Evidential Reasoning for Radiological Detection

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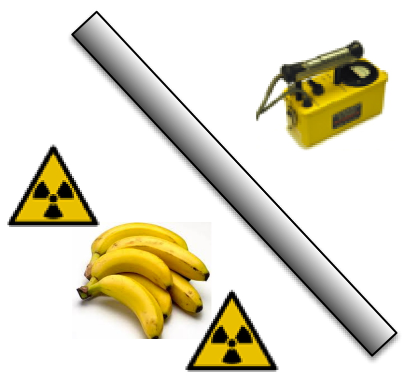
Problem: Uncertainty in Radiological Detection

Measurement is inherently statistical

Masking / shielding materials



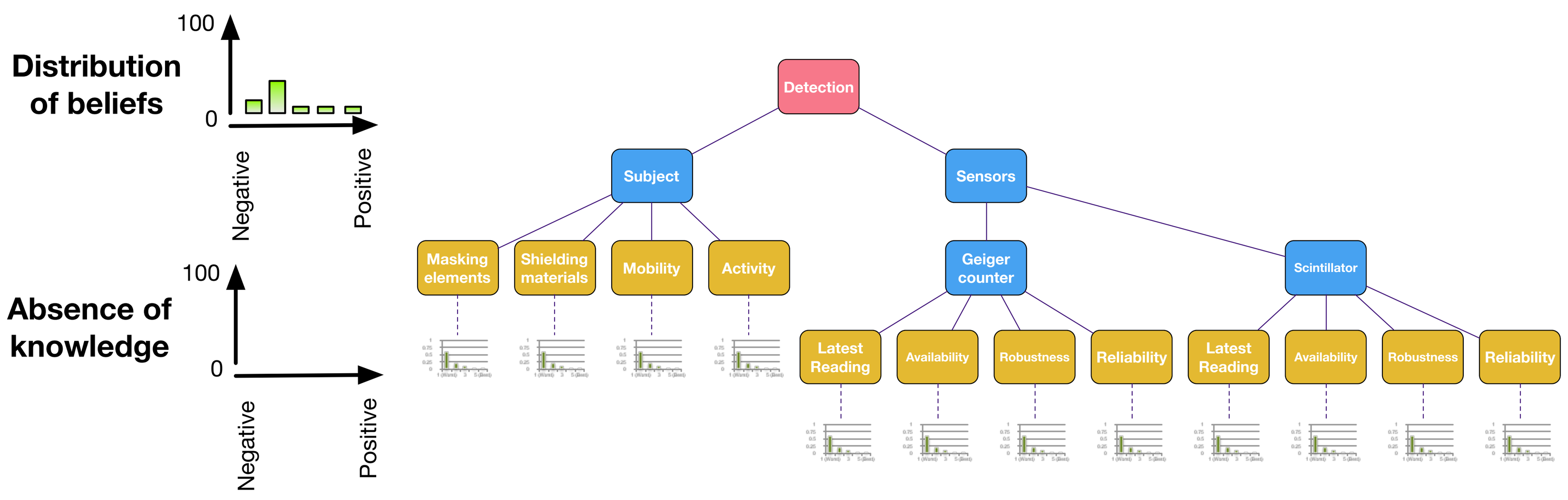
Dynamic detection settings that are hard to control

Detection settings are hard to control. Detection of radiation often takes place in settings (e.g. shipping ports) where detection is hampered. The potential source of radiation may be hidden in a container, with other sources of benign radiation that can have a masking effect. The container could include shielding materials to confound sensors. It might be difficult to get the sensor close to the subject, which might be in motion, etc.

There is a tension between automation and operator judgement Approaches that rely entirely on sensor readings can often lead to **nuisance alarms** because they fail to account for the extraneous factors mentioned above. On the other hand, relying too extensively on operator judgement can place too much of a burden on the operator and can be risky (dependent on operator experience), potentially missing **genuine threats**.

Evidential Reasoning

A Multi-Criterion Decision Analysis technique [1]. Based upon Dempster-Schäfer theory [2]. In Evidential Reasoning (ER), a decision problem is specified in the form of a hierarchy. The high-level outcome (e.g. 'has a radiation source been detected') is split into the various factors that contribute the final decision.



The data that corresponds to the evidence is provided in the form of a "belief function" - a distribution of 'belief mass' over a set of probabilities. These are arranged on a fixed ordinal scale (e.g. a Likert scale from 0 to 5). Belief functions are distinguished from conventional probability distributions because they do not have to sum to 1. Any missing belief mass amounts to "doubt". If there is no belief mass at all (the distribution is empty), it amounts to total absence of evidence.

The ER algorithm [1] works by combining lower level belief functions into higher level ones, whilst maintaining the following properties:

- If all of the functions assess have the probability of a given outcome to be 0, then the probability of that outcome in the combined function is 0.
- If all of the functions assess a given probability to be 1, then that probability in the combined function is 1.
- If, for all sub-factors, the belief mass is concentrated on a sub-set of outcomes, this must also be the case for the combined function.
- If, for a sub-factor, a given probability < 1, then this must also hold for the corresponding probability in the combined function.

We have applied ER to reason about trust in (1) the assessment of safety arguments for safety-critical software [3], and (2) the trust worthiness of multi-factor decisions taken by autonomous vehicles [4].

Linking Data to Decisions for Radiological Detection

We have used our EVIRE tool to experiment with the application of ER to the radiological detection problem. Above is a screen-shot that provides an example of what the output looks like. The decision tree represents the same nodes as are shown in the ER tree example. The leaf-nodes show belief functions that are provided by an operator. Branch and root nodes show the belief functions that are produced by the ER algorithm.

Crucially, there are different levels of uncertainty. For example, for the right-most leaf-node, no evidence was available whatsoever, which is why it was entered as an empty function. The uncertainty is represented as the background hue in the charts – deep red indicates strong uncertainty, and no hue at all represents complete certainty. This gives a rapid overview of where and why any uncertainty has fed in to the overall outcome.

Ongoing & Future Work

Formulating decision trees It is necessary to elicit the key factors that operators consider to be significant when assessing a detection problem. This will require analysis of operational protocols that will vary according to setting (e.g. ports, airports, military, hazardous scenario analysis, etc.).

Converting data and sentiment to belief functions Belief functions present a specific interpretation of the data. If the source of the data is sensor-data, then adaptors will be required that can automatically formulate a belief function from a given reading. If the input comes from an operator, then a suitable, simple interface needs to be developed.

Our current approach is to use the PAS:754 trustworthiness framework [5] (originally developed to assess software trustworthiness) as a basis for assessing a given information source. Using this, a single source is assessed in terms of: (1) reliability, (2) safety, (3) availability, (4) resilience and (5) security.

References

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[3] Nair, S., Walkinshaw, N., Kelly, T., & de la Vara, J. L. (2015, November). An evidential reasoning approach for assessing confidence in safety evidence. In Software Reliability Engineering (ISSRE), 2015 IEEE 26th International Symposium on (pp. 541-552). IEEE.

[4] Self-Aware Trustworthiness Levels and Assurance with Operational Policy (SATLAOP), DSTL-ASUR project with Fraser Nash Consulting, University of Leicester, and Qinetiq.

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