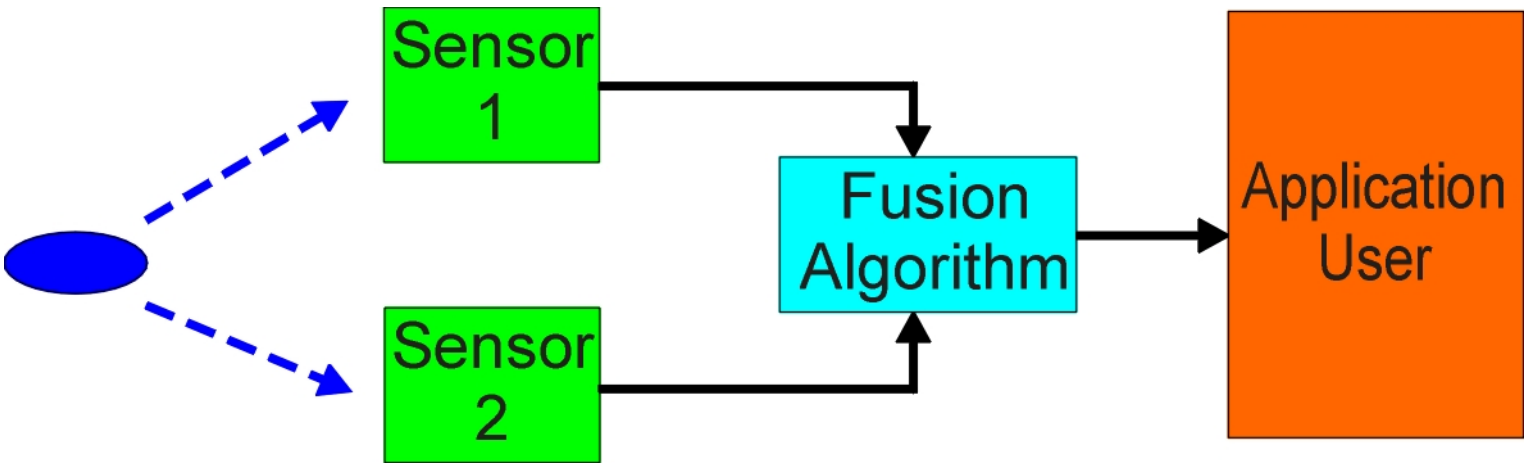
Non-Algorithmic Information Fusion

Algorithmic



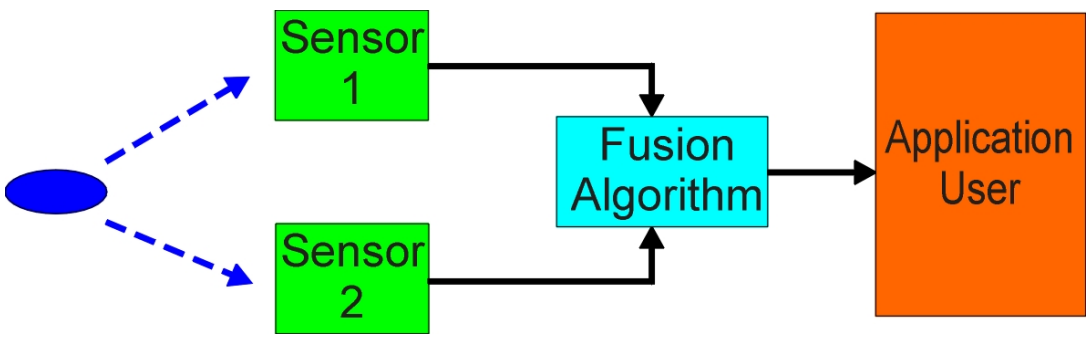
There is a strong directional element in an algorithm - this works well for moving clean information from one spot to another - it works very poorly for cognitive purposes, because we may not know where the information should be sent until we see it

Algorithmic Output

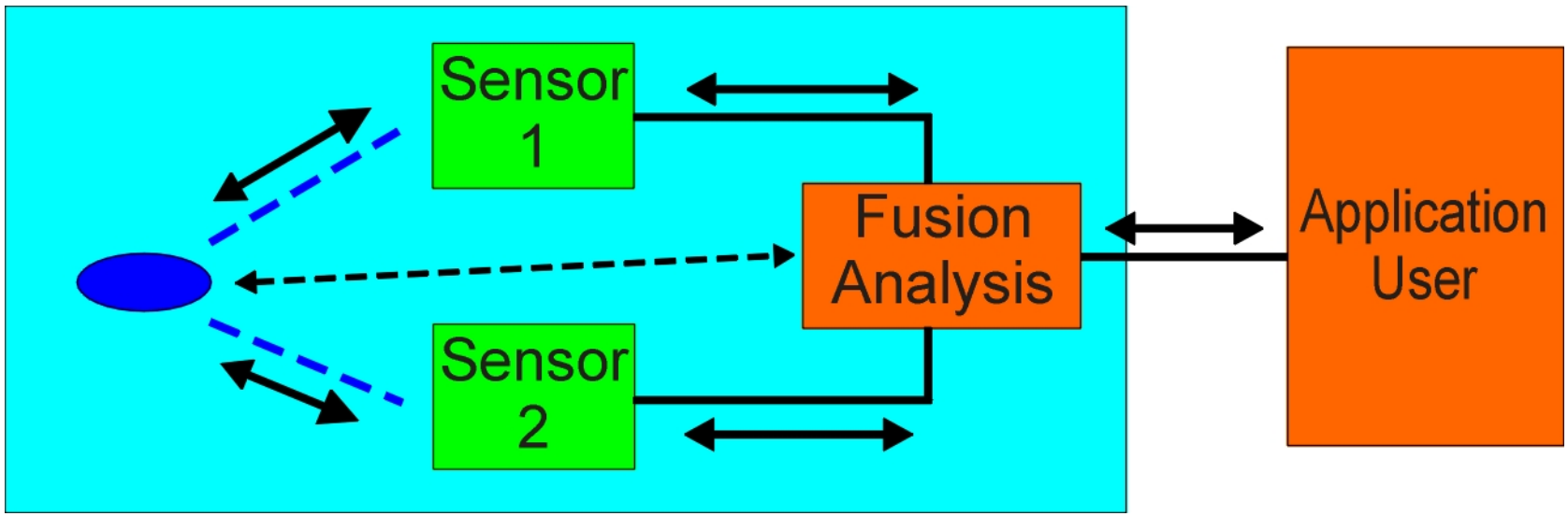
If the target detection is clean and precise, we probably don't need information fusion

If it isn't, we can't reconcile new information we receive with the initial detection - we can't make it redo the detection in light of the new information

In simple cases, we could arrange this, but when we are not sure of the order of detection or the sensor information is in different spaces, it becomes messy



Non Algorithmic



If we change the pathways to be bidirectional, we can reason about what we are doing, we can make decisions in context - we can make more sophisticated and more reliable decisions with poorer quality information

Non-Algorithmic Process

An undirected structure allows the information in the structure to determine the phasing of the solution – it does not require someone to write an algorithm to handle a situation they haven't seen (and wouldn't have expected)

The structure is undirected as to purpose, and can produce many processes depending on how it needs to be used at the time

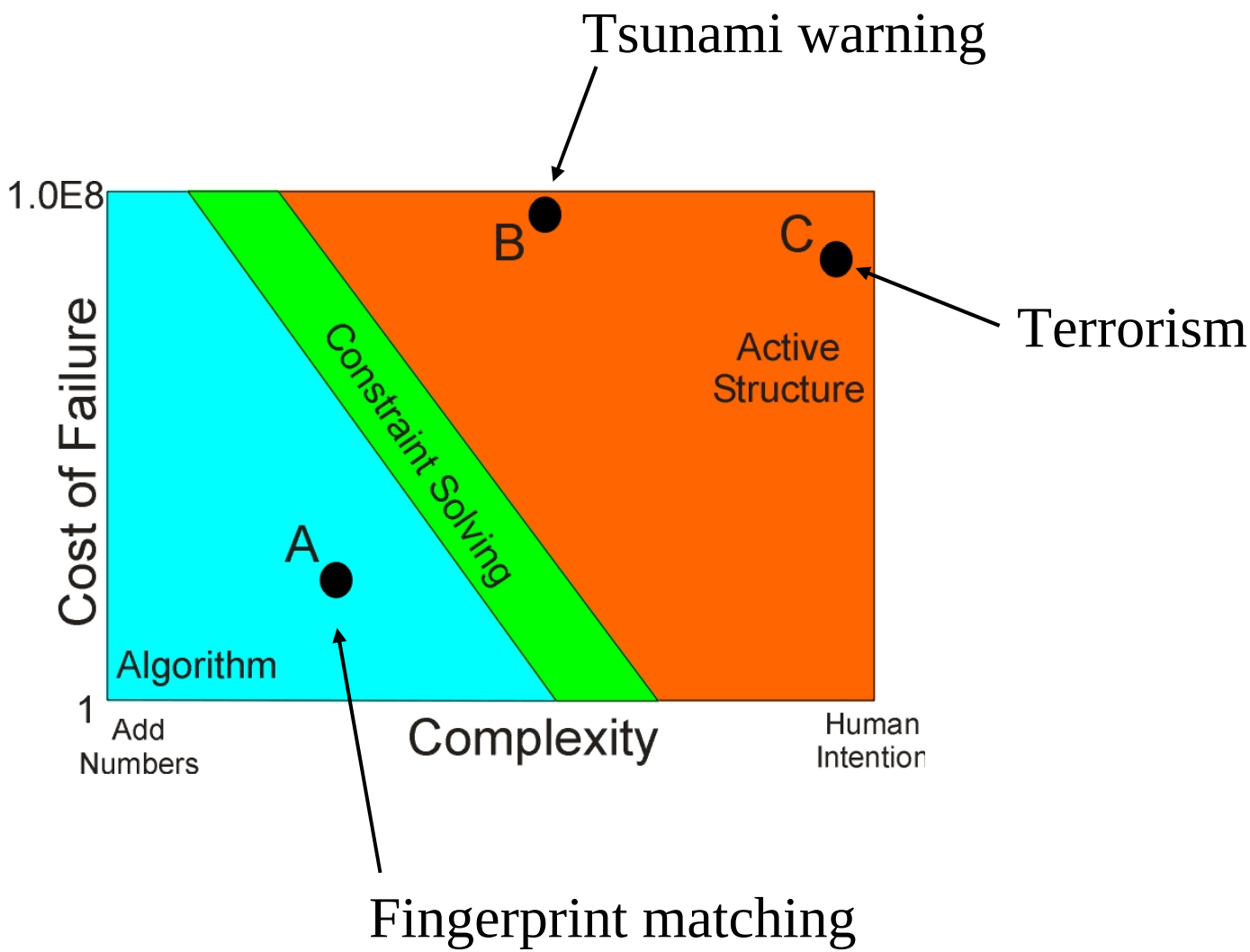
Why Non-Algorithmic?

Because algorithms are dumb – they make decisions without context, they don't use information already known, the pieces don't behave synergistically

We must only be using them because they are fast and cheap, for they fail on every other measure

If our fusion model is nearer our understanding of the problem, it should be easier to fuse disparate information

Complexity versus Cost



Constraint Solving

Fixed structure makes several assumptions:

Ranges on numbers

- Model is necessarily flat, not layered with logical connections

Compiled sets of alternatives

- Too limiting - must already know range of solution - unsuitable for dynamically constructed model

Alternatives given out at beginning

- Some alternatives are dangerous - could blow the model up

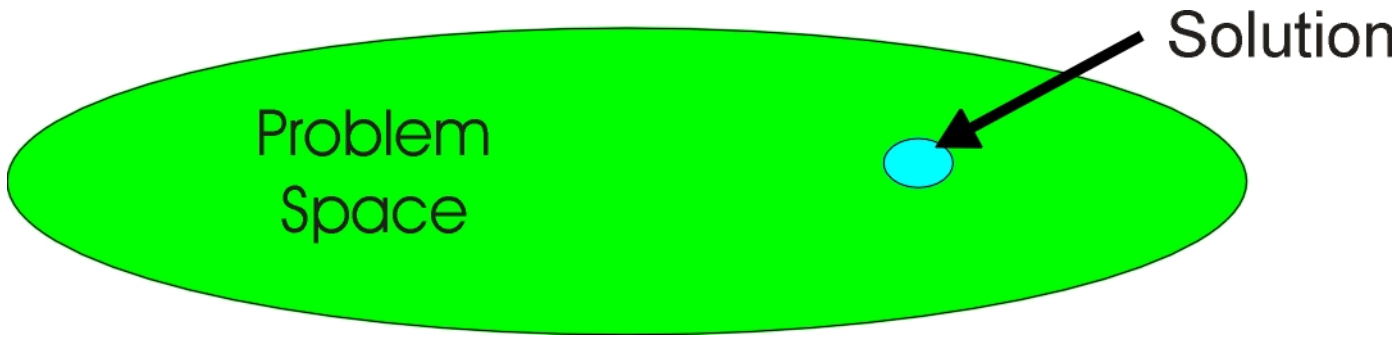
Constraint Reasoning

Model can use logical connections – can be many-layered

Numeric ranges can be transmitted as messages – no need to know range a priori

Objects can be created and destroyed

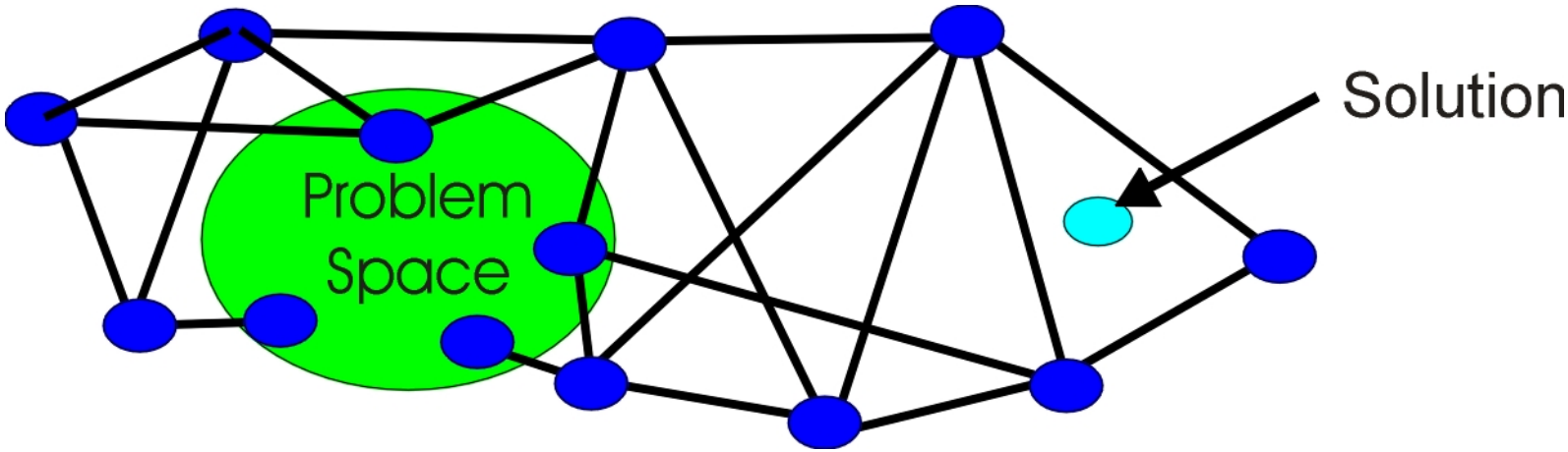
Constraint Reasoning Limitations



Conventional constraint reasoning is still an essentially static method - makes the assumption that the answer is contained in the posing of the problem.

Such problems are rather boring - the hard part has already been done

Constructive Problem Solving



Harder problems, such as targets inconsistent between two sensor streams, require building out from the problem space under constraint control until the solution space is found - a combination of structure building and constraint reasoning

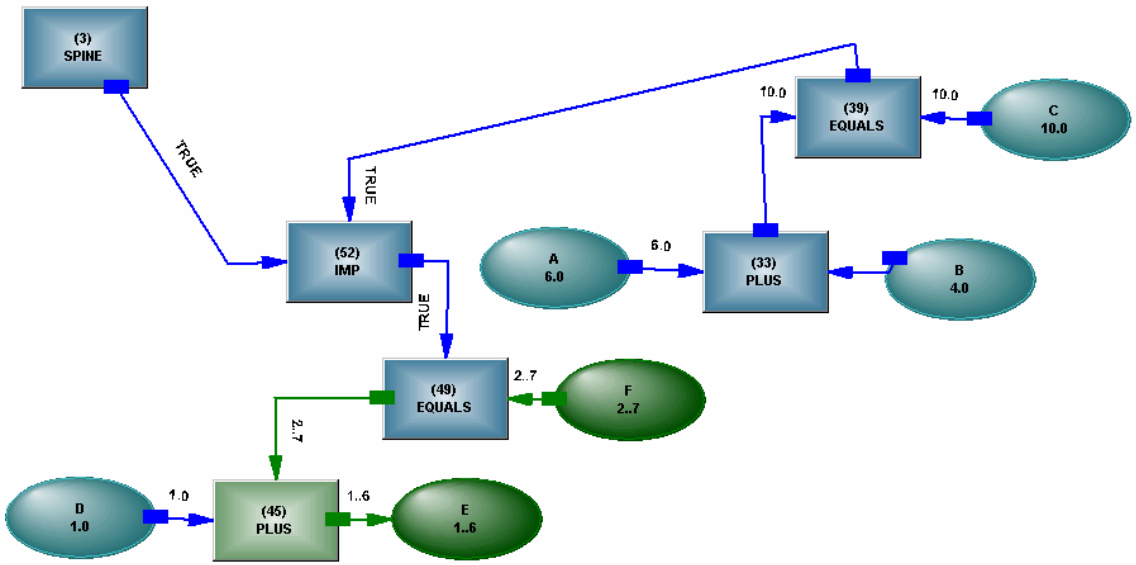
Philosophy

Non-algorithmic information fusion

- Build undirected knowledge structures
- Put everything in the structure – numbers, logic, existence, objects, relations
- Assemble a structure to describe the object we think we have detected
- Hypothesize, including the building of new structure

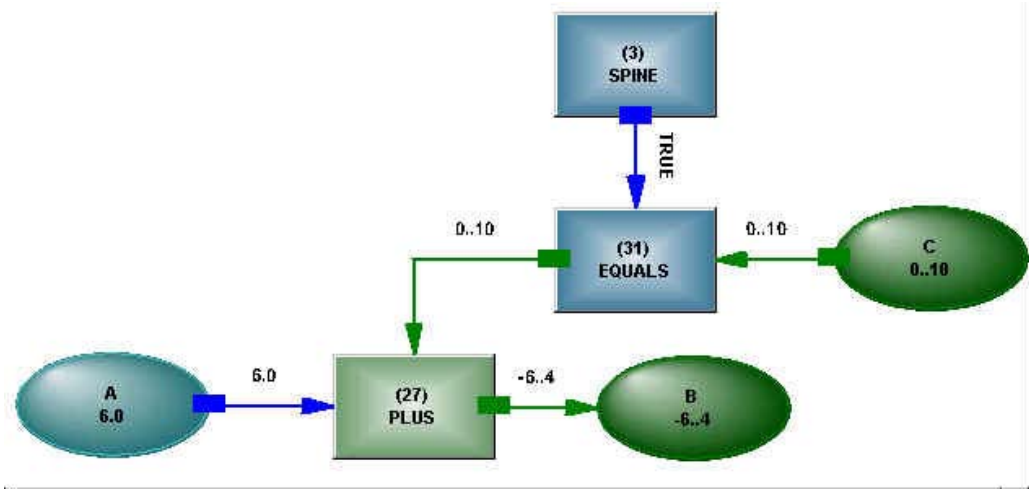
As more information in other logical dimensions becomes available, use that information to inform the decision-making

Knowledge Structure



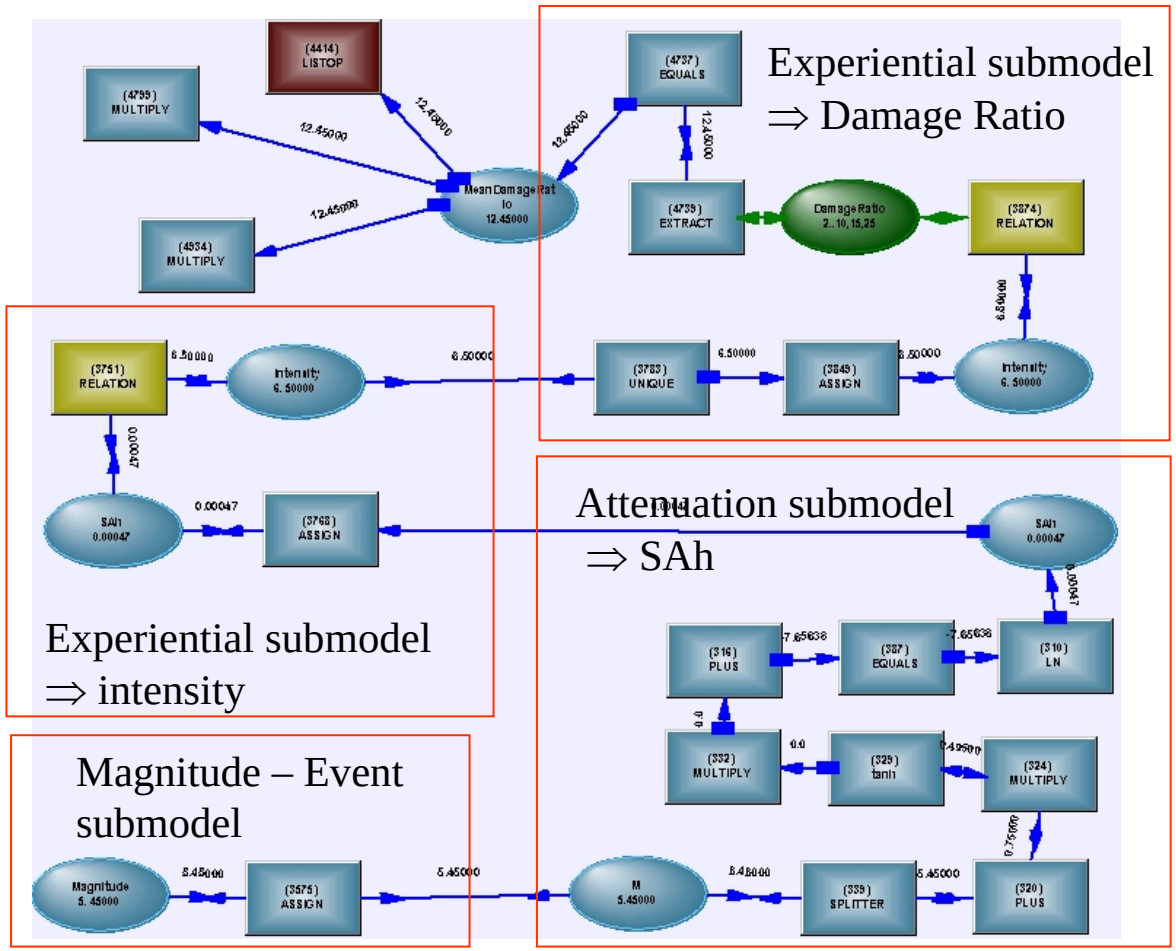
A knowledge structure can be used to reason about itself and the states within it

Atomicity



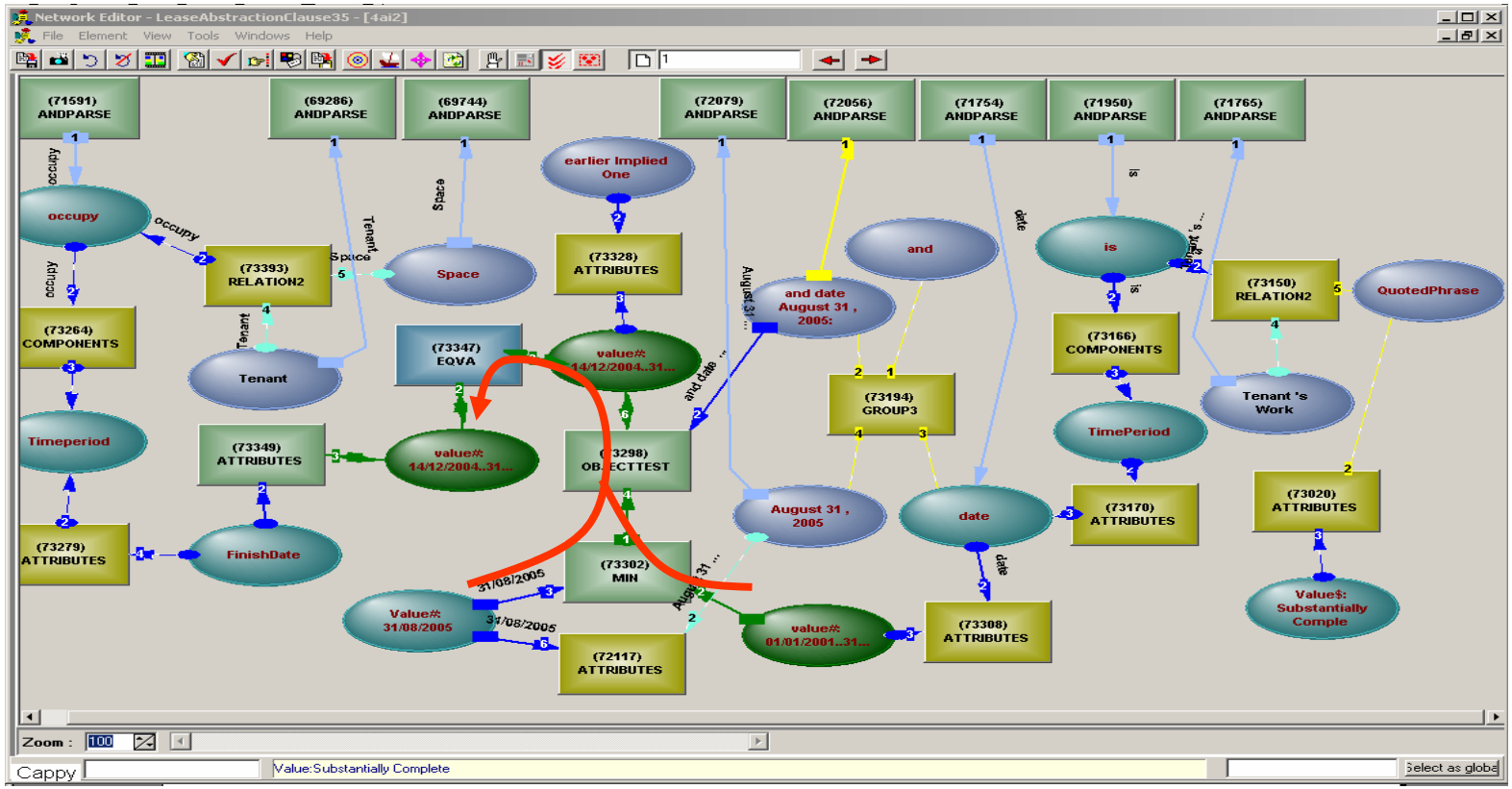
If we go down to the level of atomic operations in the structure, the phasing problems of an algorithm disappear - the structure computes its own phasing by broadcasting the result of the operation, seeing who is interested

Combining Models



Knowledge models are undirected, making it easy to combine and extend them

Dense Models

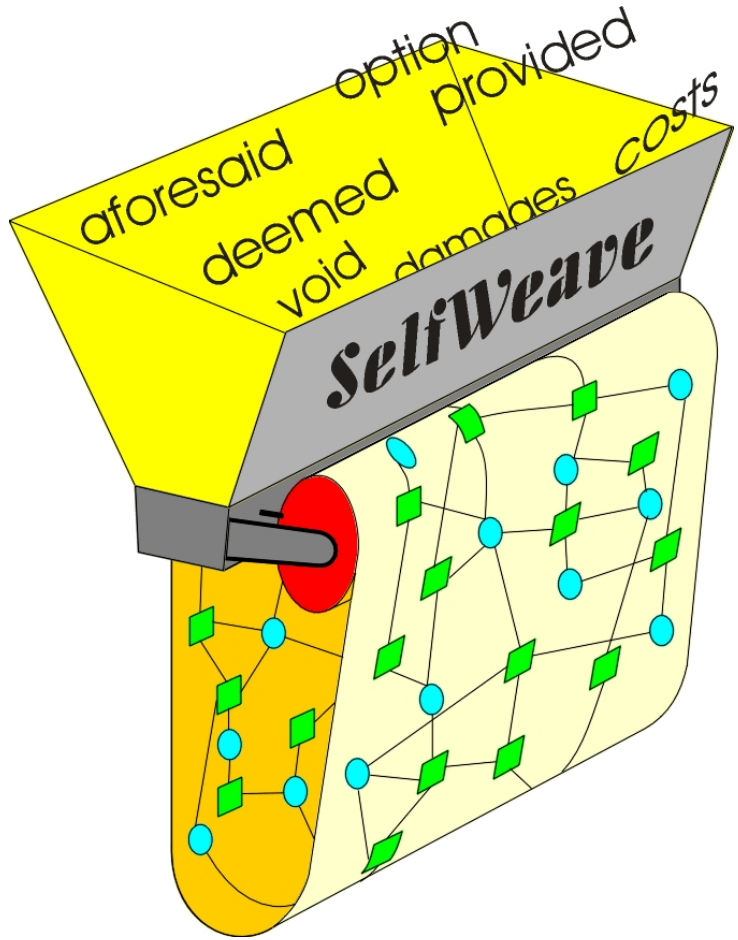


We can combine information fusion with DSS, and end up with a dense knowledge model capable of adapting to changes in context

Complex Situations

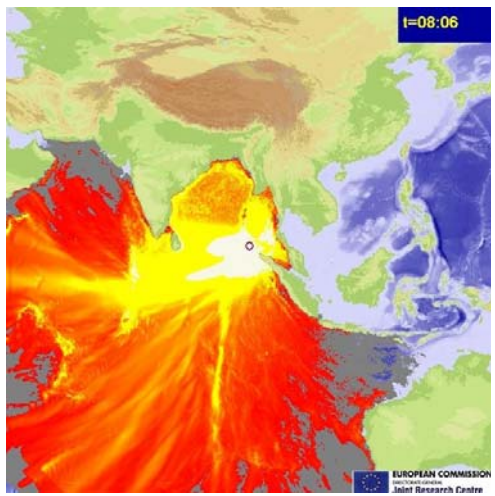
If the problem space is complex, use natural language text to build the knowledge structure

Build relations on relations where the sensor spaces are very far from each other



Example

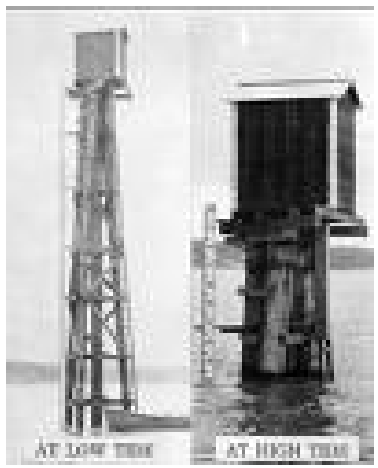
Tsunami Warning System



Sensor Types

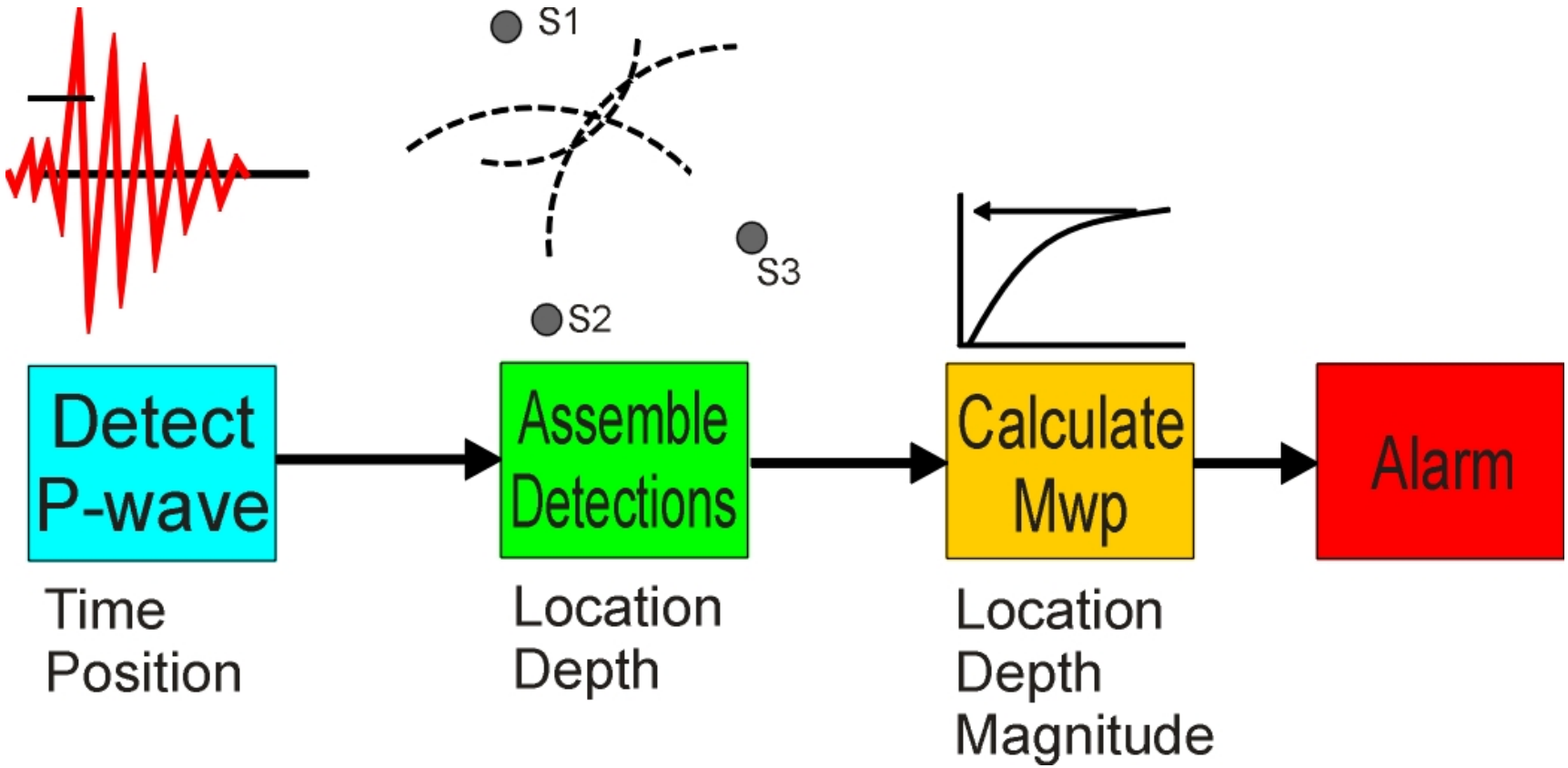
Seismometer to sense earthquakes

DART Buoy to measure deep ocean wave amplitude



Tide Gauge to measure wave height near land

Algorithm Segmentation

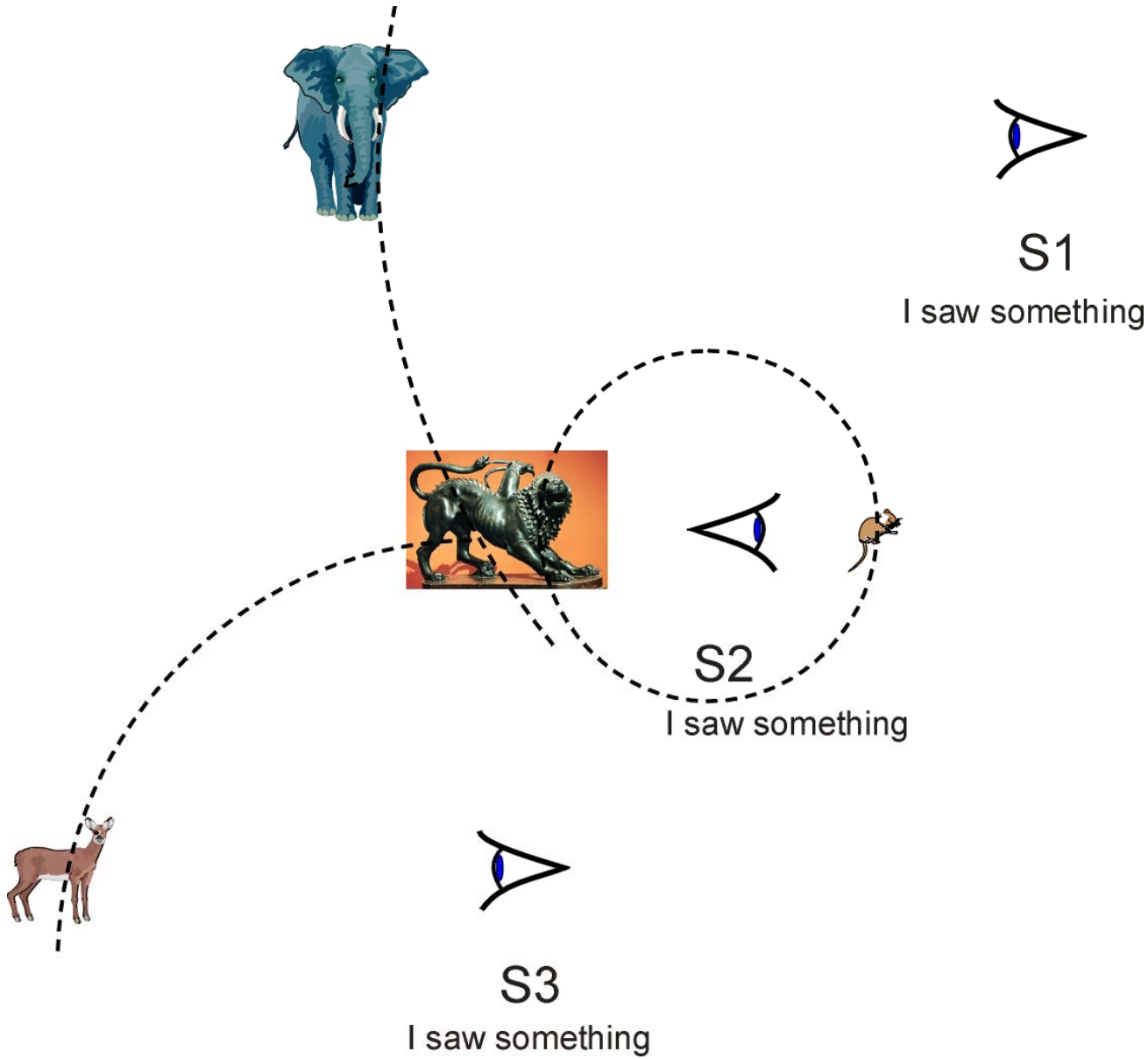


The initial alarm algorithm is directed and is segmented into three parts

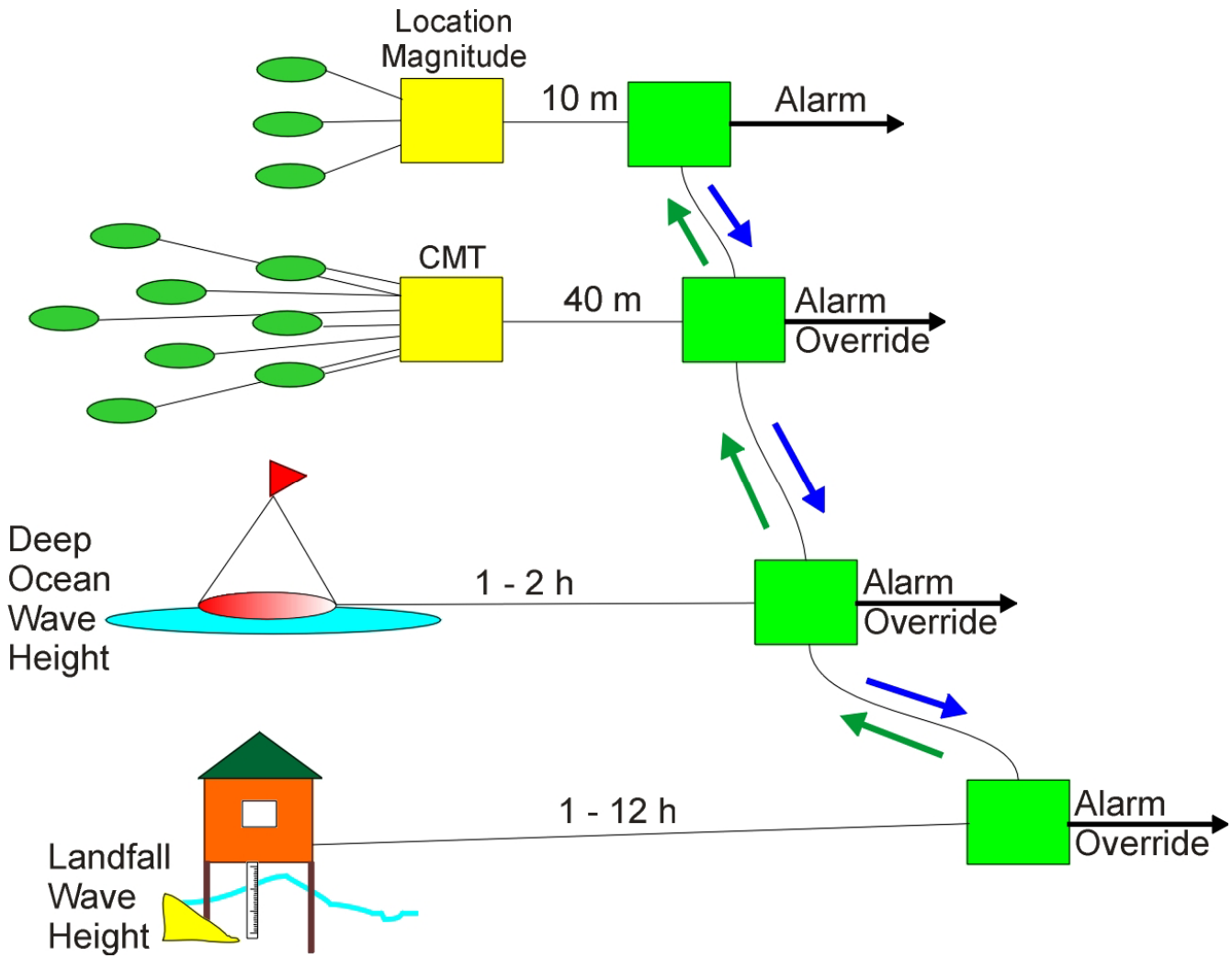
Decisions are made without context

Chimera

Building a chimera by mixing sightings of different objects - a typical problem of knowledge-poor algorithms - circulating detailed knowledge about the detections and reconciling it would help prevent such mistakes

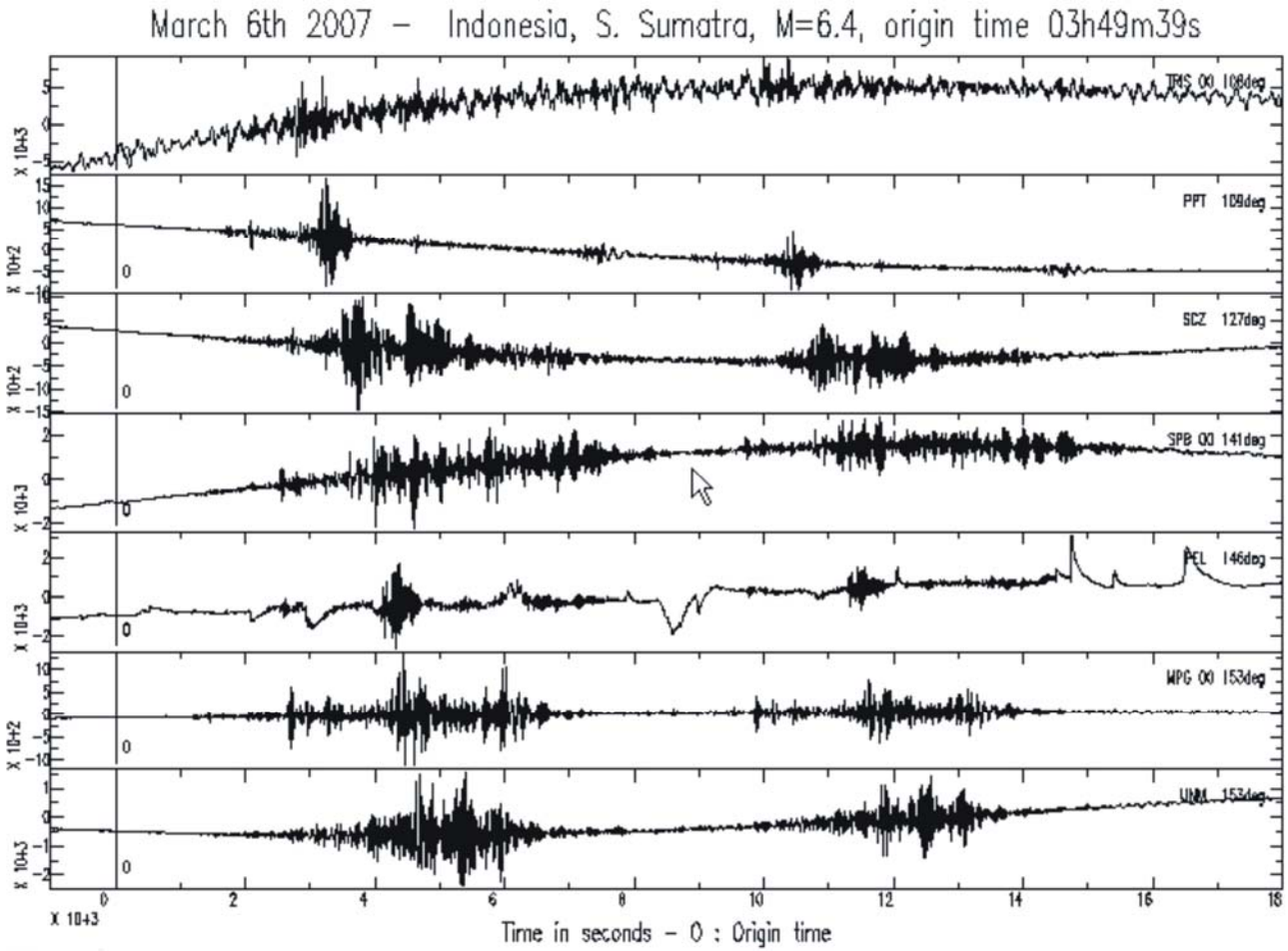


Tsunami System



There is information of doubtful validity at every stage - it needs to be reconciled backwards and forwards

Information Expurgation



Simple algorithmic methods must ignore real signals from strategic locations

Building the Event

The wide geographic area, the range of bathymetry, the sparsity of detectors, the unpredictability of the beam angle, all make it more reasonable to build the event from the available pieces as it unfolds, rather than have a prepackaged event that doesn't fit the actual case very well

There are large potential costs - either for failure to recognize severity or for false alarm

Non-Algorithmic Fusion

Allowing information to flow wherever it will until it stabilizes leads to a better solution

Dynamic structure can provide the targets, the constraints on those targets, and their behavior