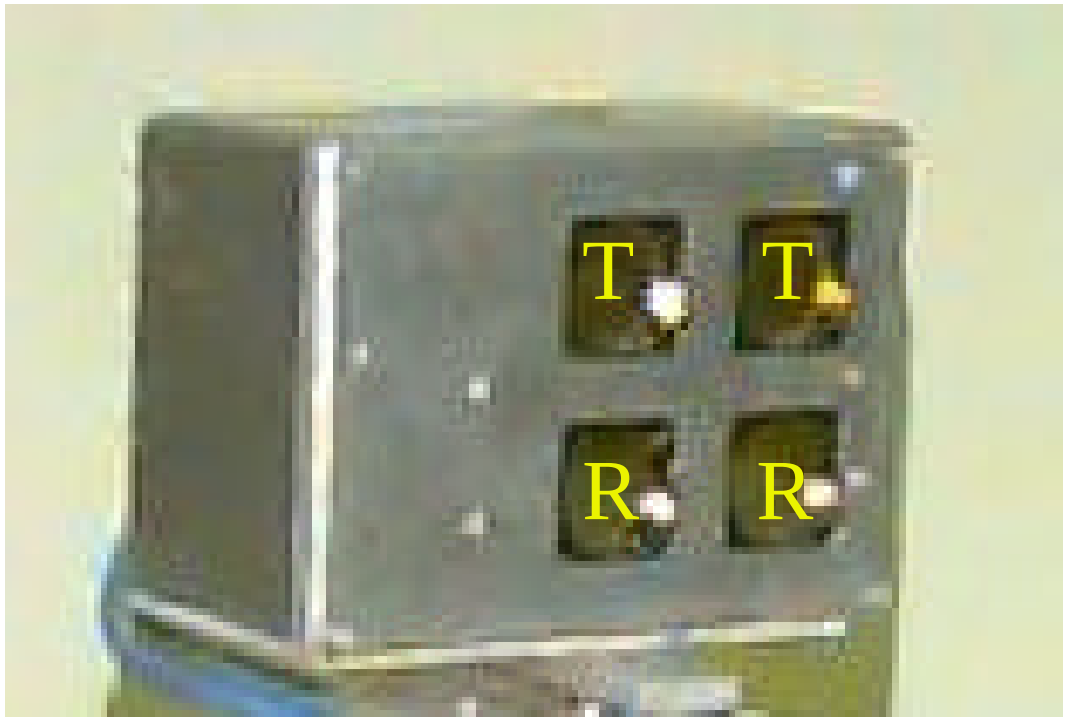
- **Robot systems are often sensor bound:**
  - eg map building, localisation, obstacle avoidance are limited by sensors, not algorithms
  - require reliable, fast, accurate cheap sensing.
- Sonar has been seen as unreliable, inaccurate.
  - eg Polaroid ranging module is a poor angle sensor
- DSPs allow sonar echo real time processing with more accurate range/bearing than laser range finders.

Introduction (continued)

- This paper introduces a new DSP sonar sensor that achieves optimal signal processing at near real time rates.
- Sensor reports range and bearing to targets to 5.4 m at 27 Hz.
  - Speed of sound alone imposes a limit of 30 Hz.
- Bearing and ranges errors are dominated by air conditions - typical still air gives:
  - 0.1 degrees, 0.2 mm error standard deviations.

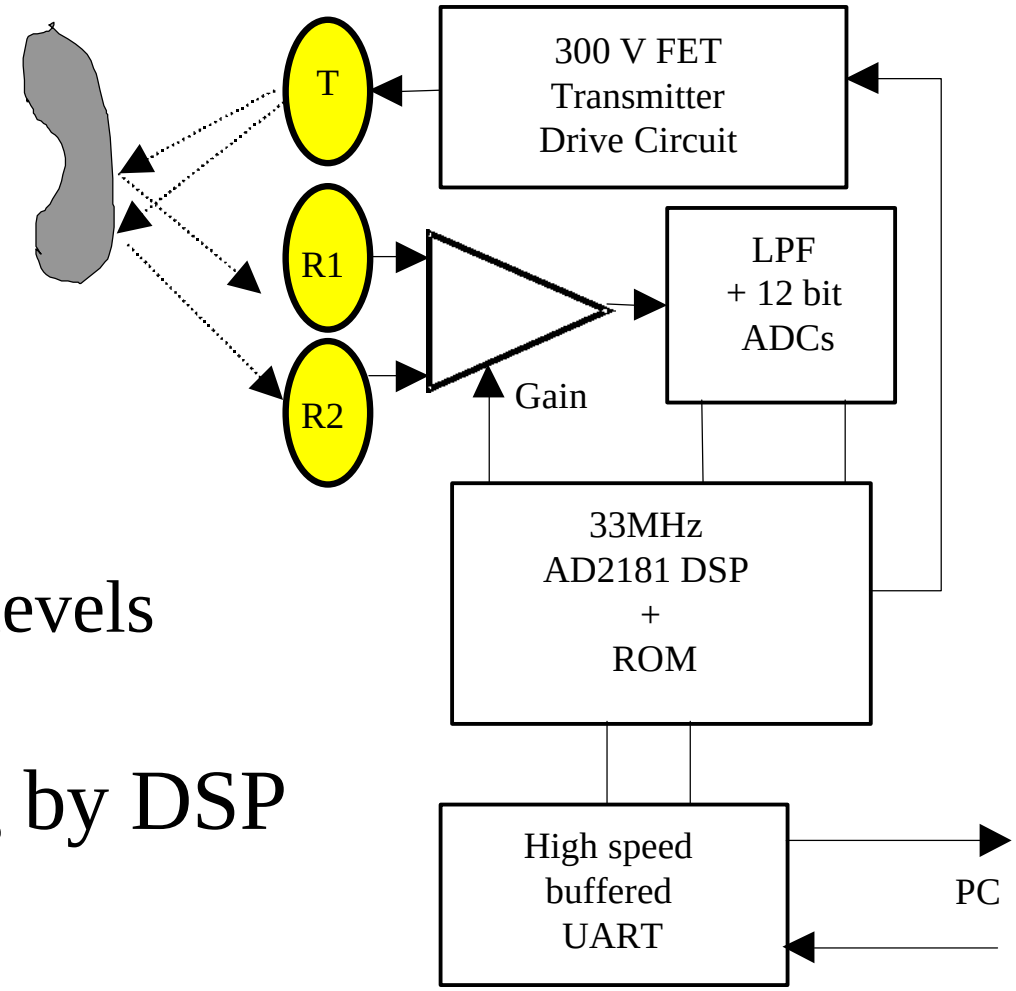
DSP Sonar System

DSP Sonar system



Custom Built Receiver

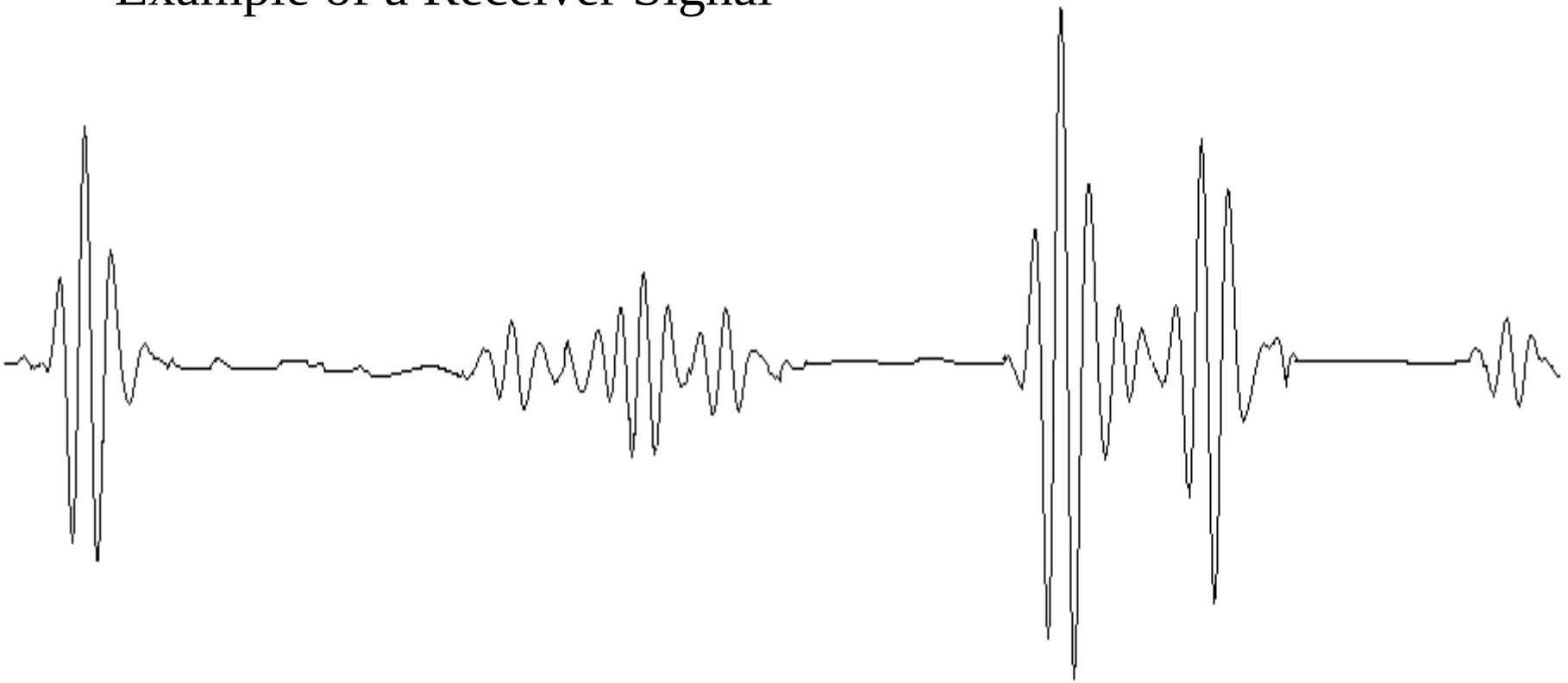
- 1MHz sampling on 2 channels
- All in one box
  - reduces noise levels
- Fast processing by DSP



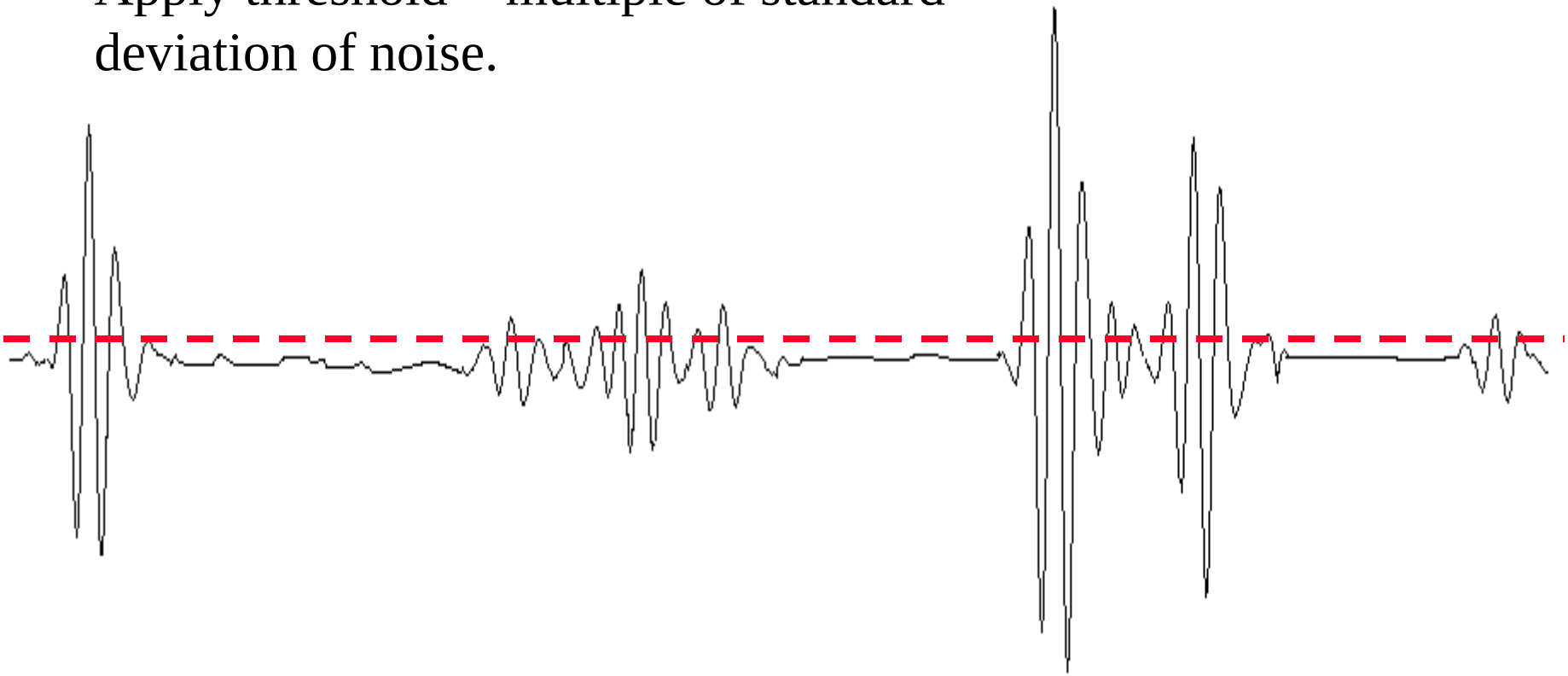
Overview of DSP Processing

- On the fly pulse extraction
- Template matching
  - parabolic interpolation for sub sample estimation
- Correspondence
- Triangulation

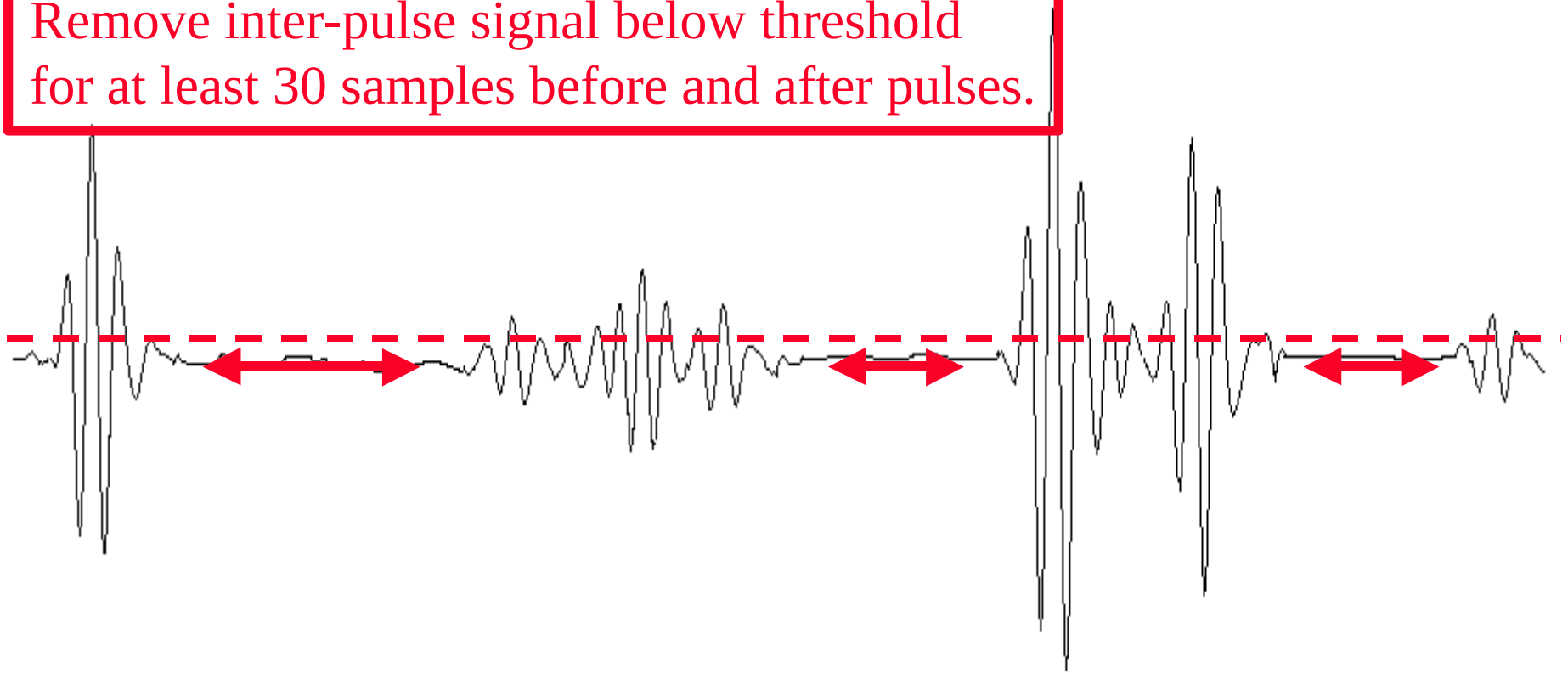
Example of a Receiver Signal



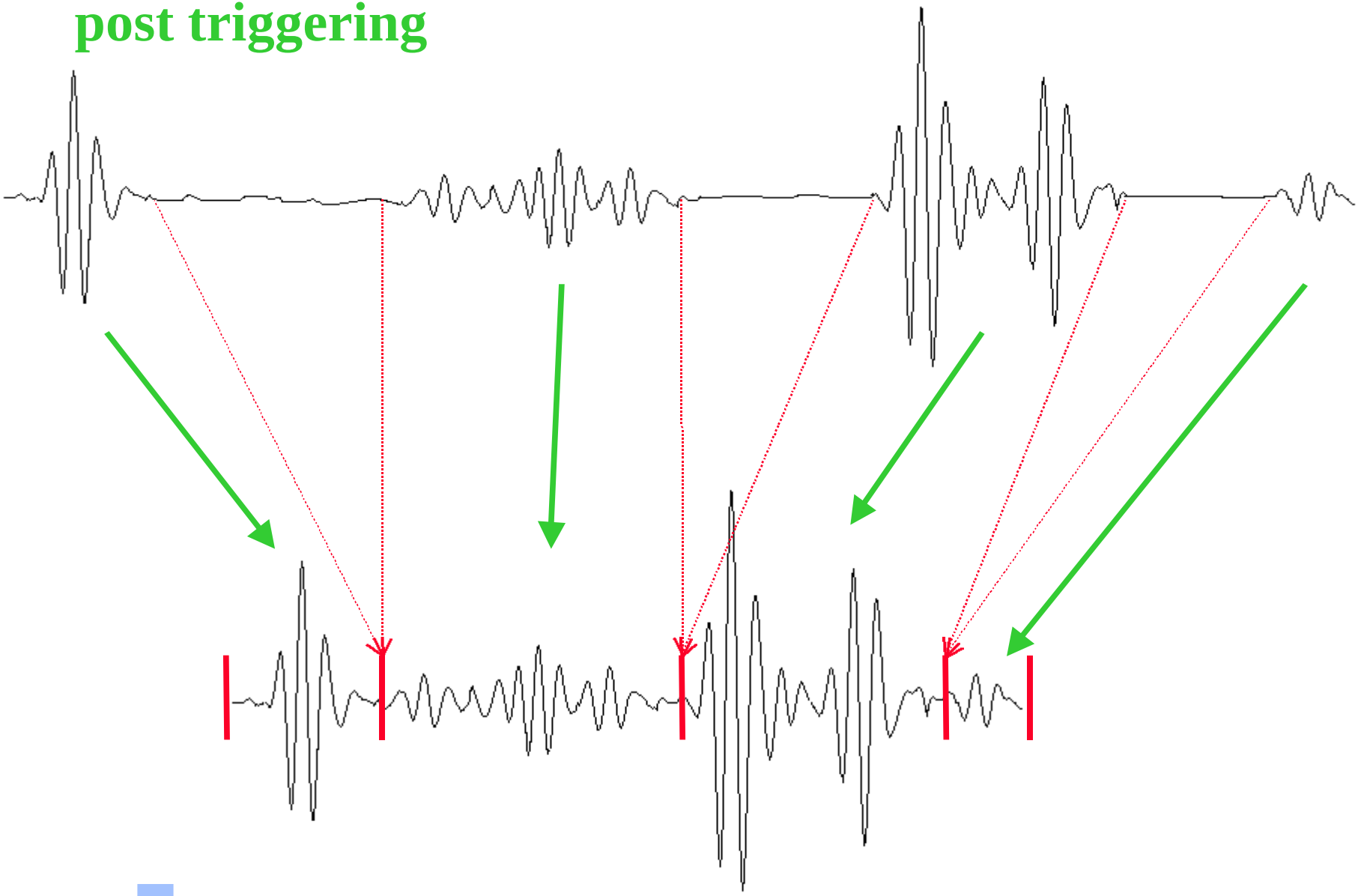
Apply threshold = multiple of standard deviation of noise.



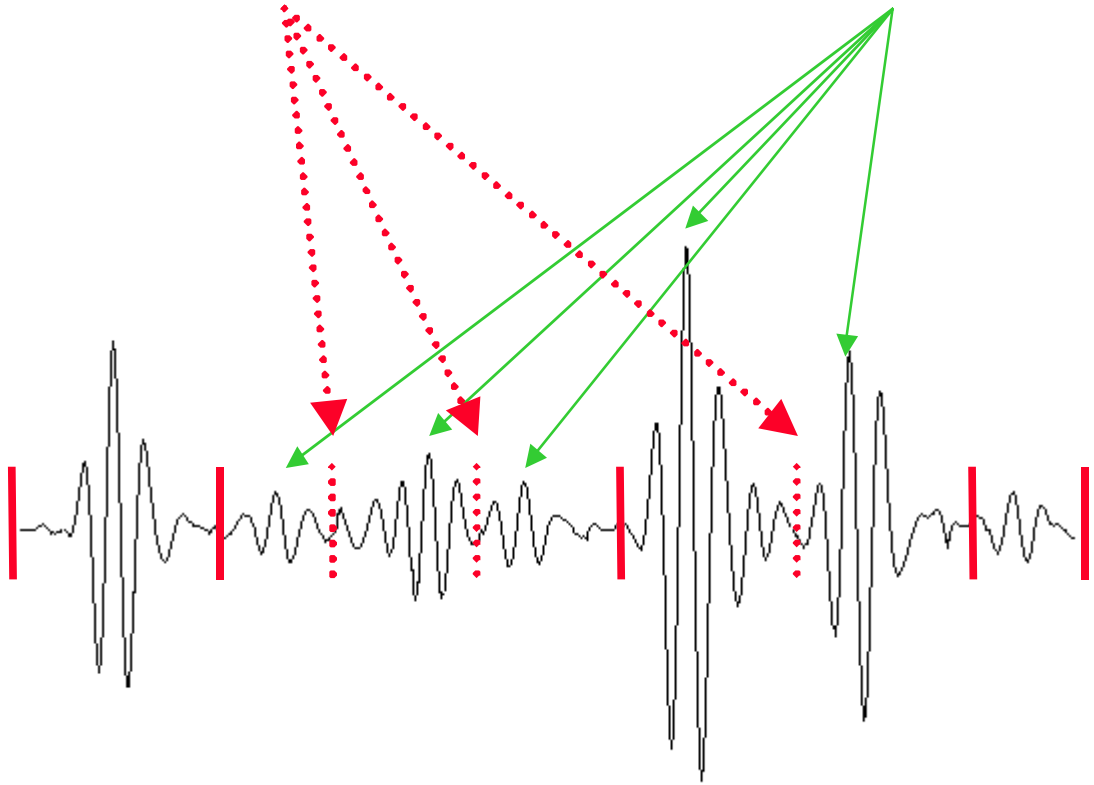
Remove inter-pulse signal below threshold
for at least 30 samples before and after pulses.



Summary of thresholding with pre and post triggering

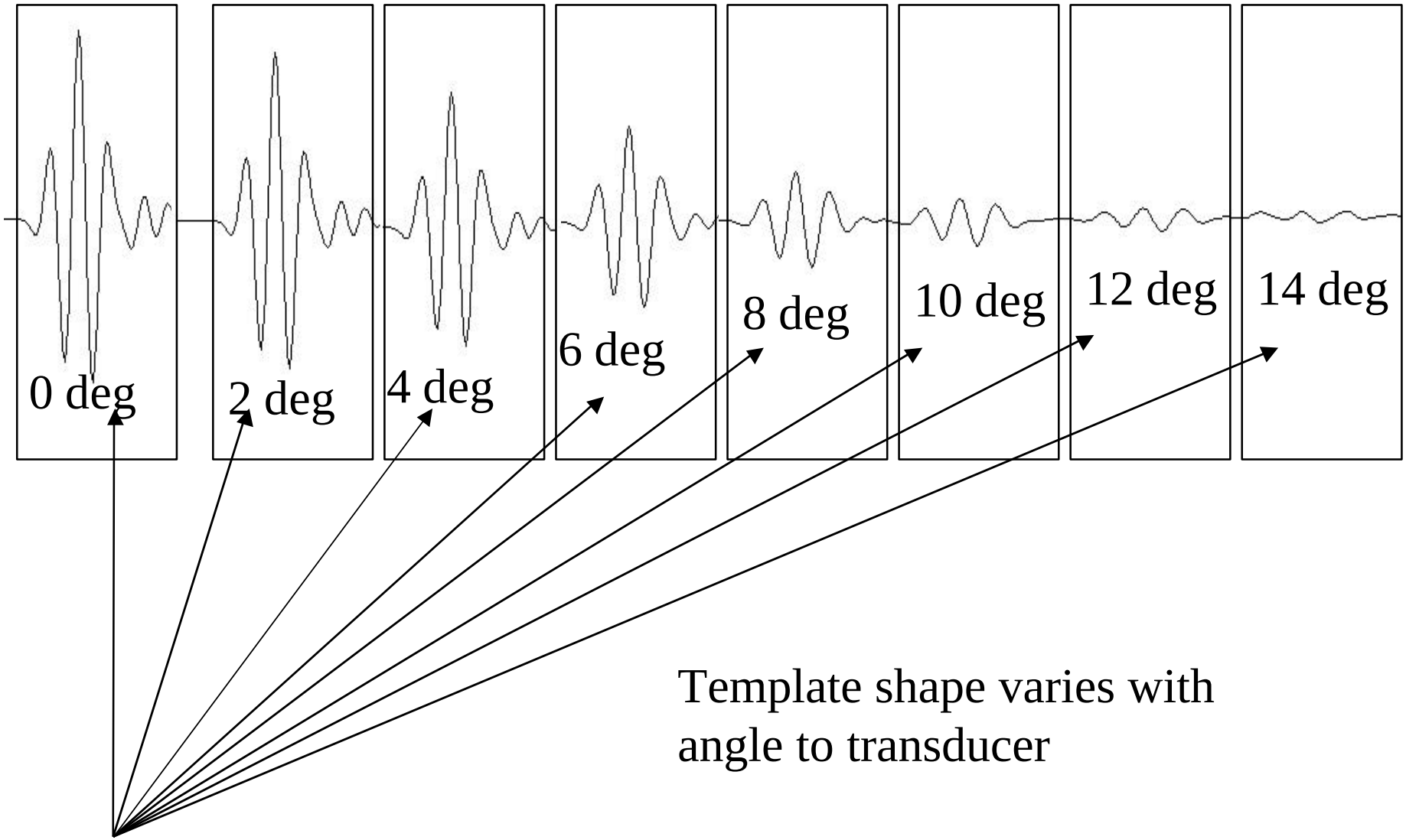


Pulse Splitting - based on signal peaks that are clear of surrounding peaks.

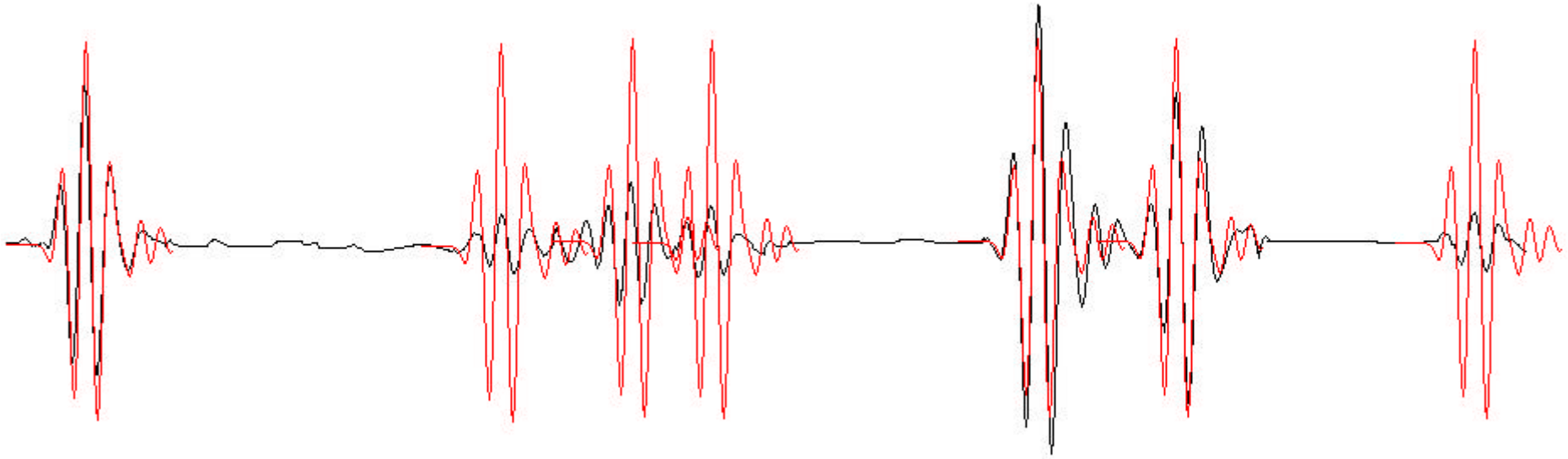


Template Matching

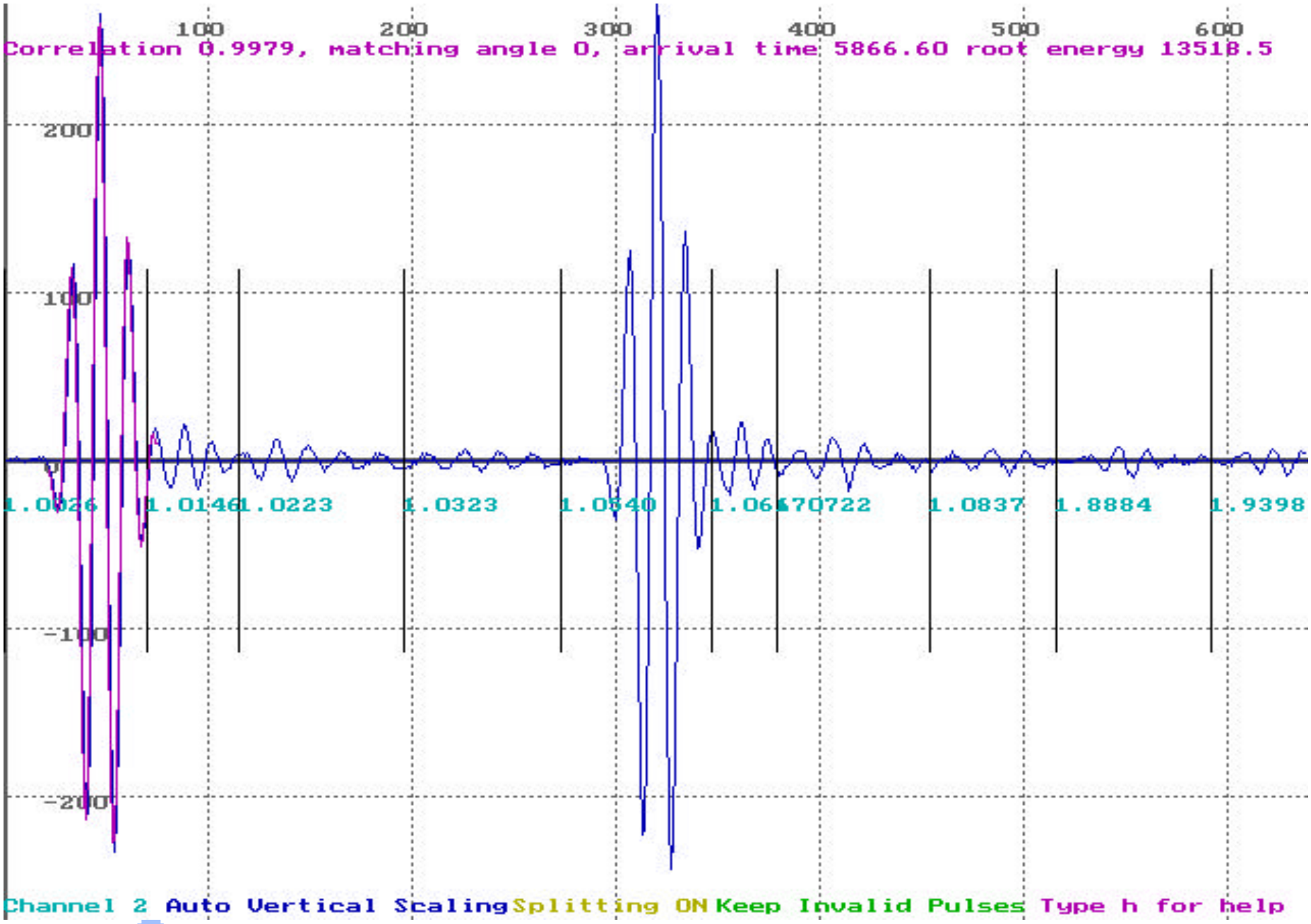
- Templates are pre-computed echo pulse shapes used in the arrival time estimation.
- Shape depends on arrival angle and range.
- This dependency has been accurately modelled - see *[Kleeman&Kuc IJRR 1995]*
- Thus the template set can be generated from a measured echo at normal incidence at 1m.


0 deg
2 deg
4 deg
6 deg
8 deg
10 deg
12 deg
14 deg
Template shape varies with angle to transducer
Transducer

Template Matching



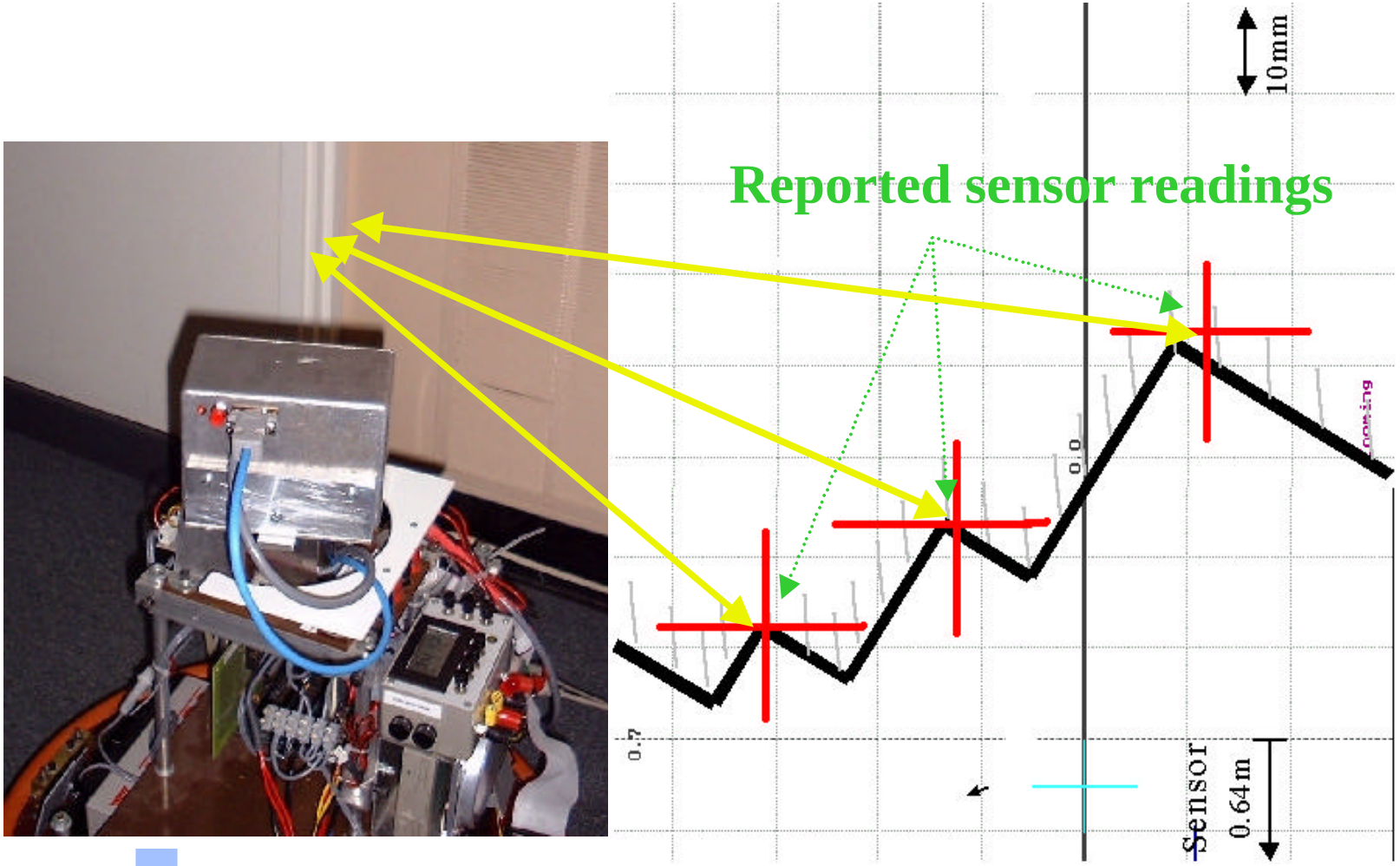
Templates shifted to best match the pulses using correlation of the template with the pulse.
Shape (not amplitude) are matched by a correlation.


100
200
300
400
500
600
Correlation 0.9979, matching angle 0, arrival time 5866.60 root energy 13518.5
200
100
0
-100
-200
1.0026
1.0146
1.0223
1.0323
1.0540
1.0670
1.0722
1.0837
1.8884
1.9398
Channel 2 Auto Vertical Scaling
Splitting ON
Keep Invalid Pulses
Type h for help

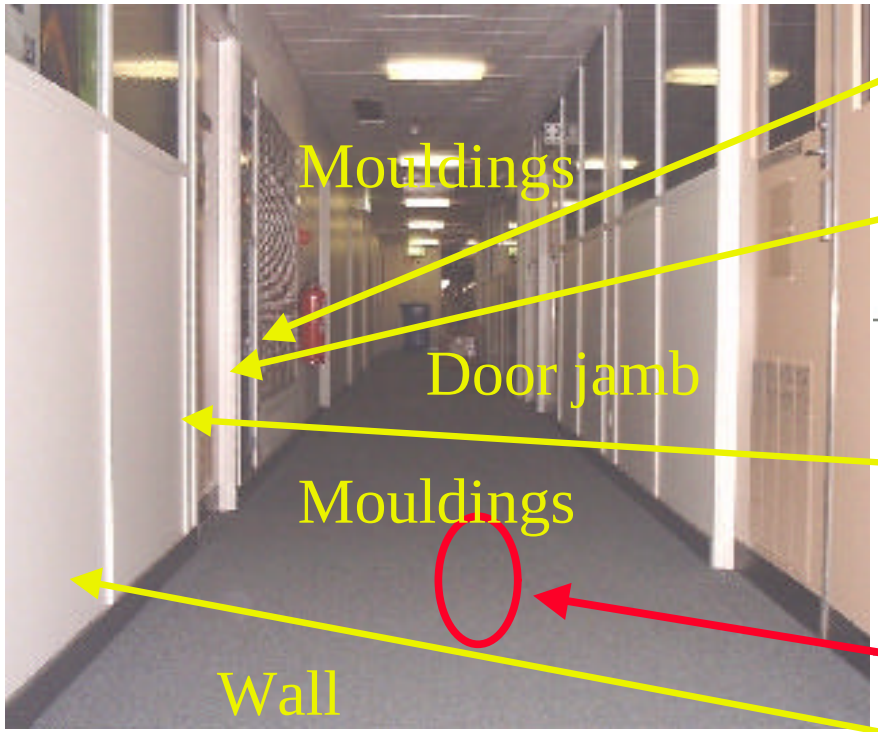
Receiver Data Association

- Left and right receiver arrival times are associated based on:
  - arrival times consistent with small receiver spacing
  - amplitudes matched
  - correlation coefficients > 95%

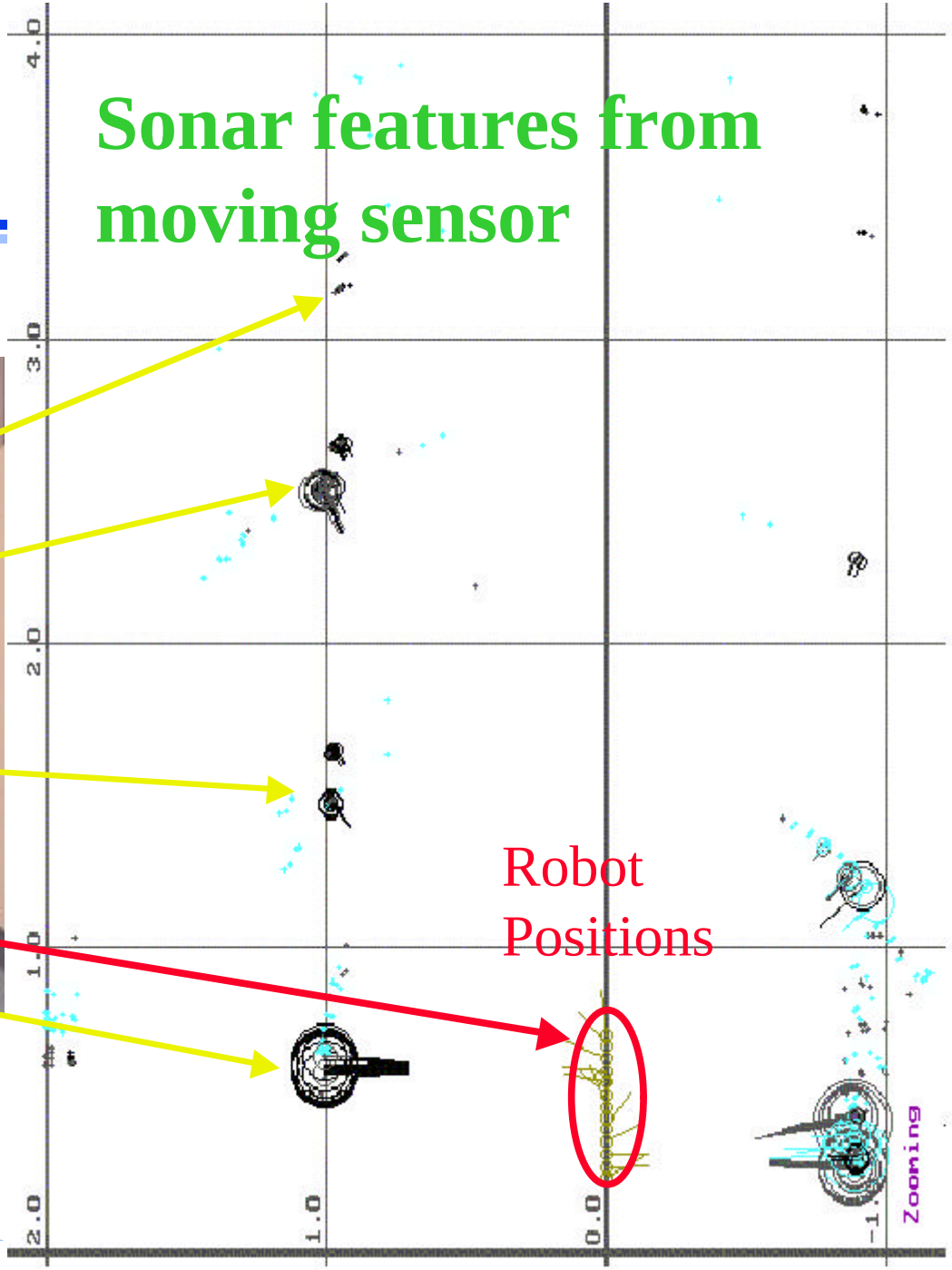
Door jamb experiment



Mapping Experiment



Sonar features from moving sensor

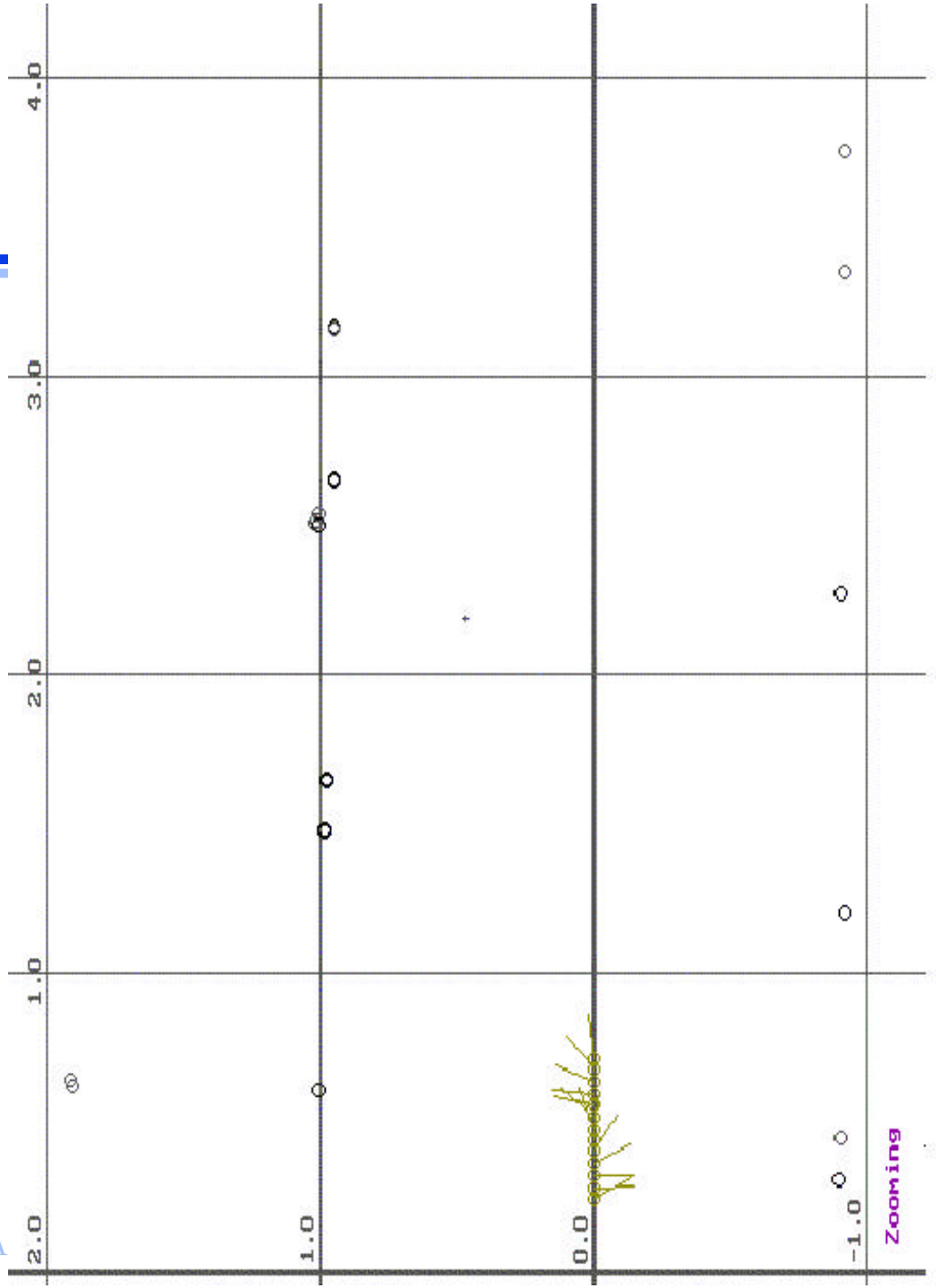


Robot Positions

Fused Targets

Raw target data in close proximity is fused based on a weighted average.

Weights are determined by amplitude and correlation values.



Conclusions and Future Work

- DSP sonar implementation allows:
  - local processing obviating high speed data communications
  - real time processing is achieved
  - portability.
- Futher work:
  - real time on the fly target classification.
  - interference rejection with double pulse coding (presented ACRA 2000, Melbourne Australia).
  - Real time SLAM.