

# Multi-Layer Atlas System for Map Management

Jean-Luc Bedwani

Expertise - robotique et civile

Institut de recherche d'Hydro-Québec

Ioannis Rekleitis

School of Computer Science

McGill University

François Michaud

Faculté de génie

Université de Sherbrooke

Érick Dupuis

Space Exploration

Canadian Space Agency

The Seventh Canadian Conference on Robotics and Computer Vision

Ottawa, Canada

June 1<sup>st</sup> 2010



UNIVERSITÉ DE  
SHERBROOKE

# Outline

- 1 Motivations of the Research
- 2 Definition of a Data Management System
- 3 Tour of Existing Systems
- 4 The Atlas Management System
- 5 Experimental Results
- 6 Conclusions

# Motivations of the Research

Can we make robots behave more wisely?

# Motivations of the Research

Can we make robots behave more wisely ?

Can we get more out of robot collected data ?

# Motivations of the Research

Can we make robots behave more wisely ?

Can we get more out of robot collected data ?

Can planetary robot exploit its collected data to be more autonomous ?

# Definition of a Data Management System

# Definition of a Data Management System

A diagram consisting of a square box with a dark brown header and a light beige body. The word "Needs" is written in white text on the header. The box has a subtle drop shadow.

Needs



# Definition of a Data Management System

## Needs

- Mapping

# Definition of a Data Management System

## Needs

- Mapping
- Localization

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading



# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship

# Definition of a Data Management System

## Needs

- Mapping
- Localization
- Navigation
- Storage
- Visualisation
- Exchange

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

- [1] M. C. Bosse, P. M. Newman, J. J. Leonard, and S. Teller.  
SLAM in large-scale cyclic environments using the atlas framework.  
*The International Journal of Robotics Research*, 2004.

# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

- [2] B. Lisien, D. Morales, D. Silver, G. Kantor, I. M. Rekleitis, and H. Choset. The hierarchical atlas. *IEEE Transactions on Robotics*, 2005.



# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

- [3] A. Kelly, A. Stentz, O. Amidi, M. Bode, D. Bradley, A. Diaz-Calderon, M. Happold, H. Herman, R. Mandelbaum, T. Pilarski, P. Rander, S. Thayer, N. Vallidis, and R. Warner.  
Toward reliable off road autonomous vehicles operating in challenging environments.  
*The International Journal of Robotics Research*, 2006.

# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

- [4] A. Jain, J. Cameron, C. Lim, and J. Guineau.  
SimScape terrain modeling toolkit.  
*In Proceedings of the 2nd IEEE International Conference on Space Mission Challenges for Information Technology, 2006.*

# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

- [5] C. F. Olson, L. H. Matthies, J. R. Wright, R. Li, and K. Di. Visual terrain mapping for Mars exploration. *Computer Vision and Image Understanding*, 2007.

# Tour of Existing Systems

System	Database	Multiple data	Lossless	Uncertainty	Dynamic	3D	Extension	Multi platform	Operator	Autonomous
Atlas framework [1]	•	•	•	•	•					•
Hierarchical atlas [2]					•					•
PerceptOR [3]		•			•	•			•	•
SimScape [4]	•	•	•			•	•		•	
SUMMITT [5]	•	•	•			•			•	
Atlas	•	•	•	•	•	•	•	•	•	•

# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

# The Atlas Management System

## Concepts

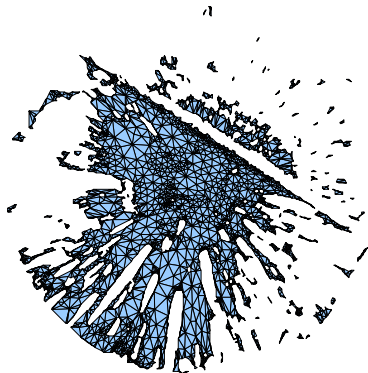
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

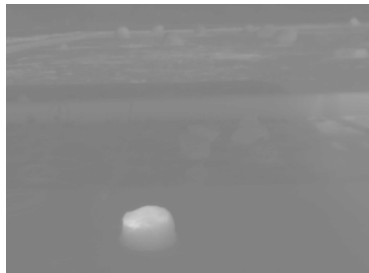
## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

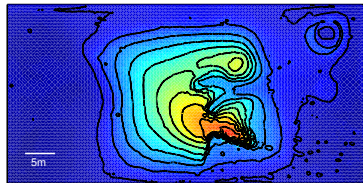




# The Atlas Management System

## Concepts

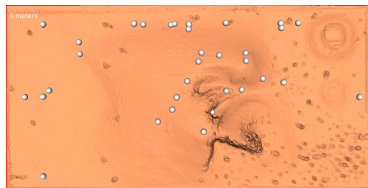
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

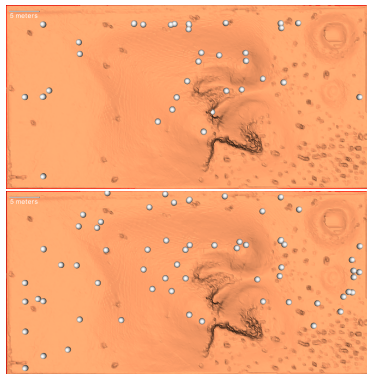
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

World  
Robot  
Sensor

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

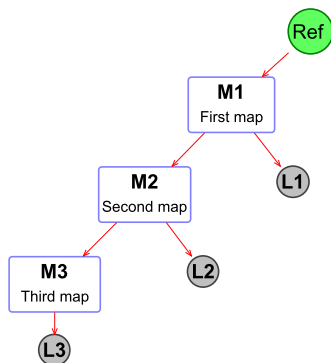
World  
Robot  
Sensor



# The Atlas Management System

## Concepts

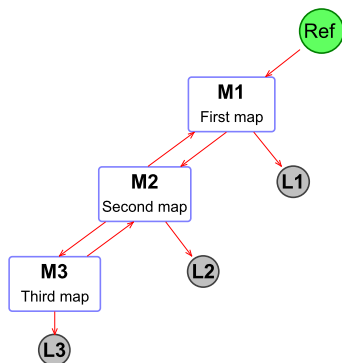
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

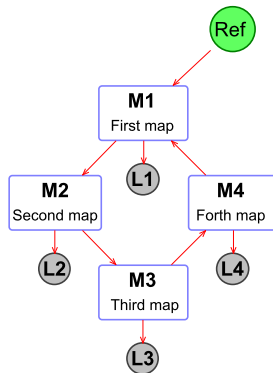




# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



## Concepts

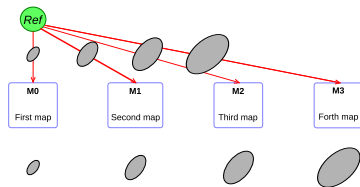
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

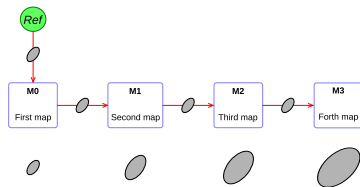
## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



## Concepts

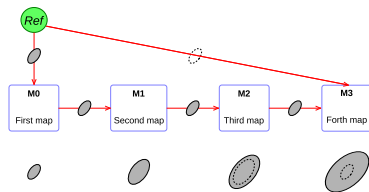
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

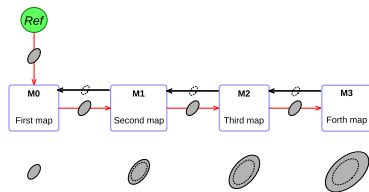
- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System

## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations

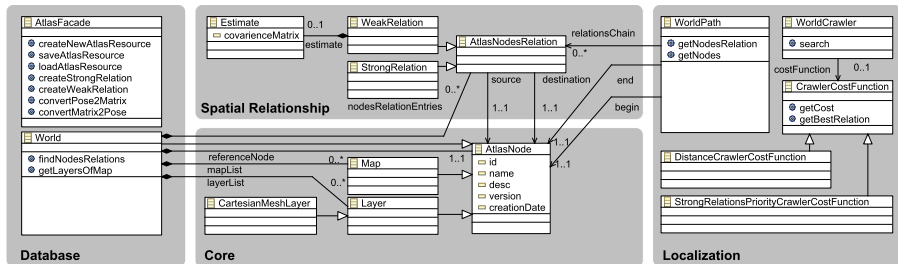


## Concepts

- Saving and Loading
- Dynamic
- Multiple data formats
- Data mining
- Hierarchy of data
- Relative spatial relationship
- Uncertainty of relations



# The Atlas Management System





# Experimental Results

**TAB.:** Mean values $\pm$ standard deviation of timing in milliseconds for different Atlas operations using meshes of three different resolutions. Results using a database of 94 different meshes.

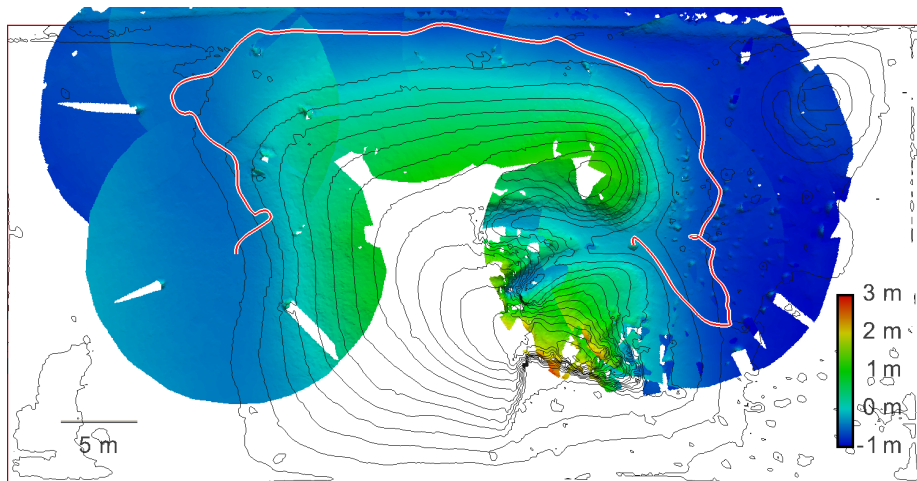
Operations	10k cells (ms)	25k cells (ms)	50k cells (ms)
Read	306 $\pm$ 80	733 $\pm$ 146	1,430 $\pm$ 311
Write	304 $\pm$ 157	1,196 $\pm$ 398	3,318 $\pm$ 1,130
Relation	0.35 $\pm$ 0.14	0.45 $\pm$ 0.9	0.48 $\pm$ 1.37
Search first	887 $\pm$ 1,150	2,040 $\pm$ 2,860	3,770 $\pm$ 5,230
Search all	9,880 $\pm$ 2,600	26,200 $\pm$ 7,020	53,000 $\pm$ 13,400
Kd-ICP	6,630 $\pm$ 4,280	22,500 $\pm$ 17,900	65,400 $\pm$ 56,600

# Experimental Results

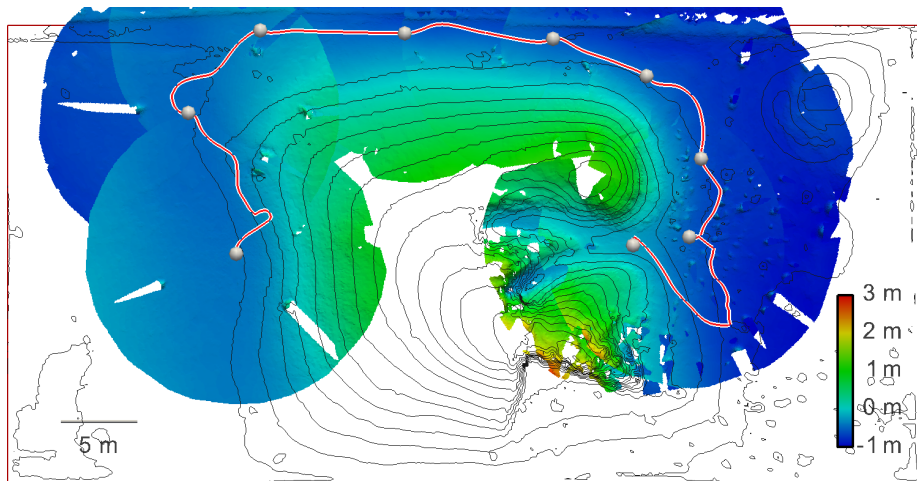
**TAB.:** Mean values $\pm$ standard deviation of timing in milliseconds for different Atlas operations using meshes of three different resolutions. Results using a database of 94 different meshes.

Operations	10k cells (ms)	25k cells (ms)	50k cells (ms)
Read	306 $\pm$ 80	733 $\pm$ 146	1,430 $\pm$ 311
Write	304 $\pm$ 157	1,196 $\pm$ 398	3,318 $\pm$ 1,130
Relation	0.35 $\pm$ 0.14	0.45 $\pm$ 0.9	0.48 $\pm$ 1.37
Search first	887 $\pm$ 1,150	2,040 $\pm$ 2,860	3,770 $\pm$ 5,230
Search all	9,880 $\pm$ 2,600	26,200 $\pm$ 7,020	53,000 $\pm$ 13,400
Kd-ICP	6,630 $\pm$ 4,280	22,500 $\pm$ 17,900	65,400 $\pm$ 56,600

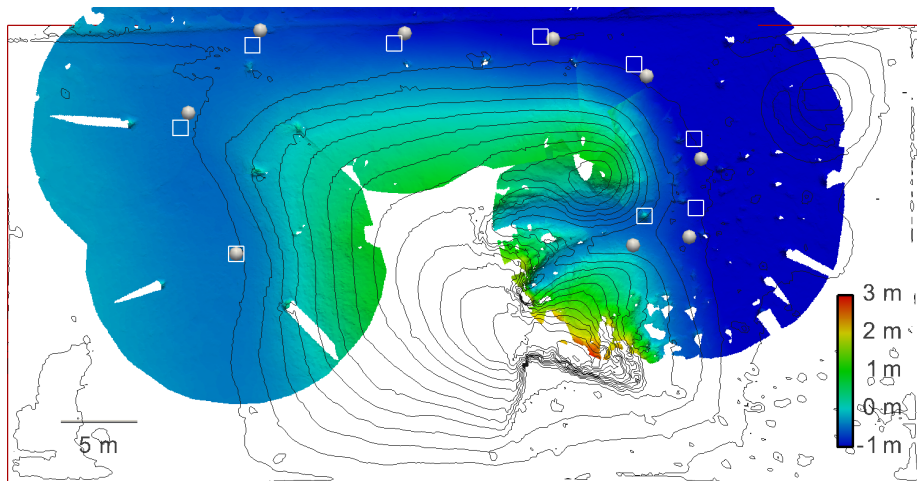
# Experimental Results



# Experimental Results



# Experimental Results



# Conclusions

Demonstrates the feasibility of a data management system suitable for robotic planetary exploration.

## Main features

- Maps are never fused by the system
- Two given maps may have multiple mutual spatial relationships
- Mechanism to select/merge these multiple estimation relations
- Updates of relative relations automatically propagates to neighboring maps
- Dynamically manage a variety of data formats
- Supports maps correlation for localization
- Planning operations can use series of maps linking two locations
- Handle uncertainty in the spatial relationship between the maps

# Questions

Bedwani.Jean-Luc@ireq.ca