A multivariate Hit-or-Miss Transform for conjoint spatial and spectral template matching

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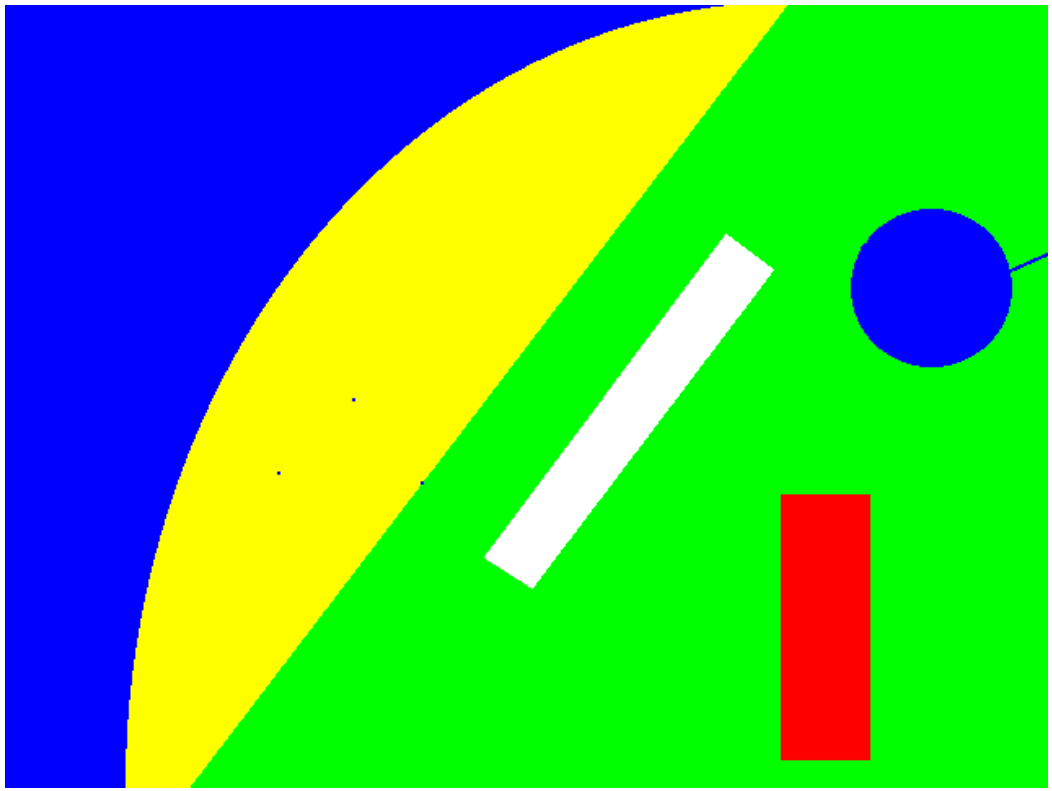
Spatial template-matching $\Longrightarrow$ Binary/Grayscale Hit-or-Miss Transform (HMT)

Spectral template-matching $\Longrightarrow$ Spectral classification



Goal: detect blue-yellow borders

How to combine both kinds of information ?

Flat erosion and dilation for greylevel images

$$\varepsilon_B(f)(p) = \inf_{y \in B} \{f(p+y)\} \quad (1)$$

$$\delta_B(f)(p) = \sup_{y \in \check{B}} \{f(p+y)\} \quad (2)$$

Using a structuring function is possible but less frequent

Examples

Original image
(256x256)

Image eroded
by a 5x5 square

Image dilated
by a 5x5 square

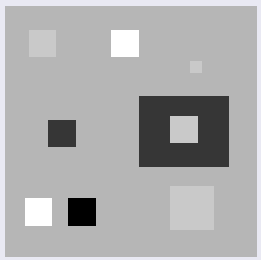
Fitting

$$\text{Fitting}_{(B_1,B_2)}(f)(p) = \varepsilon_{B_1}(f)(p) > \delta_{\check{B}_2}(f)(p) \quad (3)$$

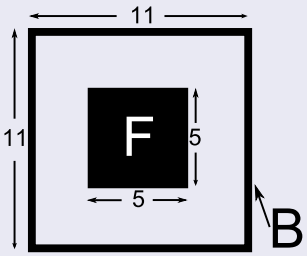
Valuation

$$\begin{aligned} \text{Valuation}_{(B_1,B_2)}(f)(p) &= \varepsilon_{B_1}(f)(p) && (\textit{Ronse}) \quad (4) \\ &= \varepsilon_{B_1}(f)(p) - \delta_{\check{B}_2}(f)(p) && (\textit{Soille}) \quad (5) \end{aligned}$$

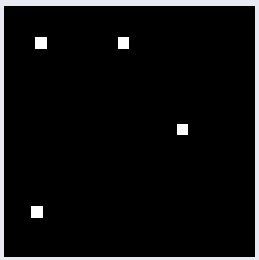
Examples



Original image (64x64)



SEs used for processing of HMT



Fitting result

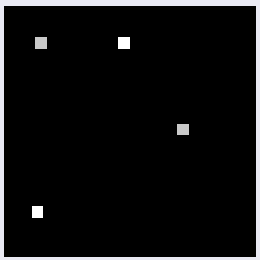


Image result of HMT by Ronse

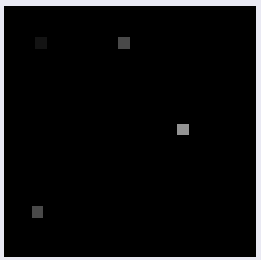


Image result of HMT by Soille

Marginal

$$\varepsilon_g(f)(p) = [\varepsilon_g(f_1)(p), \ldots, \varepsilon_g(f_n)(p)]$$

+

Straightforward extension of grayscale MM

-

No channel correlation
No vector preservation

Vectorial

$$\varepsilon_g(f)(p) = \inf_{y \in g}{}_{\mathrm{v}} \{f(p+y)\}$$

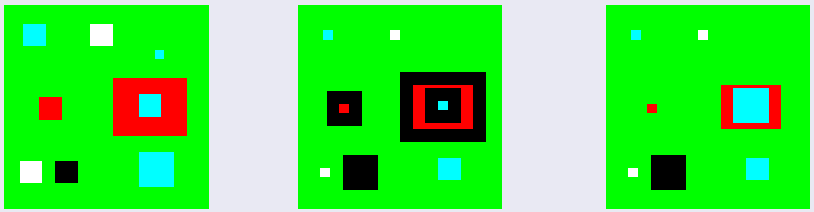
+

Channel correlation
Vector preservation

-

Choice of vectorial ordering

Examples



Original image (256x256) | Marginal erosion by a 5x5 square | Vectorial erosion by a 5x5 square

E. Aptoula, S. Lefèvre, A Comparative Study on Multivariate Mathematical Morphology, Pattern Recognition, Vol. 40, No. 11, november 2007, pages 2914-2929.

Multivariate Hit-Or-Miss Transform formulation

- Fitting

$$\text{Fitting}_B(f)(p) = \begin{cases} \varepsilon_{B_{sh}}(f_{B_b})(p) \geq B_{th} & \text{if } B_{ty} = \varepsilon \\ \delta_{B_{sh}}(f_{B_b})(p) \leq B_{th} & \text{if } B_{ty} = \delta \end{cases} \tag{6}$$

$$\text{Fitting}_S(f)(p) = \bigcap_{B_i \in S} \text{Fitting}_{B_i}(f)(p) \tag{7}$$

- Valuation

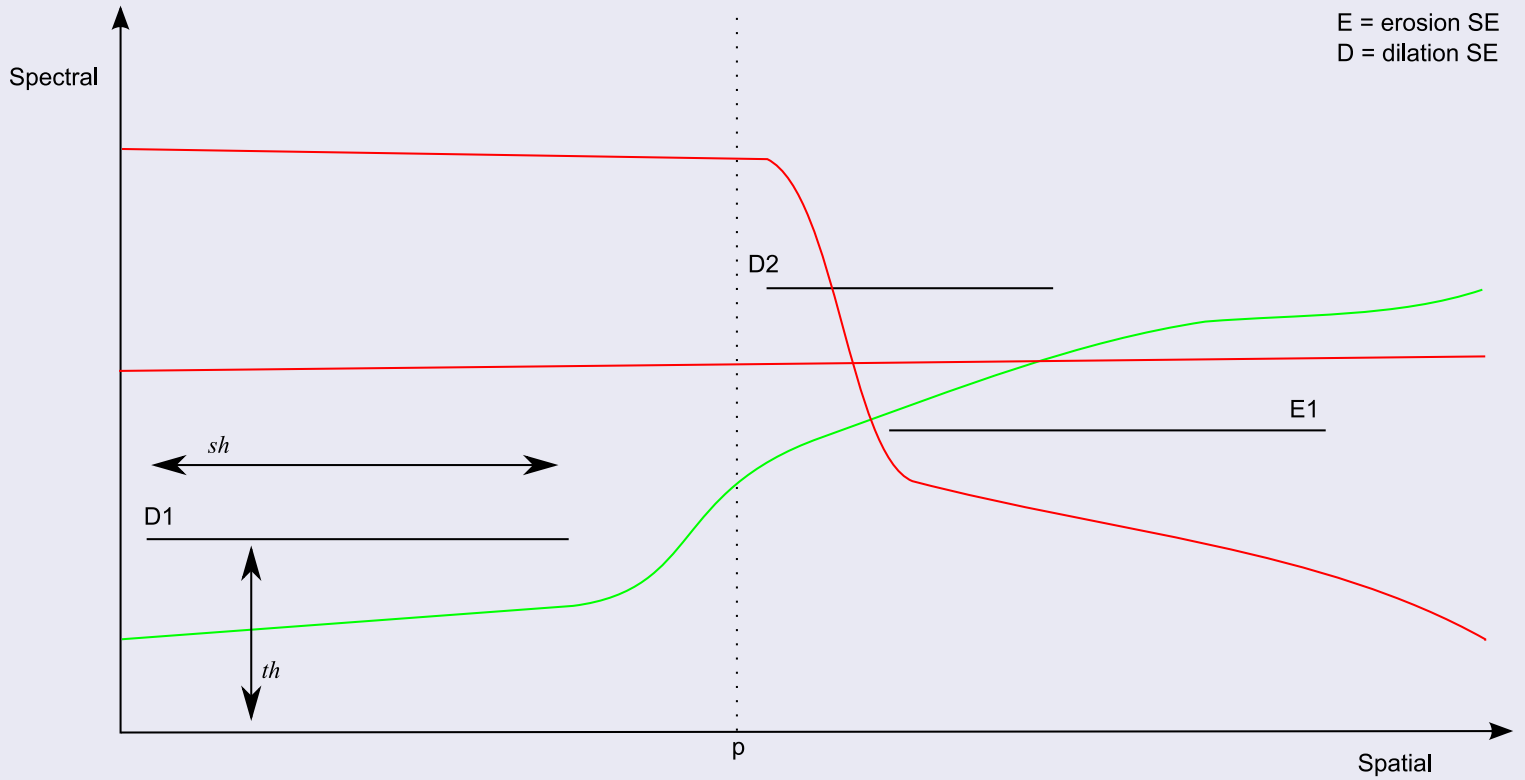
$$\text{Valuation}_B(f)(p) = \begin{cases} \frac{\varepsilon_{B_{sh}}(f_{B_b})(p) - B_{th}}{f^+_{B_b} - B_{th}} & \text{if } B_{ty} = \varepsilon \\ \frac{\delta_{B_{sh}}(f_{B_b})(p) - B_{th}}{f^-_{B_b} - B_{th}} & \text{if } B_{ty} = \delta \end{cases} \tag{8}$$

$$\text{Valuation}_S(f)(p) = \frac{1}{|S|} \sum_{B_i \in S} \text{Valuation}_{B_i}(f)(p) \tag{9}$$

MHMT SE are defined by shape(sh), band(b), threshold(th) and type(ty).

$[f^-, f^+]$ is the pixel value range in f.

Example of fitting on a band



Advantages

- Adapted to multivalued images
- Both spatial and spectral informations are considered
- Domain-knowledge may be involved
- The number of SE is not limited to a pair (erosion or foreground SE, dilation or background SE)
- No unique value range for the different bands is required
- Faster than standard HMTs

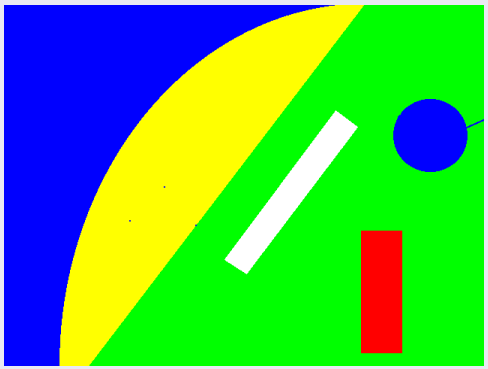
Drawbacks

- SE construction is not trivial
- Not robust to noise
- Band correlation is considered only through a fusion operator

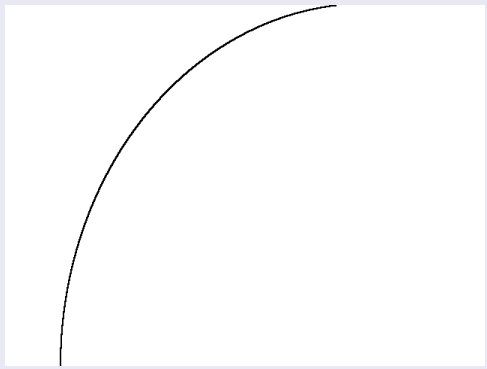
Goal

- Extraction of border between blue and yellow areas
- Processing of MHMT with opposite linear structuring elements

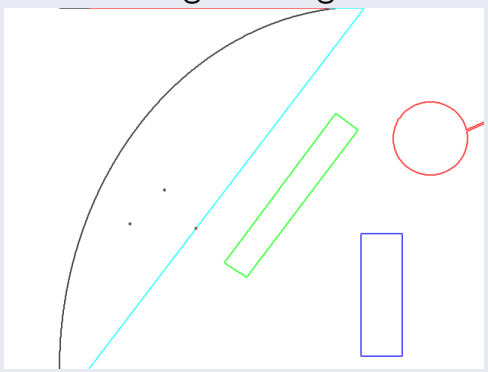
Comparison with standard edge detector



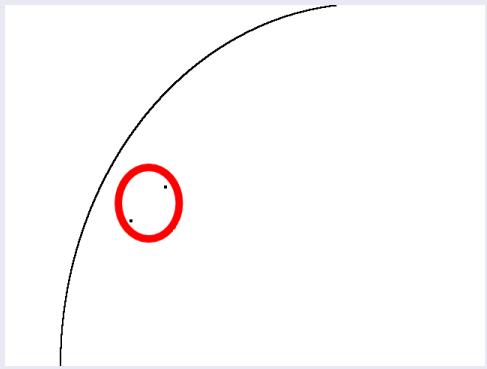
Original image



MHMT

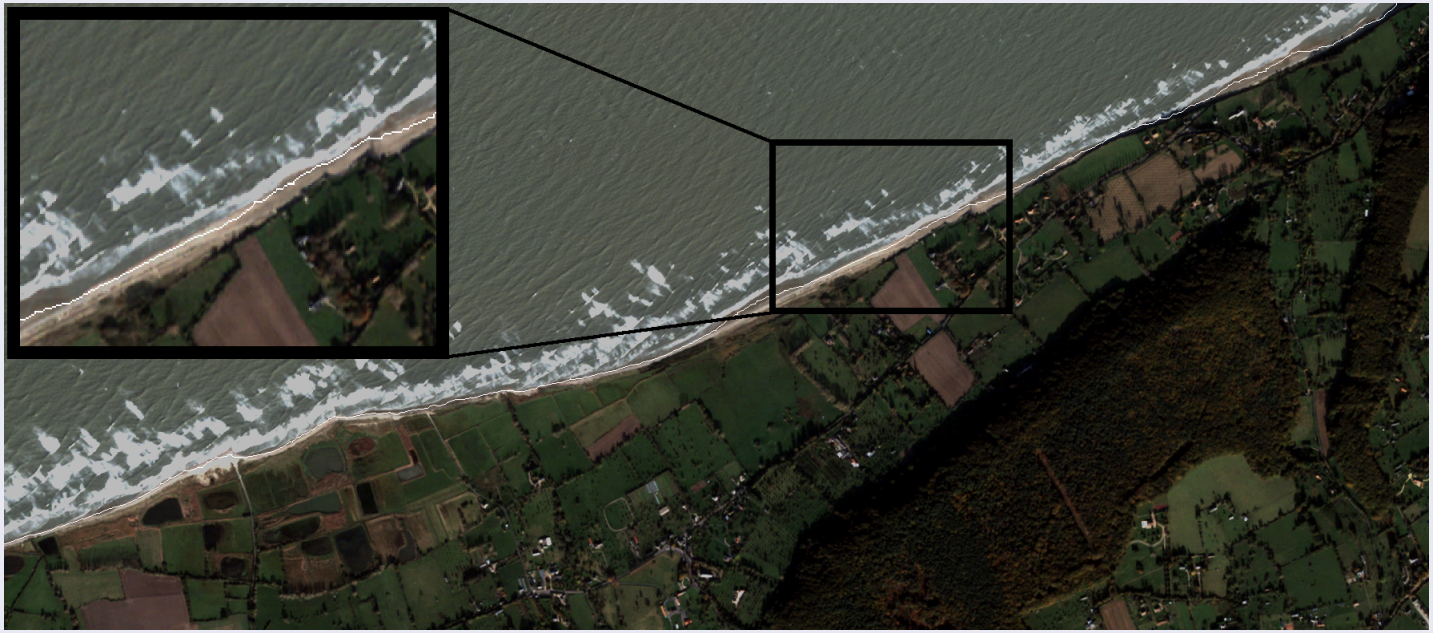


Sobel



Intersection of edge detections on band Y and B

Coastline Extraction on Normandy Coast



QuickBird image at spatial resolution of 2.4 m / pixel ((c)Digitalglobe)

Average location error

Wetlands areas	Soft rock hillslope	Sandy beaches with dunes	Hard rock cliff
0.45	2.32	1.79	0.35

A. Puissant, S. Lefèvre, J. Weber, Coastline extraction in VHR imagery using mathematical morphology with spatial and spectral knowledge, ISPRS 2008 Congress, Beijing, China, July 2008

Coastline Extraction at different resolutions

30m/pixel

20m/pixel

10m/pixel

5m/pixel

Comparison with Bagli's method for coastline extraction

	30m	20m	10m	5m
Bagli and Soille, 2003	0.055	5.655	7.443	5.145
MHMT	0.035	0.195	0.79	0.079

Contribution of this work

- A HMT formulation adapted to multivalued images and combining spatial and spectral information
- A relevant method for extracting specific edges and boundaries

Future works

- Apply MHMT to other fields
- Ensure robustness to noise
- Use of structuring functions
- Semi-automatic methods for SE definition

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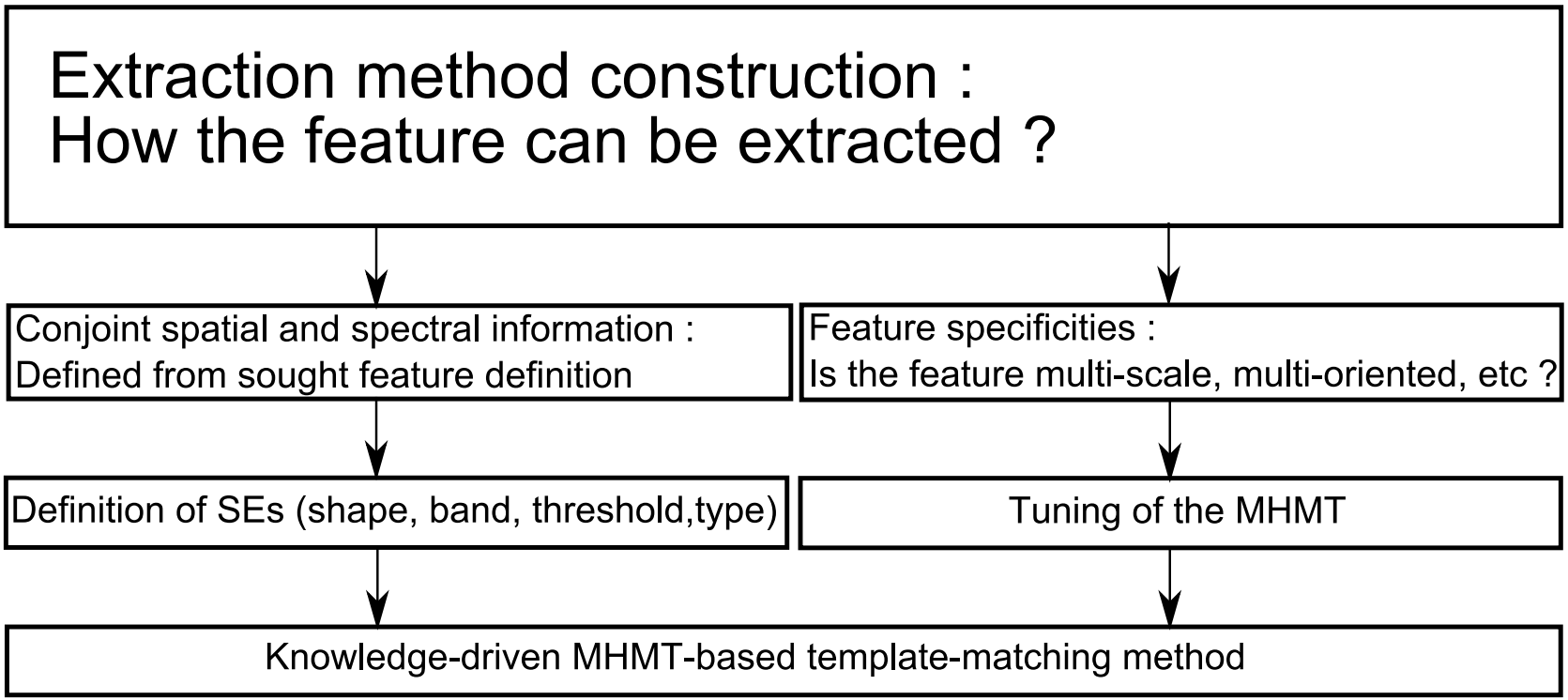
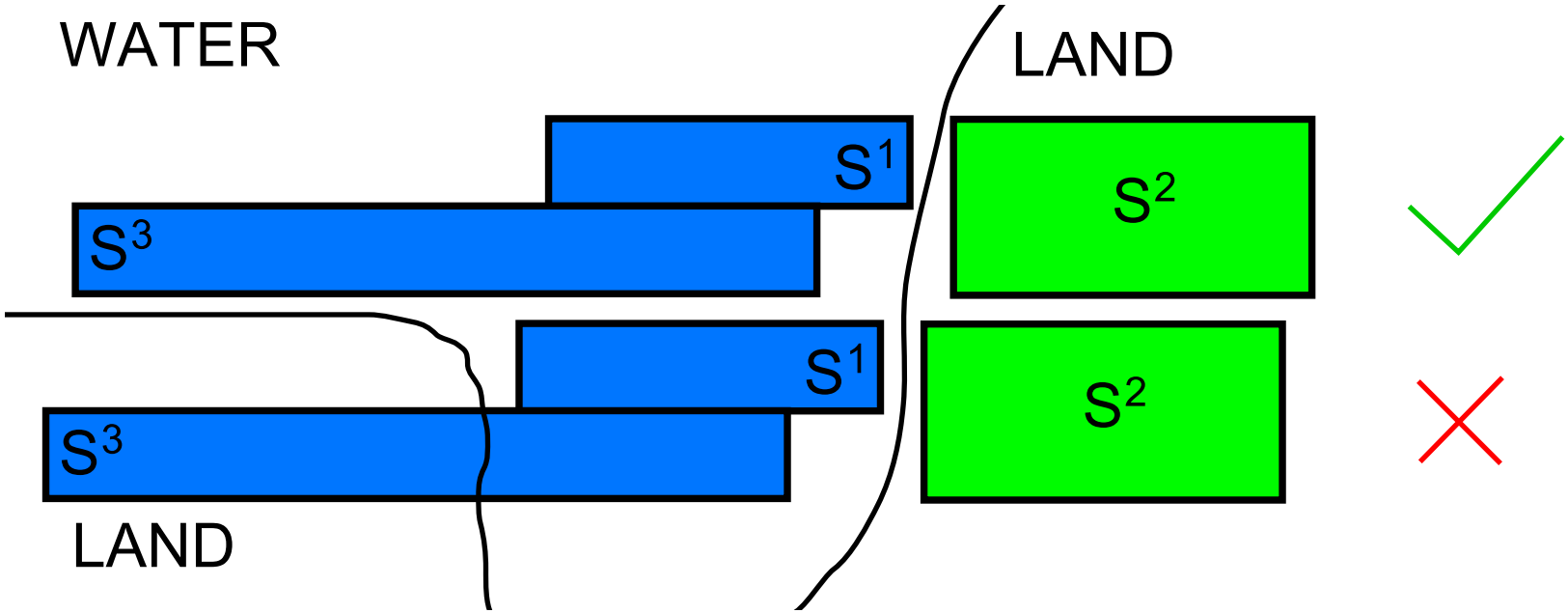
http://ecosgil.u-strasbg.fr/


Extraction method construction :
How the feature can be extracted ?
Conjoint spatial and spectral information :
Defined from sought feature definition
Feature specificities :
Is the feature multi-scale, multi-oriented, etc ?
Definition of SEs (shape, band, threshold,type)
Tuning of the MHMT
Knowledge-driven MHMT-based template-matching method


WATER
LAND
S^1
S^2
S^3
S^1
S^2
S^3
LAND