LINE IN THE SAND: MATCHED FILTER CONCEPTS

Prabal K. Dutta
The Ohio State University, Dept. of Electrical Engineering
205 Dreese Laboratories, 2015 Neil Ave, Columbus, OH 43210
dutta.4@osu.edu

The purpose of this document is to communicate and clarify our thinking about the matched filter architecture. The job of the matched filter is to detect and classify intruders. The matched filter should be able to classify the following types of intruders:

- A vehicle like a car, truck, or tank with a significant ferromagnetic component.
- A soldier carrying ferro-magnetic materials like a gun.
- A person carrying no ferro-magnetic materials.
- The absence of an intruder.

Our current plan is to use two sensors: a magnetometer and either micropower impulse radar or ultrasonic ranger. To be minimally useful, we assume that the sensors are able to reliably discriminate between at least three environment states for the magnetometer and two states for the ranger. In the case of the magnetometer, these three states are high, low, and no signal, corresponding to a decreasing presence of a metallic object. For the ranger, the states are the presence (true) and absence (false) of an object within the sensor's field of view.† Let the variables x and y represent the states of the magnetometer and ranger, respectively. We define a set of functions whose domain is given by x : {high, low, no} and y : {true, false}, and whose range is {true, false}. The functions are vehicle(), soldier(), person(), and none(), and their values are, as a function of x and y, described based on a simple set of heuristics:

- Large metallic objects, as detected by a magnetometer reading of "high", are always classified as vehicles.
- A large metallic object far away may register the same "low" reading on the magnetometer as a small metallic object nearby. Therefore, we use range as a secondary discriminator to provide the "near" and "far" heuristics necessary for classifying the intruder as a soldier or a vehicle, respectively.
- A magnetometer reading of "no" simply indicates earth's magnetic field remains undisturbed near the sensors. In these cases, there could be two scenarios. One scenario is that there truly is nothing present (which would correlate with a "false" value for the rangefinder). The other scenario is that there is something present, but that it does not contain a sufficiently large (or any) magnetic content, and hence does not register with the magnetometer. In the former case, we have nothing to classify (e.g. "all clear") and in the latter case, we infer the presence of an object and classify it as a person.

The detection heuristics are enumerated in Table 1.

Table 1: Detection heuristics.

<table>
<thead>
<tr>
<th>Rangefinder (y)</th>
<th>Rangefinder (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>True</td>
<td>False</td>
</tr>
<tr>
<td>Vehicle() == true</td>
<td>Vehicle() == true</td>
</tr>
<tr>
<td>Soldier() == false</td>
<td>Soldier() == false</td>
</tr>
<tr>
<td>Person() == true</td>
<td>Person() == true</td>
</tr>
<tr>
<td>None() == false</td>
<td>None() == false</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Magnetometer (x)</th>
<th>Magnetometer (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Vehicle() == false</td>
<td>Vehicle() == false</td>
</tr>
<tr>
<td>Soldier() == true</td>
<td>Soldier() == true</td>
</tr>
<tr>
<td>Person() == false</td>
<td>Person() == false</td>
</tr>
<tr>
<td>None() == true</td>
<td>None() == true</td>
</tr>
</tbody>
</table>

There are various other ideas that need to be thought through on the matched filter architecture that are being postponed in the interest of circulating a working document.

- The specific message data types are not determined.
- The matched filter depends on the existence of modules that encapsulate the magnetometer and range sensors, and can provide a total of six meaningfully distinct states between the two. Obviously, this is a low bar to set for our sensors, but one that is likely achievable. If it turns out that we must collapse our detection heuristics to a 2x2 matrix (the minimally useful output), then we may need to forego the ability to detect a soldier. One the other hand, we may find that the sensors or signal processing provides far richer data and we have larger and more continuous (i.e. finer granularity) domains rather than the strictly discrete ones described above. Such an approach would allow a Bayesian estimation approach to classification, allowing more complex (e.g. non-binary) inferences and confidence levels.
- A distributed matched filter could make better classification decisions based on neighbors' sensor values. To be meaningful however, these reading should have a temporal locality to them. The Snapshot service seems like the appropriate mechanism to capture and communicate these distributed sensor readings.

† The specific mapping between the raw sensor values and the high/low/no and true/false outputs are not described here. It could be implemented with a simple threshold scheme, an adaptive algorithm, self-calibration, etc. There could exist environmental noise so we assume the existence of simple strategies like an n-point filter or hysteresis to eliminate random noise components from affecting the estimation.