Thermal Video Processing Support for Rescue Operations

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Tools for Rescue Operation Management – Today
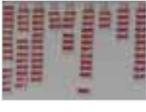
Tools for Rescue Operation Management – SHARE
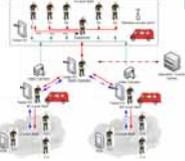
SHARE Overview: MAP3D

SHARE Overview: PTS Video

SHARE Overview: Interactive Resource Management
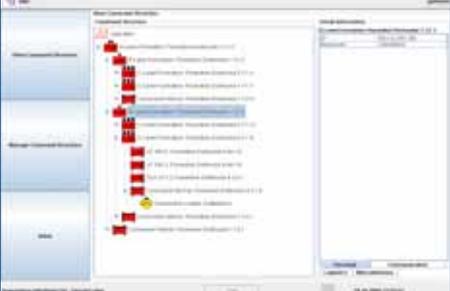
SHARE Overview: Thermal Video Processing

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SHARE architecture

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SHARE architecture
Thermal image and video processing

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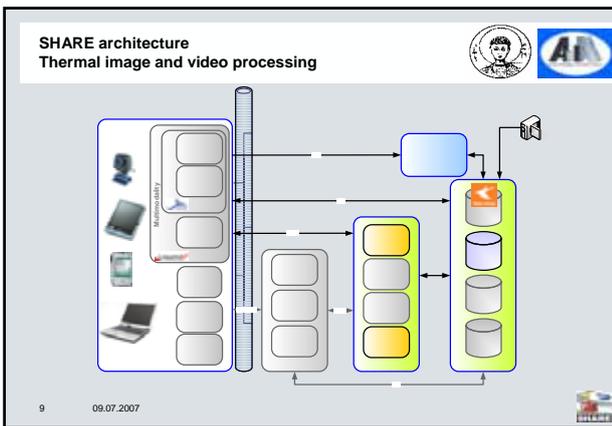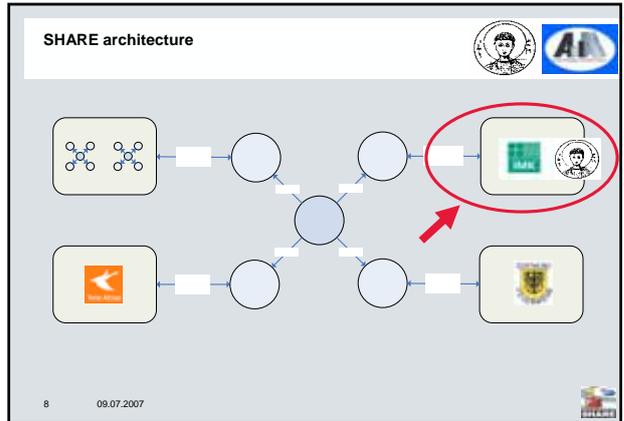
Objectives

- **To provide tools** for image and video analysis for assisting a fire-brigade or another rescue team during and after the rescue operation.

- **Integration** of state-of-the-art techniques for analyzing images/videos acquired using a thermal camera in a fire/smoke environment.

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Normal vs. thermal view: An example

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General aims

Fire focus
Fire occurrences according to hotspot detection
to localize the fire, estimate its spreading and
determine/estimate its change in time.

Person detection
Human occurrences in thermal videos to
localize human silhouettes to derive rescue
and positioning information.

Person tracking
Human movement analysis in the fire videos
according to the trajectory analysis of them.
E.g. slower/faster movements, directions.

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Retrieval

Digital
Message Form
Client

Web Cam

ASR

TCP

FTP

Thermal Camera
Video / Image
Processing
Server

Thermal Camera

Map
Database

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End-user requirements

Colorization
The thermal camera view is generally B&W. The grey tones make it difficult to get a quick overview of thermal characteristics of different objects.
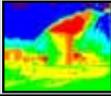
Interactive object detection and recognition
The recognition of objects is difficult. The user has to click on any area and the recognition module should mark the object. A further requirement is identification i.e. as a person.

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End-user requirements

Tactical effectiveness
A very important function is the time control of tactical effectiveness. This function is needed to see the thermal condition of an object within different periods (e.g. 10 seconds steps). The thermal status of the marked object is visualized by colored faces. This helps the officer in charge to verify the effectiveness of his tactic, and to correct the methods very fast.

t=0s   t=10s   t=20s

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Integration of the thermal video processing component

AUTH released:
➢ Sample client application
➢ XML Schema to define the control message interface
➢ A test version of the service application

Main SHARE Client

| MAP | DMF | VIDEO | TC | RET. |

Archive / FTP File System

Ontology entry for new video

Get data from file system (ftp)

Ontology

Inserting metadata

Put data into file system

Control Traffic: Video file name, processing parameters

Thermal Video Processing

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Integration of the thermal video processing component

- Defining GUI requirements for the SHARE client

- Creating a service module with supporting video processing tasks for the second prototype

- Creating a command message interface

- Releasing a sample client

- Adding XML parsing functionalities to interpret the control message and prepare Java source for ODS

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Requirements for the client GUI

- SHARE thermal video processing tools (1st prototype GUI):

SHARE Tools

☐ Boundary Detection   ☐ Boundary Tracking   ☐ Boundary Object Recognition

☐ HotSpot Detection
☐ Adaptive HotSpot Detection   ☐ Colorization   ☐ Tactical Effectiveness

OK   Cancel

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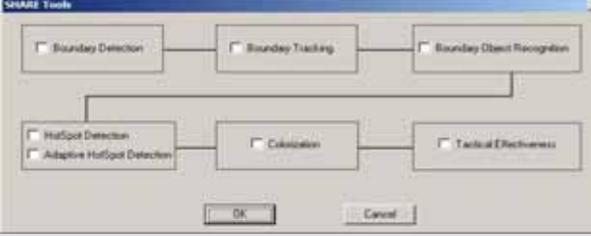
Requirements for the client GUI

- Selection of regions of interest (1st prototype GUI):

| Bounding box | Snake |

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Definition of a control message interface

- Information sent from the client to the service:
  - Data server and directory information for the input video (video output is generated here, as well),
  - Name of the file to be processed,
  - Processing tasks together with their ROIs and scope (start frame/end frame information),
  - The control message is defined in terms of an XML Schema, and thus the message is sent as an XML file (IP package).

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Control message interface, root class
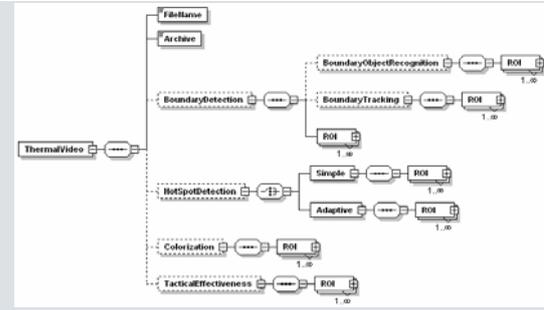
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Control message interface, ROI class
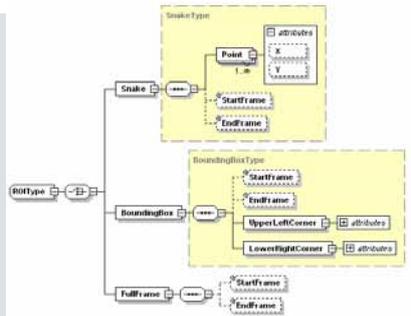
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Research activities

- Content description of thermal videos

- Fire detection with Fourier analysis

- Supervised object extraction by snakes
  - Tracing quadtrees for better concavity performance
  - Content adaptive heterogeneous snakes

- Automatic object detection and recognition
  - Creating human pose database
  - Hierarchical clustering for template databases
  - Textual description of database for faster matching
  - Divide and conquer strategy for affine distortions
  - Object simplification for faster matching

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Research activities
Content description of thermal videos
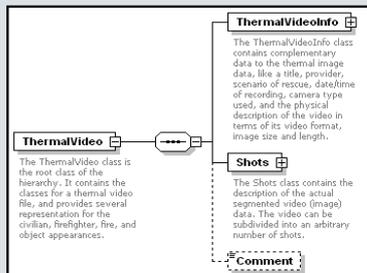
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Research activities
Content description of thermal videos
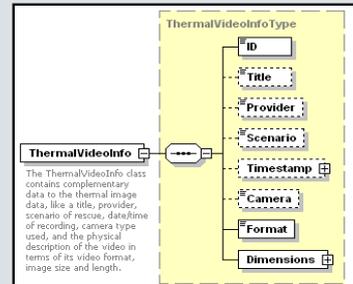
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**Questions on fire:**
➢ Is there any fire in the XXX scenario?
➢ Is there any fire in the XXX scene?
➢ Is there any fire in the XXX scene having YYY status?
➢ Where is the fire in the XXX scene at the YYY time?
➢ Where is the fire in the XXX scene having YYY status?
➢ What is the status of the fire in the XXX scene?

Questions on human:
➢ Are there any humans in the XXX scenario?
➢ Are there any humans in the XXX scene?
➢ Are there any humans in the XXX scene having YYY status?
➢ Where are humans in the XXX scene at the YYY time?
➢ Are there any humans in the XXX scene having YYY status?
➢ Where are humans in the XXX scene having YYY status?
➢ What is the status of humans in the XXX scene?
➢ Are there any humans in the XXX scene having YYY activity?
➢ Where are humans in the XXX scene having YYY activity?
➢ What is the activity of humans in the XXX scene?

▪ Fire has a special behavior in the frequency domain, so temporal Fourier analysis can be executed to check it, as fire usually has 0.5-20Hz flickering. Artificial fire:

$F(u)$ is the average temporal Fourier transform for the changing points.

▪ Natural fire:

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Research activities
Fire detection with Fourier analysis

- Non-fire videos does not contain strong peaks in the investigated frequency domain

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Research activities
Supervised object extraction by snakes

- GVF snakes are used to extract objects starting from some user defined initial points
- Insufficient number of snake iterations can miss concavities
- Improvement of concavity performance and reduction of iteration steps are useful

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Research activities
Supervised object extraction by snakes

Snake (active contour) model:
$$v(s) = (x(s), y(s)) \quad (0 \le s \le 1)$$

Energy functional to minimize:
$$E_{snake} = \int_0^1 E_{int}(v(s)) + E_{image}(v(s))ds$$

Internal snake forces:
$$E_{int} = (\alpha(s)|v_s(s)|^2 + \beta(s)|v_{ss}(s)|^2)/2$$

External force field (GVF):
$$G(x;y) = (q(x;y); r(x;y))$$

which minimizes:
$$\iint \mu(q_x^2 + q_y^2 + r_x^2 + r_y^2) + |\nabla E|^2 |G - \nabla E|^2 dxdy \qquad q = \frac{\partial E_{image}}{\partial x} \quad r = \frac{\partial E_{image}}{\partial y}$$

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Research activities
Divergence of GVF field

For a vector field: $F(x,y) = P(x,y)\mathbf{i} + Q(x,y)\mathbf{j}$

Its divergence is defined as: $divF = \frac{\partial P}{\partial x} + \frac{\partial Q}{\partial y}$

High divergence: Low divergence:

Thresholding to decide: $divF < \theta$

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Improving GVF snake
Triangle step

- We detect bad snake segments based on divergence, estimate snake directions and select a new snake point inside the concavity

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Research activities
Supervised object extraction by snakes

- Tracing quadtrees for better concavity performance
  - We cover the expected object boundary with a grid with larger scale (quadtree decomposition)

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Research activities
Supervised object extraction by snakes

- Tracing quadtrees for better concavity performance
  - A boundary tracer is generalized for the „thick arc" representation, followed by pixelwise iterations to finish

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Research activities
Supervised object extraction by snakes

- Content adaptive heterogeneous snakes
  - We can make faster the snake iteration within homogeneous subregions (regions can be defined e.g. by quadtrees)
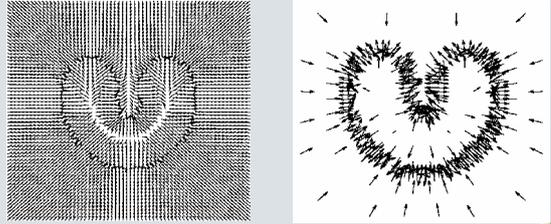
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Research activities
Supervised object extraction by snakes

- Content adaptive heterogeneous snakes
  - The snake captures the rough boundary in a few iteration steps on the larger grid (e.g. four steps is needed for U-shape)

  - A common advantage of these quadtree-based approaches that they are adaptive (the quadtree is based on the image content), and noise suppression can be applied.

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Research activities
Object detection and recognition

- Creating human pose database

  - For detection, based on whole object (human) silhouettes a database is created with different activities and views

  - Activities:
    - Running
    - Walking
    - Falling/lying
    - Sitting (testing reasons)
    - Punching (testing reasons)

  - Views:
    - Front
    - Side
    - Top

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Research activities
Object detection and recognition

- Creating human pose database
  - Realistic 3D modeling software was used

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Research activities
Object detection and recognition

- Creating human pose database

Walking	Running
Falling/lying	Punching (demo)

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Research activities
Object detection and recognition

- Creating human pose database
  - Since chamfer matching is used to locate database templates…

  - …boundary tracing is applied to extract database elements

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Research activities
Object detection and recognition

- Hierarchical clustering for template databases
  - Templates are organized into hierarchy for faster matching
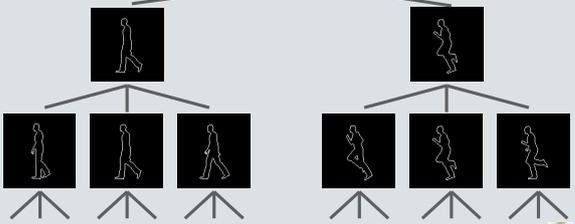
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Research activities
Object detection and recognition

Research activities
Object detection and recognition

- Textual description of database for faster matching
  - Database is stored as an XML file containing silhouette vectors

```
– <database>
 – <level1>
  + <level1_1>
  + <level1_2>
  + <temp39>
  + <temp36>
    <coordinates>(-54,-3)
    </coordinates>
  </level1>
 + <level2>
 + <level3>
 + <level4>
 + <level5>
</database>
```
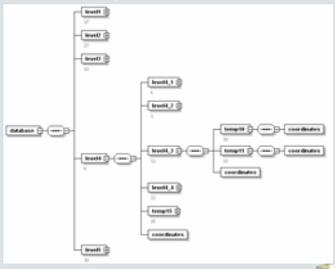
Research activities
Object detection and recognition

- Divide and conquer strategy for affine distortions
  - The templates may occur in a geometrically distorted way
  - Usually, affine transformations are sufficient to be considered
  - A „divide and conquer" strategy is used to restrict the search of the affine (6D) parameter space

Evaluate   Subdivide   Evaluate   Subdivide   Evaluate
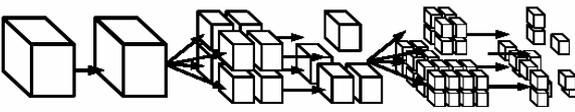
Research activities
Object detection and recognition

- Object simplification for faster matching
  - For further speed up a point reduction method was developed which preserves the most optimal subset for chamfer matching
  - It can be applied to any sets in arbitrary dimension. Contours:

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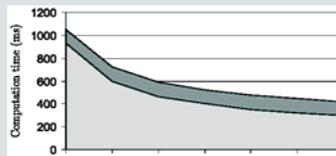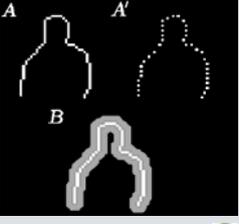
Research activities
Centroidal Voronoi Tessellation (CVT) framework

Given
- $\Omega \in \mathbb{R}^d$
- a density function ρ
- k points $\{x_i\}_{i=1}^k$ in Ω

the set $\{V_i\}_{i=1}^k$ is a Voronoi tesselation (**VT**) of Ω corresponding to the points $\{x_i\}_{i=1}^k$ if, for each i,

$V_i = \{x \in \Omega : |x - x_i| \leq |x - x_j| \text{ for } i \neq j\}$
the **C**enter of Mass of each Voronoi set V_i, $i = 1, \ldots, k$, is given by

$$z_i = \frac{\int_{V_i} x \rho(x) \, dx}{\int_{V_i} \rho(x) \, dx}$$

*** VT = CVT if $z_i = x_i$ for all i ***

generic VT

CVT

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Research activities
Centroidal Voronoi Tessellation (CVT) framework

Given
- any set $\{y_i\}_{i=1}^k$ of k points in Ω
- any tessellation $\{W_i\}_{i=1}^k$ of Ω

let
$$F(\{y_i, W_i\}) \equiv \sum_{i=1}^k \int_{W_i} \rho(x)|x - y_i|^2 \, dx$$

electrical engineer: distortion value
statistician: variance
planner, manager: cost

if $F(\{z_i, V_i\}) = \min_{\{y_i, W_i\}} F(\{y_i, W_i\})$
then
$\{V_i\}_{i=1}^k$ is a CVT with generators $\{z_i\}_{i=1}^k$

tessellations of a square

tessellations on a sphere

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Research activities
Region-based Centroidal Voronoi Tessellation

We should remove points from the original template in such a way that is optimal with respect to the matching function.

Optimization problem

Problem: Reduce the set $A \subseteq B$ with $|A| = N$ to $|A'| = K$, such that the distance map of A' remains as close as possible to the distance map of A within B

A   B   A'

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Research activities
Region-based Centroidal Voronoi Tessellation

Iteration:
1. Construct the Voronoi tessellation $\{V_i\}_{i=1}^K$ of B with generators $\{z_i \in A \mid i = 1, \ldots, K\}$;
2. Define the new set of generators as the points of A closest to the centroids of $\{V_i\}_{i=1}^K$;
3. Repeat steps 1 and 2 until some stopping criterion is met.

Other algorithms (e.g. random sampling) are also possible.

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Research activities
Object detection and recognition

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Research activities
Object detection and recognition

- Object simplification for faster matching
  - … and regions:

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Research activities
Object detection and recognition

- Object simplification for faster matching
  - Simplification can be done with weighting the set differently

$$\widetilde{\varrho}(\mathbf{x}) = \frac{d(\mathbf{x}, \overline{B^c})}{d(\mathbf{x}, \mathrm{sk}(A)) + d(\mathbf{x}, \overline{B^c})}$$

$$\varrho(\mathbf{x}) = \frac{\widetilde{\varrho}(\mathbf{x})}{\int\limits_{B} \widetilde{\varrho}(\mathbf{y})d\mathbf{y}}, \quad \text{for } \mathbf{x} \in B$$

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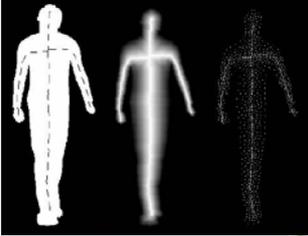
Research activities
Object detection and recognition

- Simplification using a skeleton-based weight function

	Simplification			
	No (original)	Unifom (trivial)	Unifom (CVT)	Weighted (skeleton)
Standing	80,9%	81,2%	81,1%	94,0%
Walking	85,8%	86,2%	86,2%	94,6%

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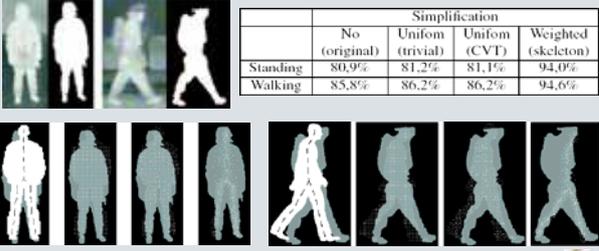
Software module – 2nd prototype

- Tasks in the 2nd prototype

  - Colorization
  - Hotspot detection
  - Fire detection
  - Boundary detection
  - Boundary tracking
  - Boundary object recognition
  - Automatic object detection

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Software module – 2nd prototype

- Colorization tool

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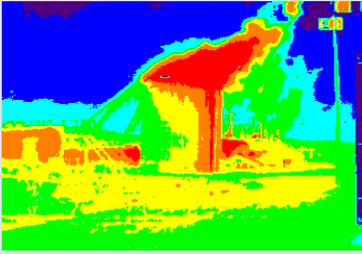
Software module – 2nd prototype

- Hotspot detection tool

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**Software module – 2nd prototype**

- Fire detection tool

```
– <FireAppearance>
    <ID>1</ID>
    <TimeIn>10:00:23</TimeIn>
    <TimeOut>10:00:30</TimeOut>
  – <FireInstances>
    – <FireInstance>
        <ID>1</ID>
      – <ROIMarking>
          <ID>1</ID>
        – <Representation>
            <ID>1</ID>
          – <BoundingBox>
              <Width>70</Width>
              <Height>19</Height>
            – <Center>
                <X>67</X>
                <Y>170</Y>
              </Center>
```

Software module – 2ⁿᵈ prototype

- Boundary detection tool

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Software module – 2ⁿᵈ prototype

- Boundary object recognition tool

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Software module – 2ⁿᵈ prototype

- Boundary tracking tool

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Software module – 2ⁿᵈ prototype

- Automatic object detection

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Thank you

Thank you for your attention.

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