Using an Expert System to Update Forest Maps

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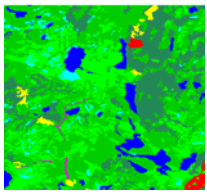
The problem of change detection

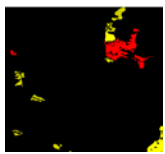
Given:

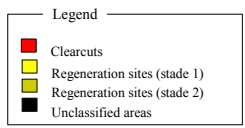


An old forest map (1988)

A new satellite image (1999)

Asked: explanation of changes during the period





Research Objective

- Change detection is a important in remote sensing
  - Climate change, environmental change, natural resources monitoring, forest management.
- Map update is still made by human interpretation
  - Expensive and time consuming
- Satellite images are becoming increasing accurate
  - E.G: Ikonos images have a 1 meter pixel precision
  - Difficult to remain update with features of new image analysis algorithms
- Objective of our research project:
  - Assisting human image interpreters in map update

Why an Expert System Approach ?

- Most automated approaches to image interpretation focus on algorithmic techniques.
  - Few approaches try to integrate IA methods.

- An expert system approach would allow to integrate:
  - Expert rules of thumbs for image analysis
  - Background knowledge about regions of interests
  - Knowledge about the strengths and weakness of image analysis algorithms

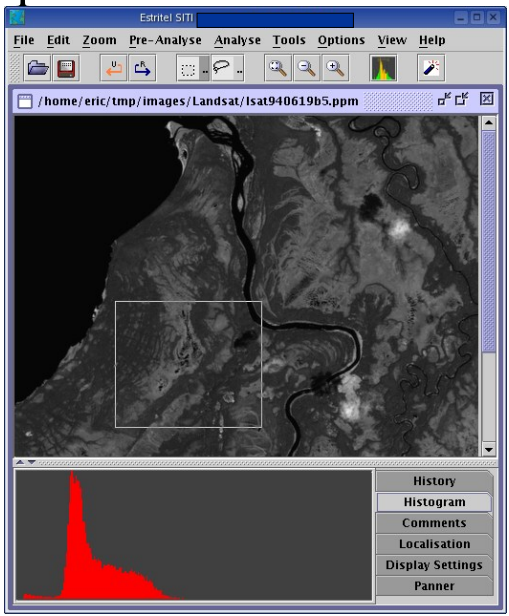
Plan of the Talk

- Our approach
  - Data selection and acquisition
  - Image processing selection
  - Image interpretation
- Conclusion

Our approach

- The expert system is split into three simpler expert systems:
  - Data selection
  - Image processings selection
  - Interpretation
- Rationale:
  - Updating a map is a long process and each step needs specific skills
  - Splitting the problem reduces the complexity for
    - Implementing the system and managing it
    - Using the system

Graphic User Interface



System Architecture

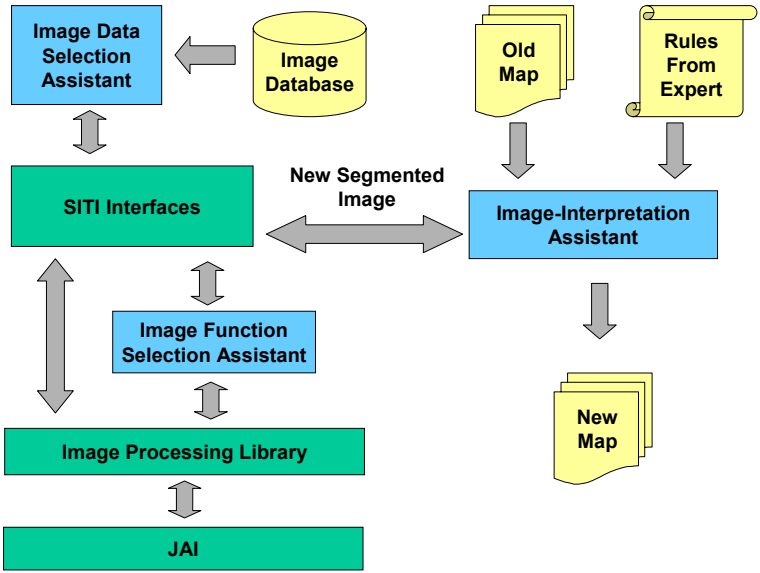
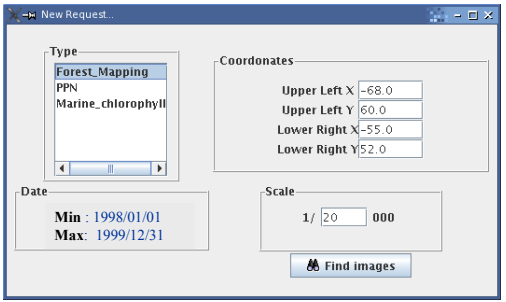


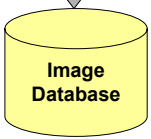
Image Data Selection Assistant (IDSA)

- The challenge of selecting the right images
  - A lot of sensors are available on the market
  - The user may already own a huge amount of images for different zones, different dates and different sensors.
  - The choice of the image depends of the task, precision quality, and price, …
- IDSA methodology:
  - A database of images and sensors
  - A rule-based system for image data selection

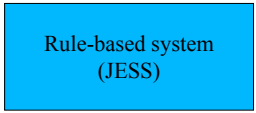
Image Data Selection Assistant (IDSA)



Request from the user



Do a search in a SQL Database



Filter results that matches user requests

No

Yes

Image Data Selection Assistant (IDSA)

- Samples rules
  - IF Theme(Forest) AND Have_Image(TM) AND Have_Image(MSS)
    => Remove_Image(MSS)

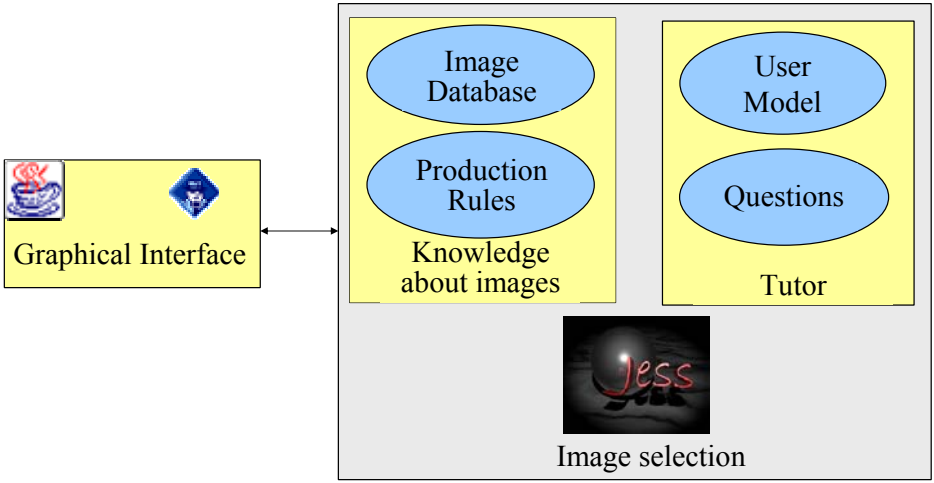
TM image are more precise than MSS image

- IF VeryHumidZone(true) OR WetSeason(true)
  => UseRadar(true) AND UseOptic(false)

For humid zones or during wet season, images may contain clouds.

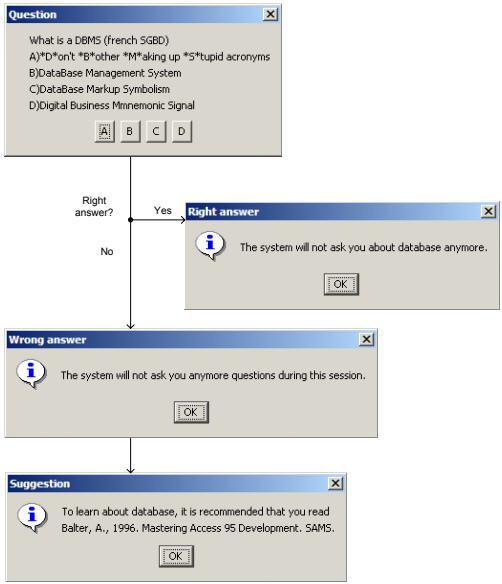
Radar images are preferable over optical images

IDSA Architecture



IDSA Tutor

Elicitating the user model



Sample output by IDSA

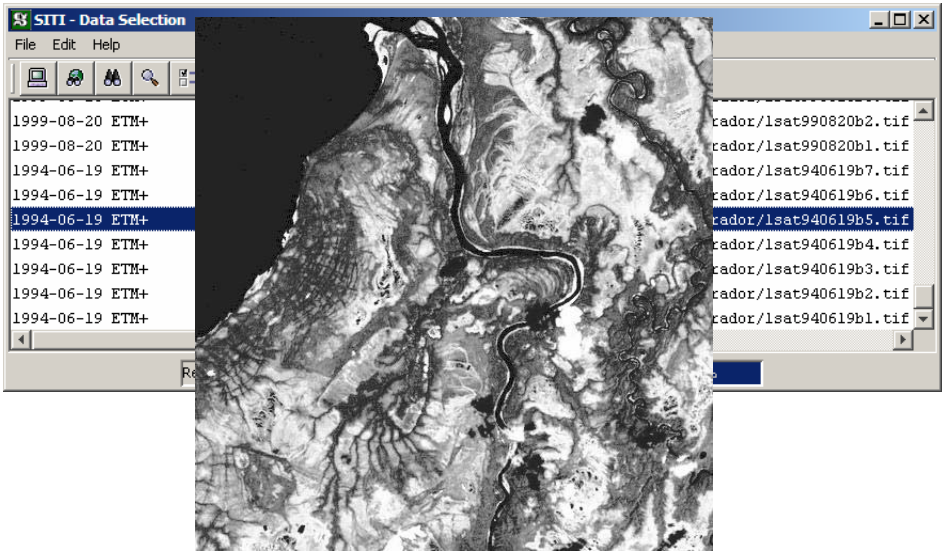


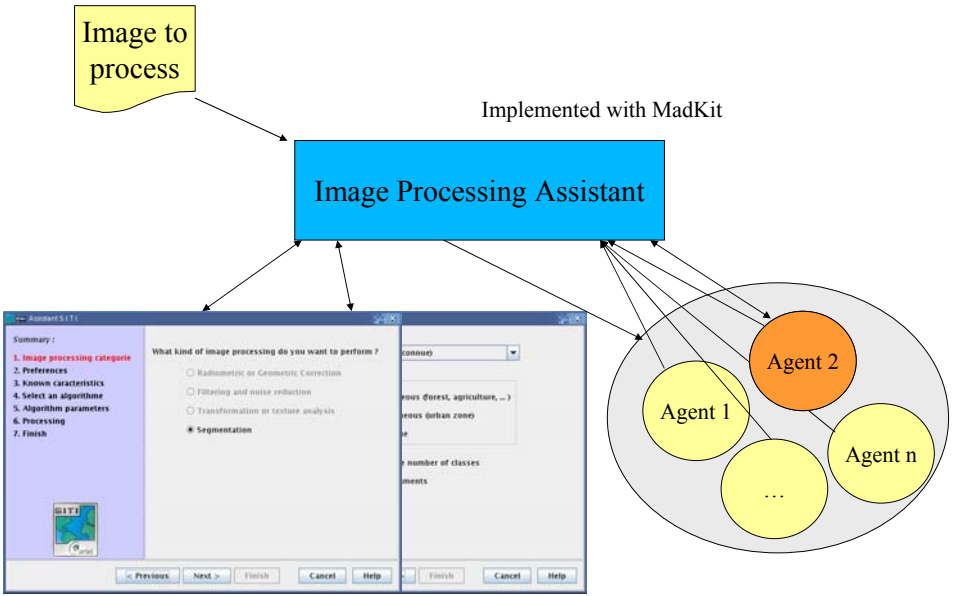
Image Processing Assistant (ASA)

- Before interpreting a map, several pre-processing steps are needed
  - Atmospheric corrections
  - Image filtering
  - Geometrics corrections
  - Classification and segmentation
- For each step, many algorithms may exist, with different strengths and virtues depending on:
  - Image type (sensor and resolution)
  - Speed of processing
  - Known parameters for the scene
  - Background knowledge

Image Processing Assistant (ASA)

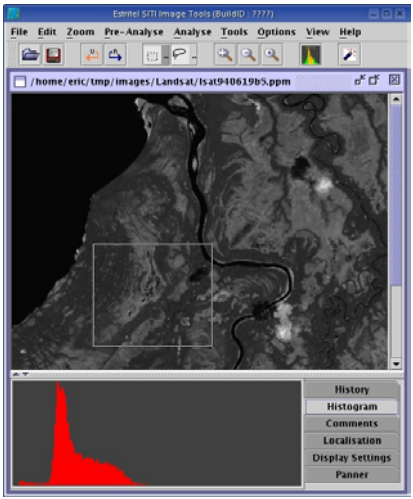
- Multi-agent system
  - Each algorithm is represented by an agent
  - ASA acts as a broker that negotiates with agents
- The decision process
  - The user chooses the type of image processing he wants to perform
  - Agents that can process the request are activated
  - The user gives preferences and known variables about the request
  - Each agent makes a bid for the request
  - ASA chooses the best offer from the agents and contacts the winner to perform the image processing

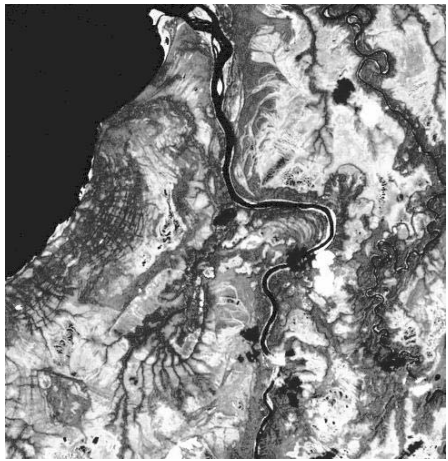
Image Processing Assistant (ASA)



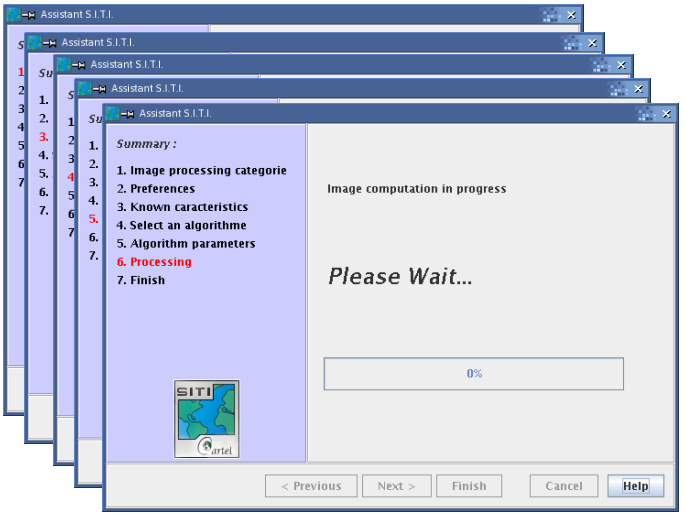
Example of Interaction with ASA

The user has currently loaded in SITI a LandSat image of a zone the Labrador (Canada)



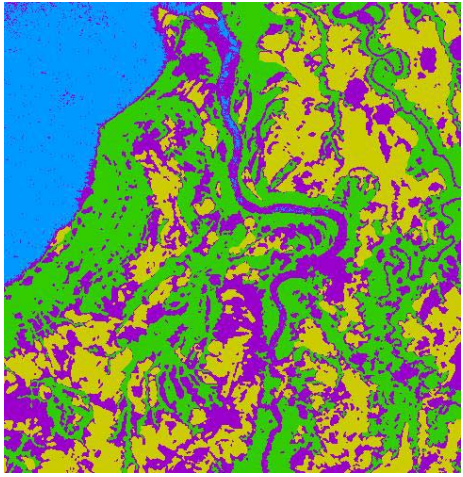


Example of Interaction with ASA



Example of Interaction with ASA

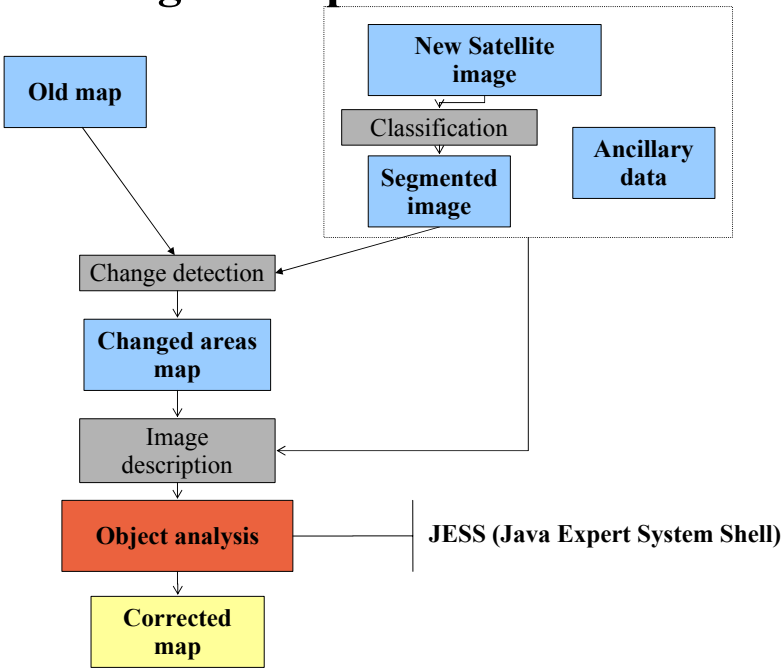
Result of segmentation

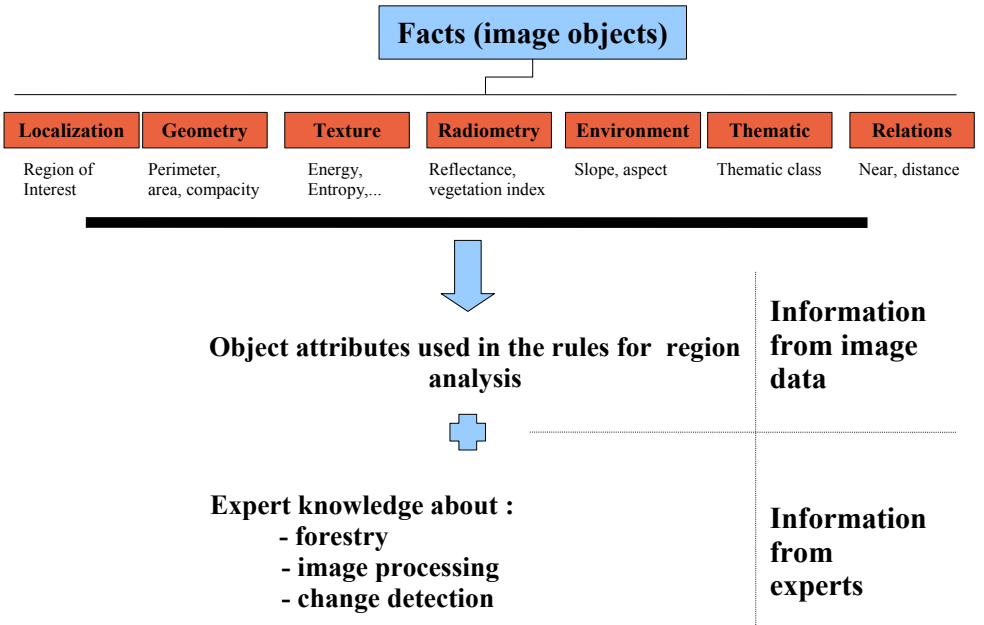


Classified Image Interpretation Assistant (CI2A)

- **A segmented/classified image is a new map, but rarely accurate**
  - Noise filtering and image classification/segmentation, have a limited accuracy
- **Human expertise is required to refine the output of the segmentation step**
  - Using an old map as reference and background knowledge
- **CI2A assists in this refinement process**
  - Using a knowledge base about image interpretation: radiance, textural, contextual, temporal, background knowledge (old map)
- CI2A verifies the correctness of segmented regions (forest cut, regeneration site, water, …)

CI2A : Image Interpretation Assistant




Facts (image objects)
Localization
Geometry
Texture
Radiometry
Environment
Thematic
Relations
Region of Interest
Perimeter, area, compacity
Energy, Entropy,...
Reflectance, vegetation index
Slope, aspect
Thematic class
Near, distance
Object attributes used in the rules for region analysis
Information from image data
Expert knowledge about :
- forestry
- image processing
- change detection
Information from experts

Illustrations of production rules

- The reduction of a vegetation suggests a loss of vegetation cover (with some degree of confidence)

```
(defrule prob-recent-oldforest-ndvilow

  (declare (salience 20))


  ?f <-  (object (number ?number)
                 (oldclassName mixed|dense|open|shrub)
                 (ndvi ?ndvi))
 (test (< ?ndvi ?*ndvilow*))
=>
 (probClassSeg "store" ?number recent (* ?*conf-ndvi* 0.8)))
```

- A cut or a road in the vicinity of a changed area suggests a clearcut.

```
(defrule neighb-class

   (declare (salience 20))

   ?f1 <- (object (number ?number))
   ?f2 <- (object (number ?number1)  (className ?class))
=>

  (probClassSeg "store" ?number ?class (* ?*conf-neigh* 0.8))
  (retract ?f2))
```

- For some areas we have ground samples used by forest managers.
- If a region's attributes match those of a sample then the region has to be in the same thematic class.

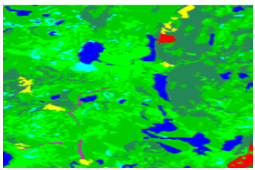
```
(defrule samples-location-near
   (declare (salience 20))
   ?f<-(object (number ?number) (centerObj TRUE) (xc ?xc) (yc ?yc))
=>
   (checksamples "dist" ?number ?xc ?yc 1000))

(defrule samples-location-near-print
    (declare (salience 20))
   ?f<-(checkspec ?number ?classname ?class)
   ?f2<-(object (number ?number) (band $?bd) (centerObj TRUE))
=>
   (bind ?distTmp (statCalculator "verifyNeighClass" ?class $?bd))
   (if (> 1 ?distTmp)
       then
      (assert (prob-class ?number ?classname (* ?*conf-samples* 0.8) 0)))
(retract ?f))
```

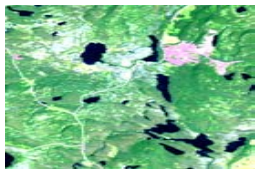
- Certain types of changes can occur only after a given time period.
- Regeneration sites appear after a clearcut and are visible on a satellite images if they are at least 2 years old.

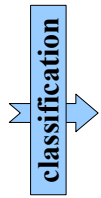
```
(defrule prob-recent-oldforest
   (declare (salience 20))

  ?f<-(object (number ?number) (oldclassName cut))
   ?f2<-(period (year ?year))
   (test (< 2 ?year))
=>
  (probClassSeg "store" ?number regen1
       (* ?*conf-transi* 0.7)))
```

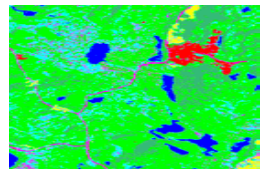
Example of a region in Labrador

Input:







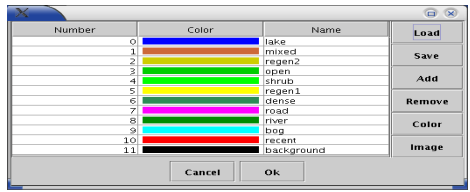


Original map (1988)

Satellite image (1999)

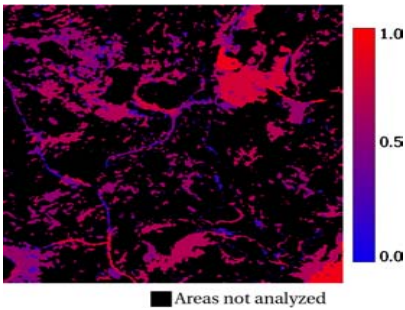
Segmented image

Thematic classes defined by an expert and used in CI2A.



Example of a region in Labrador

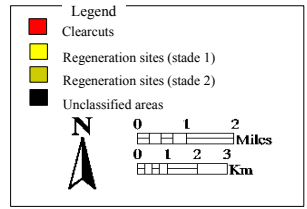
Output:



Identification of disturbed areas on the Labrador region and creation of a certainty map.

Size: 10 km x 10 km

Takes 2.7 min on a Pentium 800 MhZ

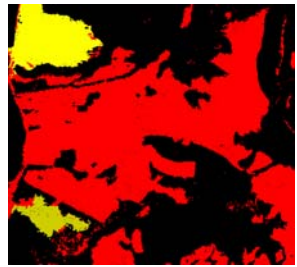


Comparison with traditionnal approaches

Type	Change detection	Identification	Input data
Partially automatized methods	Image differencing	statistical classification	Old and new image
	Principal components analysis	statistical classification	Old and new image
	Cross-correlation analysis	statistical classification	Old map and new image
Human interpretation	Visual detection	Visual identification	Old map and new image

Method	False alarm (%)	Good identification (%)
Image differencing	7	80
Principal components analysis	7	79
Cross-correlation analysis	6	53
Human interpretation	0	90
CI2A	2	86

Results on VHSR image (Ikonos)



Human interpretation **CI2A**

The human interpretation costs 7-8 hours for this small area.

CI2A gives a result quite similar in 5 min.

Strengths of CI2A

- Because it uses production rules:
  - CI2A has easy explanation capabilities.
  - Is modular:
    - New rules can be added easily
    - Debugged easily.

Limitations / Future Developments

- Difficult to elicitate the certainty factors
- Certainty factors are not probabilities
- Acquiring the knowledge base is time consuming
- JESS is a heavy-weight expert system shell

Conclusion / Acknowledgements

- SITI consists of three Expert Systems
  - Data selection and acquisition
  - Image processing selection
  - Image interpretation
- Still a prototype, but promising
- Thanks to:
  - Natural Science and Engineering Research Council (NSERC)
  - Canada Centre for Remote Sensing
  - Sepia Technologies Inc.