University Defence Research Centre (UDRC)
In Signal Processing

Sponsored by the UK MOD

[O16] Target Detection in Clutter for Sonar Imagery
Theme: Classification and multi-modal fusion

PI: Yvan Petillot, Heriot-Watt University, Scotland
Researchers: Nicolas Valeyrie

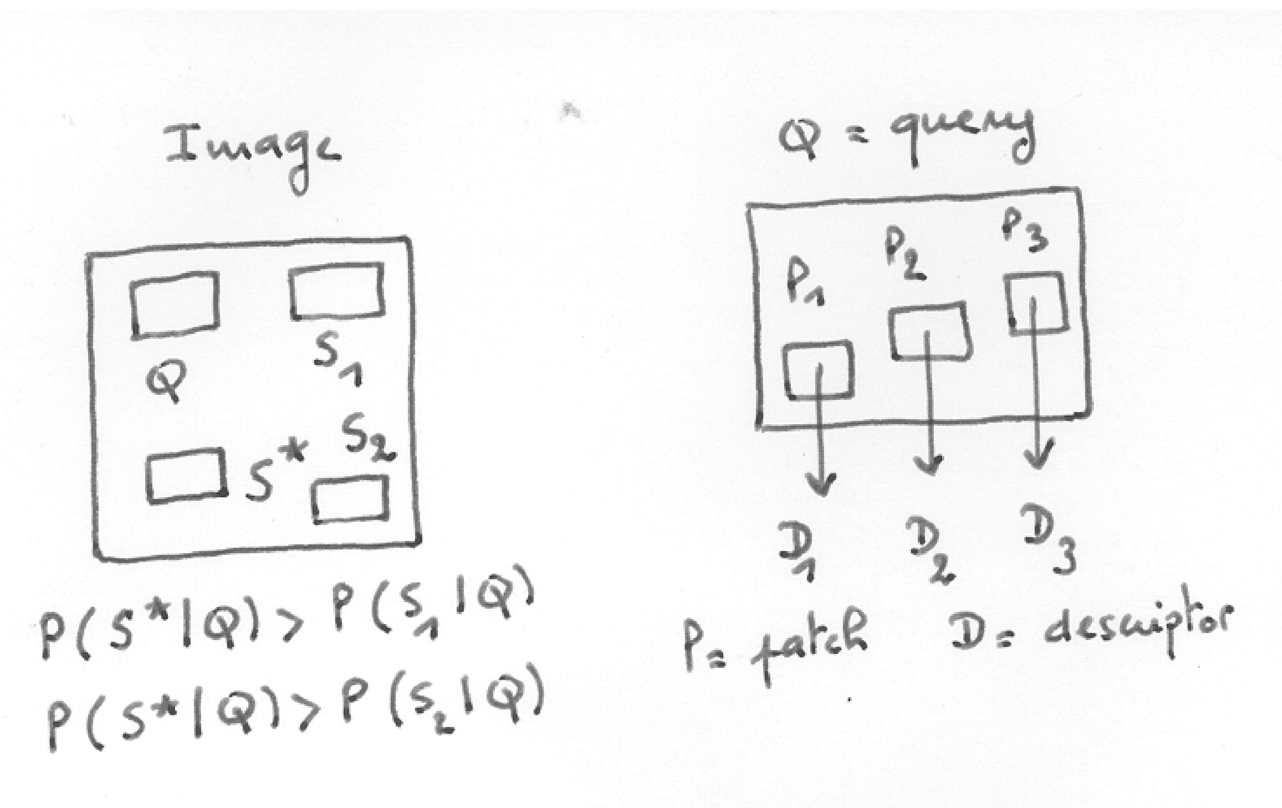
SUMMARY

This work is on the detection of mines in sonar images. The main objective is to show that it is possible to reveal mines as anomalies with respect to the seabed. What is naturally required is to be able to measure the similarity between regions of a sonar image. Such a measure has to account for the variability of the types of seabed. We used the concept of similarity by composition. A query, that is, a specific region of a sonar image, is compared to the rest of the image, that is, the reference. The query is broken into many overlapping patches. What is measured is how easy it is to compose the query using patches from the reference.

We consider a query signal Q which is a rectangular region extracted from the sonar image under study. We consider the rest of the image as a reference R. We look for the signal S* in the reference which is most similar to the query Q, that is

$$S^* = \arg\max_S \mathbf{P}(S\,|\,Q)$$

where $\mathbf{P}(S\,|\,Q)$ quantifies the amount of similarity between any candidate signal S, in the reference R, and the query Q.



We used the concept of similarity by composition [BI07]. The query signal Q is broken into many small overlapping patches, and so are the candidate signals S. Every patch is characterised by a descriptor D and a position P relative to a pre-defined centre C.

$$Q \equiv (C_Q, D_Q^1, P_Q^1, D_Q^2, P_Q^2, \dots D_Q^n, P_Q^n)$$
$$S \equiv (C_S, D_S^1, P_S^1, D_S^2, P_S^2, \dots D_S^n, P_S^n)$$

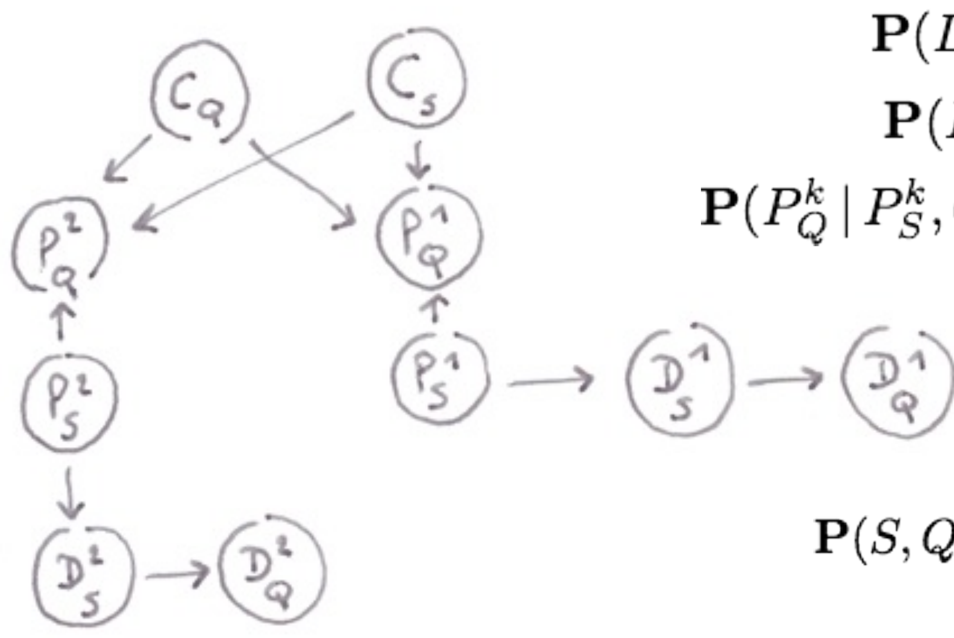
The statistical dependences between the centres, the patches' descriptors, and the patches' positions are modeled by a Bayesian network.

$\mathbf{P}(S\,|\,Q)$ is now the conditional distribution of S given Q.

Maximum a posteriori estimation

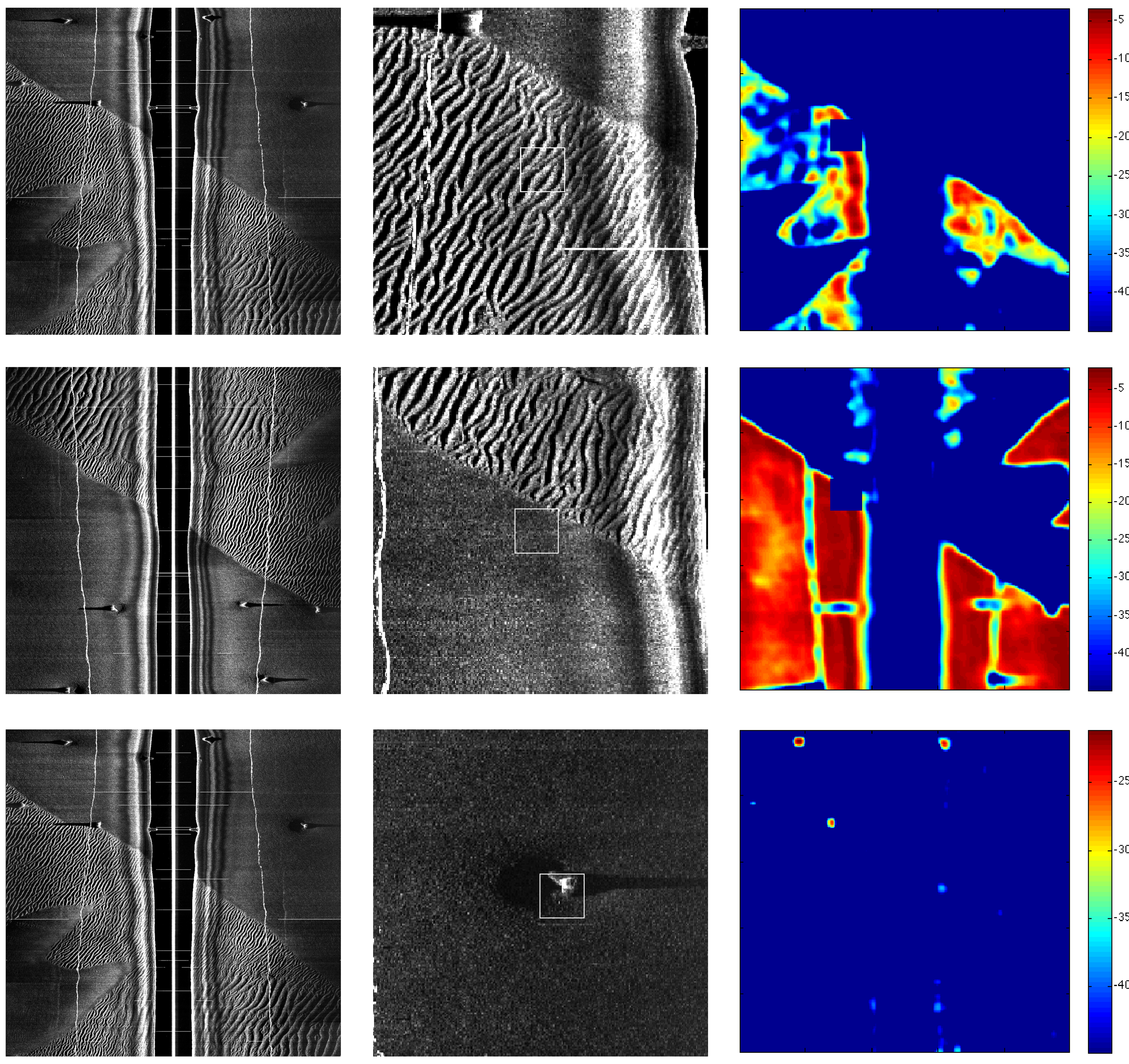
$$\begin{aligned} S^* &= \arg\max_S \mathbf{P}(S\,|\,Q) \\ &= \arg\max_S \mathbf{P}(S,Q)/\,\mathbf{P}(Q) \\ &= \arg\max_S \mathbf{P}(S,Q) \end{aligned}$$

Practically, the maximisation over the set of all possible candidate signals S is performed with the help of a belief propagation algorithm [YFW01].



$$\mathbf{P}(D_Q^k\,|\,D_S^k) \to \text{Gaussian distribution}$$
$$\mathbf{P}(D_S^k\,|\,P_S^k) \to \text{Dirac distribution}$$
$$\mathbf{P}(P_Q^k\,|\,P_S^k, C_S, C_Q) \to \text{Uniform discrete distribution}$$

$$\mathbf{P}(S,Q) = \mathbf{P}(C_S)\,\mathbf{P}(C_Q) \times \prod_k \Big[\mathbf{P}(P_S^k)\,\mathbf{P}(D_Q^k\,|\,D_S^k)\,\mathbf{P}(D_S^k\,|\,P_S^k) \times \mathbf{P}(P_Q^k\,|\,P_S^k, C_S, C_Q)\Big]$$



Left. Sonar image. Middle. Query signal. Right $\mathbf{P}(S,Q)$ associated with all possible signals S in the image. The score is displayed in a logarithmic scale. Red = high similarity. Blue = low similarity.

[YFW01] J. Yedidia, W. Freeman, and Y. Weiss, Understanding Belief Propagation and its Generalisations, International Joint Conference on Artifitial Intelligence, 2001
[BI07] O. Boiman and M. Irani., Similarity by composition, In Advances in Neural Information Processing Systems, 2007.

[dstl]

MINISTRY OF DEFENCE

EPSRC
Engineering and Physical Sciences Research Council

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) and the MOD University Defence Research Centre on Signal Processing (UDRC).