GPU TECHNOLOGY CONFERENCE

CUDA in Urban Search and Rescue : Mission Planning Module for ICARUS Project

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IMM

NVIDIA CUDA RESEARCH CENTER

ICARUS

- **I**ntegrated **C**omponents for **A**ssisted **R**escue and **U**nmanned **S**earch operations
- Participants:
  - 24 partners
  - 10 countries
  - 2 end-users:
    - B-FAST
    - Portuguese Navy
  - 3 large industrials
  - NATO / NURC
- Total Budget: 17.5 M€

ICARUS-IMM

- Integration of Unmanned Search And Rescue tools in the C4I systems of the Human Search And Rescue forces
- Development of a training and support system of the developed Unmanned Search And Rescue for the Human Search And Rescue teams

Mission Planners

- Provide the unmanned platform operators with tools for fast and accurate initial mission planning
- Lower the cognitive load of the operator during mission execution
- The planner uses a semantic model as the basis for reasoning
- Reasoning framework designed for CUDA

CUDA Hardware

Supermicro RTG-RZ-124OI-NVK2:

- 2 x 2.8GHz Xeon CPU (2 x 10 cores)
- 256 GB RAM
- 1.25 TB SSD
- 2 x NVIDIA GRID K2 card

Notebook with GeForce 660m as a personal terminal.

GeForce Titan mission planning station.

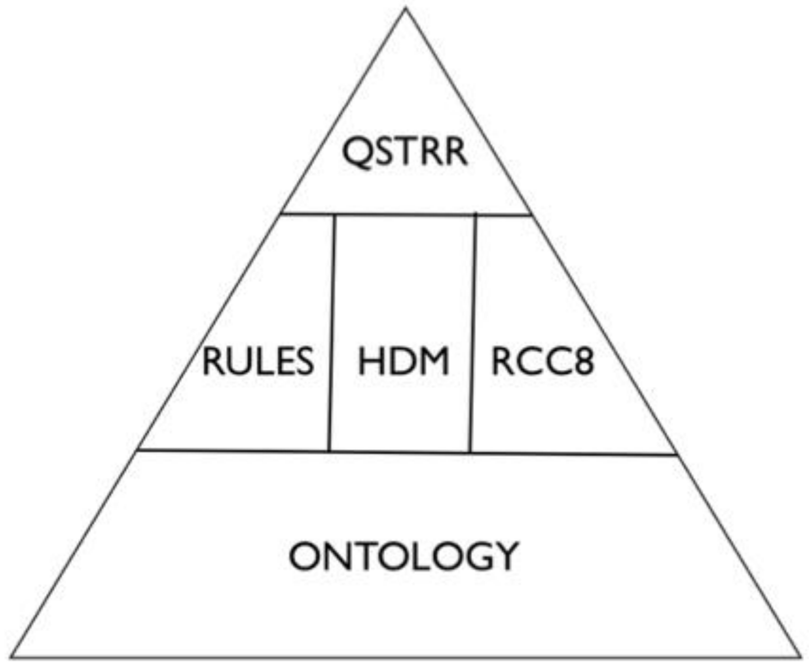
Semantic Model

"A semantic map for a mobile robot is a map that contains, in addition to spatial information about the environment, assignments of mapped features to entities of known classes. Further knowledge about these entities, independent of the map contents, is available for reasoning in some knowledge base with an associated reasoning engine."*

Semantic model – a formalized description of the environment, based on provided ontology, which provides information about entities in the environment, their parameters and relations.

*A. Nüchter, J. Hertzberg ,"Towards semantic maps for mobile robots", Robotics and Autonomous Systems Volume 56 Issue 11, November, 2008 , 915-926

Ontology



QSTRR – Qualitative Spatio-Temporal Representation and Reasoning

Basic sets:

- Concepts
- Relations
- Rules

Integration with HDM (Humanitarian Data Model)

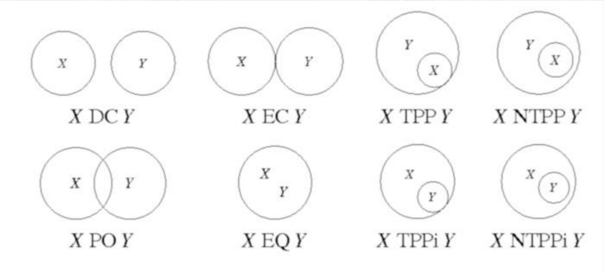
Concepts

Concept	Parameter	Parameter type	Parameter values	Comments
Building				
	Size	concept		
	Type	string		
	victim probability	string	no_victims low medium high	
	Is_Searched	bool		
	Is_Damaged	bool		
	Damage_level	string	low medium high complete	
	Material	Material concept		
	Address	Address concept		

"Classes" of objects that are in the environment

- Physical entities
- Abstract entities
- Parameters

Relations



Region Connection Calculus 8

Sequences of relations may be defined

Quantitative description of PO relation

Rules

Rules are the representation of general boundaries of the ontology. They are the basis for reasoning.

Statement:

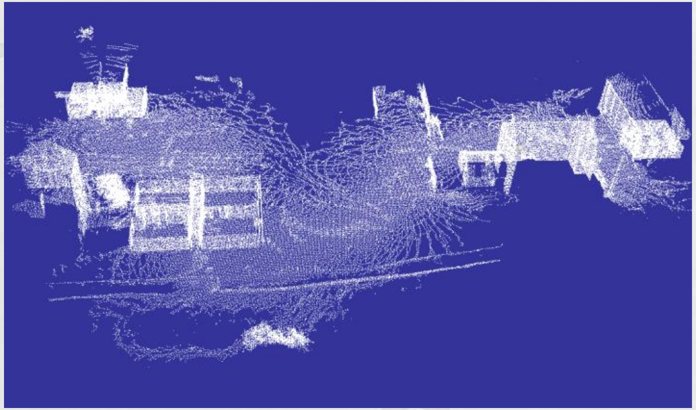
Area that is safe to navigate does not have obstacles.

Rule:

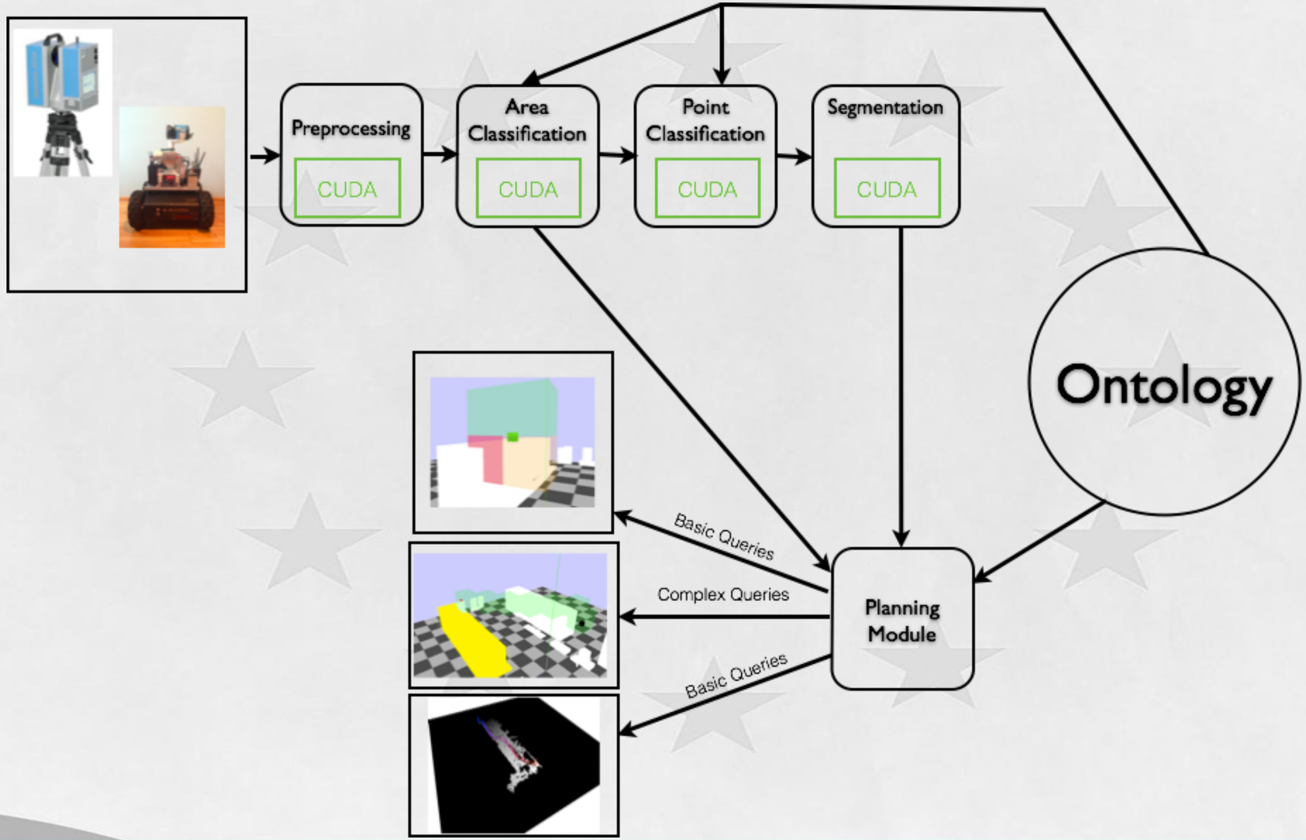
Area:Safe is in relation DC with physical concepts.

Data Sources

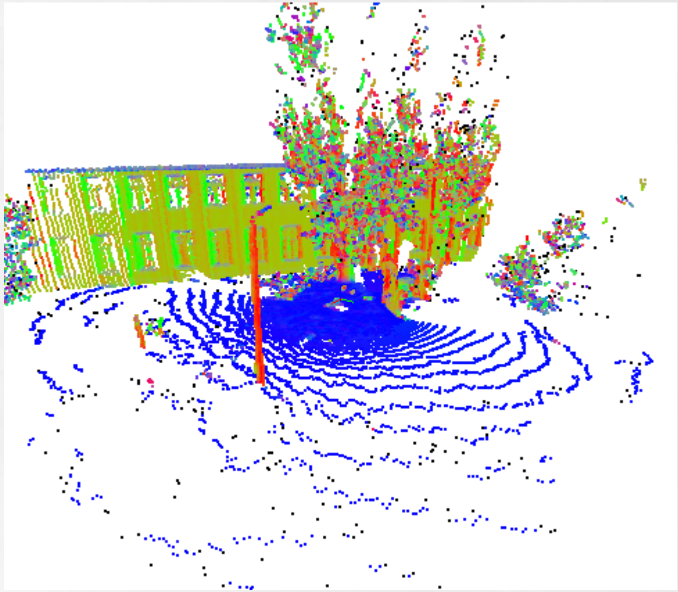
- GIS (Geographical Information System)
- Ground 3D Point Clouds
- Aerial 3D Point Clouds (from images)



Semantic Model



Preprocessing



Steps:

- Regular Grid Decomposition
- Normal Vectors Computation
    - PCA/SVD algorithm
    - Calculation of shape descriptors from eigenvalues:

      E(e1,e2,e3)

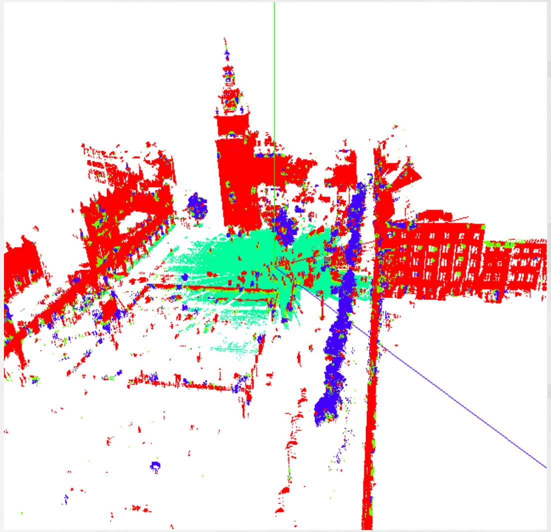
      Linear=(e1-e2)/e1

      Volumetric=e3/e1

      Planar=(e1-e3)/e1
- Filtration

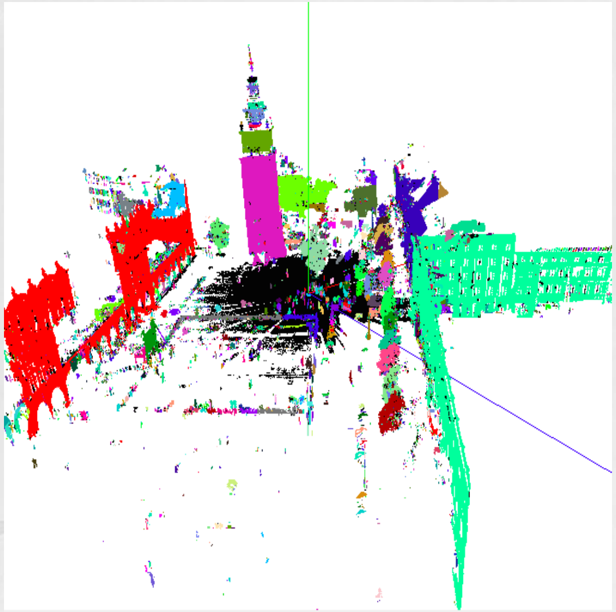
Normal Vectors: 0.82s +Descriptors: 0.85s
300 000 points

Classification and Segmentation

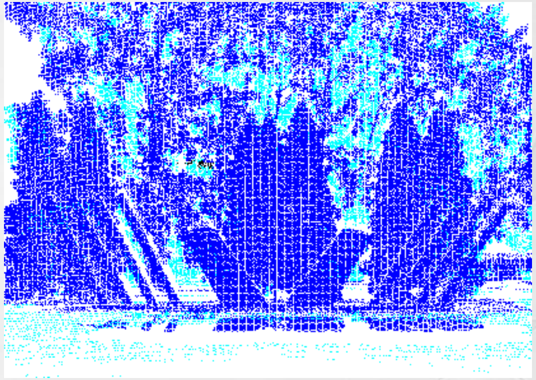


General Steps:

1. Ground Seed Search
2. Ground Filtration
3. Generation of normal vectors angles histogram
4. Initial Classification
5. Classification correction
6. Segmentation

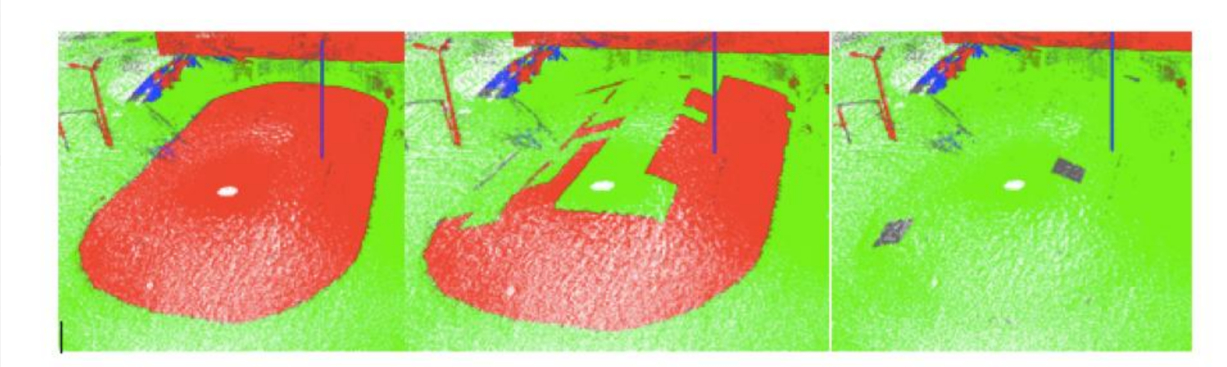


ICARUS

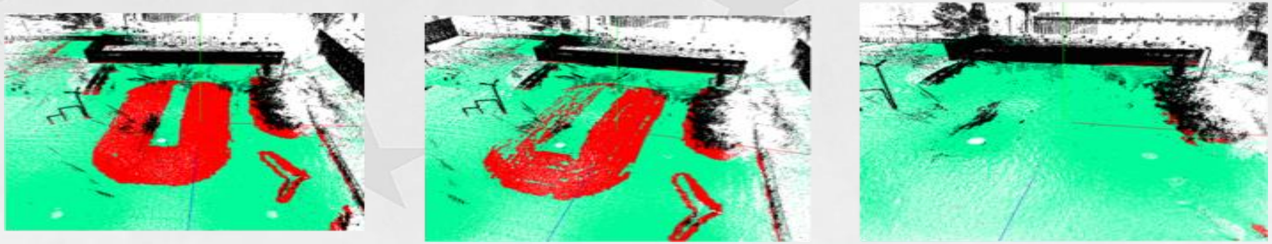


Increased Accuracy

Traversability by max slope:

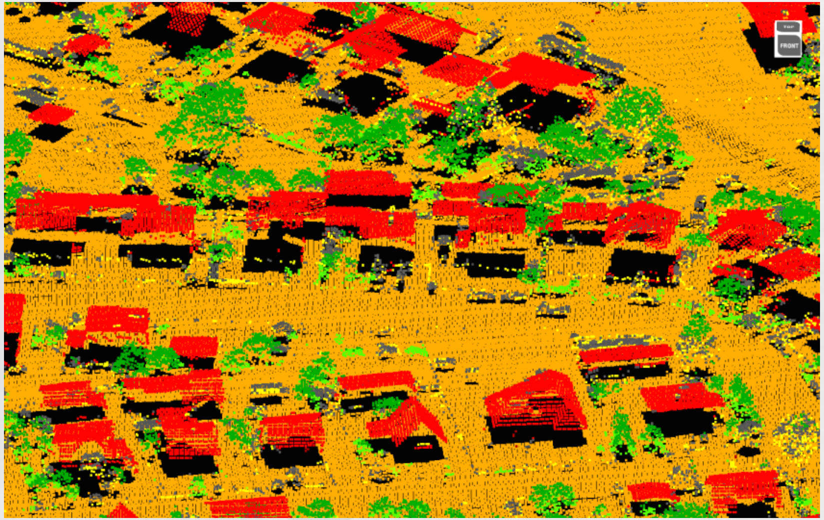


10° 18° 25°



Aerial Point Clouds

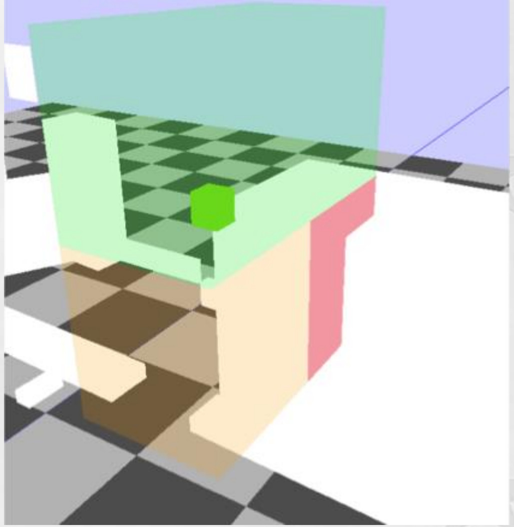
- Commercially available library developed by Dephos Software (CUDA-based)
- Fast point classification to 5 object classes:
  - Ground
  - Building,
  - Vegetation (3 types)
- Computation Time:
  10 mln points, 1200x1050m:
  from 45s (low accuracy) to
  120s (high accuracy)
  Geforce Titan

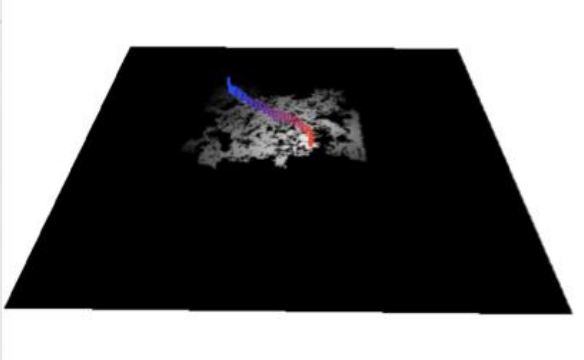


DEPHOS SOFTWARE

Basic planning problems

Basic Reasoning – reasoning performed on a single concept instance.





Cost Wave propagation algorithm*

Area Information

Return: *Set S of area concepts in relation DC with robot concept*

*"Qualitative Spatio-Temporal Representation and Reasoning for robotic applications",Janusz Bedkowski, January 20, 2015

Complex planning problems

Problems that require defining a full hypothesis space.

Transforming complex problem to large number of independent simple queries

Examples of Queries:

- Global multi-Waypoint path optimization (traveling salesman problem)
- Patrol path search
- Building exploration path search
- Network repeater position search
- Optimal perception position search

General Planning Query

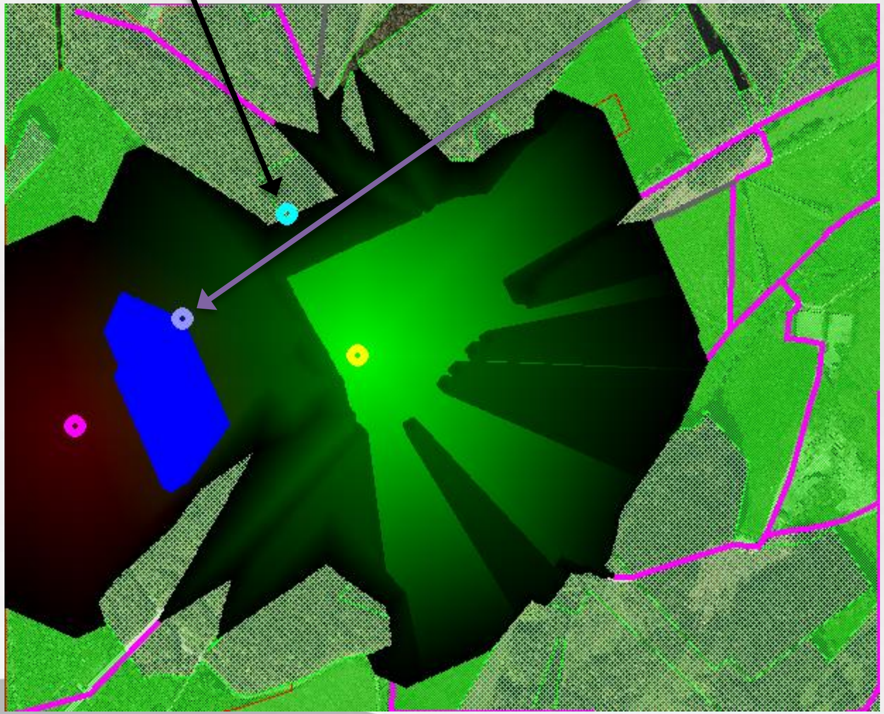
INPUT: Semantic model S
INPUT: Hypothesis set H={h_i} where h_i is and instance of a concept
INPUT: Query set Q={q_j} where q_i is a rule
OUTPUT: An instance of concept o, that is the solution to the problem

```
for all q_j ∈ R do
  for all h_i ∈ H in parallel do
    if Check(q_j,h_i) != PASS then
      remove(h_i)
    end if
  end for
end for
o = QunatitativeEvaluation(H)
```

Network repeater

Robot initial position

Found optimal repeater position



Hypothesis space: robot concepts with position and simulated signals strength.

Rules:

Is position reachable?

Is signal one strong enough for the position?

Is signal two strong enough for the position?

Quantitative evaluation:

Cost of path

0.4-4s

Path optimization

INPUT: Semantic Model S
INPUT: Set W of waypoints
OUPUT: Sequence of waypoints that represents the local minimum of cost
for all pairs $\{w_i, w_j\}$ where $w_x \in$ W **do**
  C_{ij}=CalculateCost(S,$\{w_i, w_j\}$)
end for
Sequence of waypoints Q
while Cost(Q')<Cost(Q) **do**
  Q'=MinCost(SwapTwoWaypoints(Q),C)
end while

Hill-Climbing algorithm

Conclusions

- Raw data converted into a semantic model of the environment – use of CUDA allows per point approach without increasing computation time.
- Mission planning framework dedicated for parallel computing
- Converting complex problems into large sets of simple, low cost queries

Thank You for your attention

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