3DNSITE: A networked interactive 3D visualization system to simplify location awareness in crisis management

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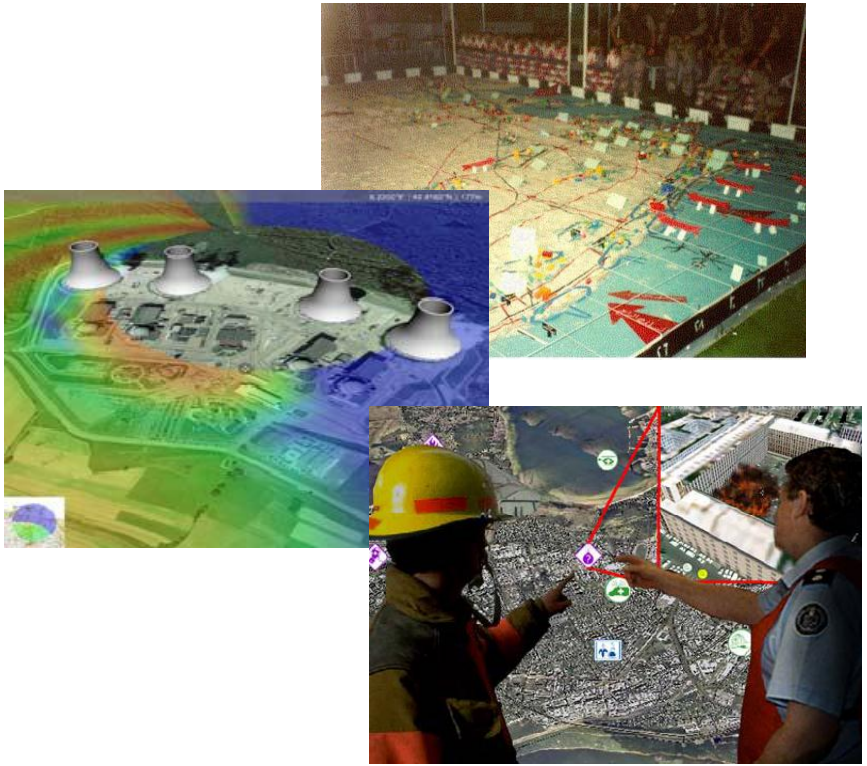
Context and motivations 1/2

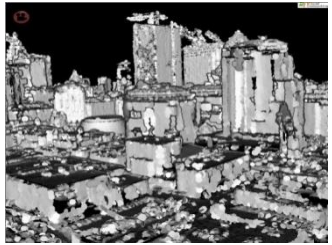
- **New crisis of growing complexity**
  - The typical modern scenario
    - Dense population concentration
    - Complex architectural environment
  - Essential for public authorities to adopt proper decision support tools and crisis simulation systems

- **New collaborative approaches and technologies are researched in the IT**
  - Emergency operations handling
  - Agents, crisis managers training
  - Emergency procedures planning



Context and motivations 2/2

- **Complex scenario**
  - Important to simplify location awareness and remote navigation
  - Exploration of the near-3D data



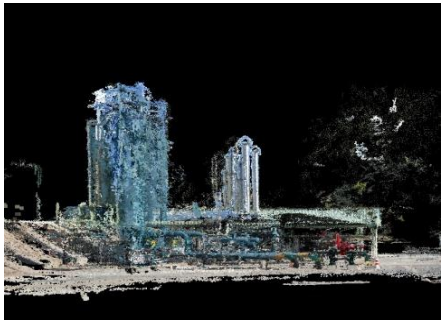
- **Important data for the security domain**
  - Combination of detailed 3D model of the site with georeferenced aligned 2D images
  - Data sometimes already available or easy to acquire/update
  - *Eg. SfM pipeline: cheap to acquire and update, no specific hardware is needed*

3DNSITE system introduction

- **Client-server 3D visualization tool**
  - Streaming and visualizing large tridimensional hybrid data
    - 3D point-clouds or meshes
    - Related aligned images projected on the model
- **Included in a general training and decision framework for emergency operations**
  - Indigo system
  - Evaluated with real-world datasets and real users

Challenges

- **Efficient and scalable distribution and visualization of the data**
  - Different capabilities devices
  - Different performances networks
- **Interactive frame-rates**
  - Huge 2D/3D data *(hundreds of images, massive 3D models coming from different sources,etc.)*
- **Fast and efficient navigation interface**
  - Users not skilled with VR and 3D objects interaction



Related work 1/2

- **Several solutions have been presented for maps browsing, 3D mobile navigation, etc.**

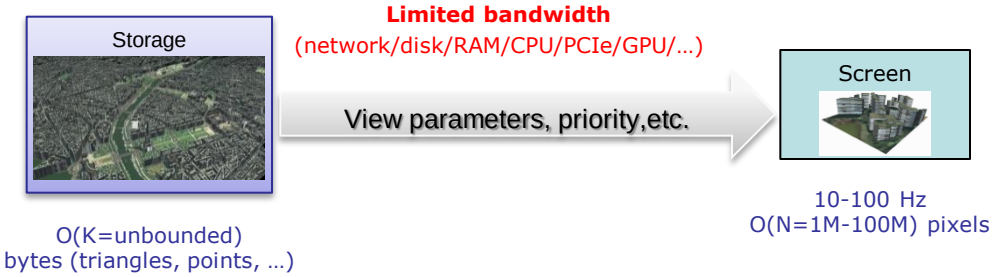
- **…but only a few existing browsers support the joint navigation of mixed 2D/3D datasets**
  - **PhotoTourism**[Snavely et al. 06] - **PhotoSynth** [Microsoft 07]
  - [Snavely et al. 08], [Vincent et al. 07], [Kopf et al. 10], [Goesele et al. 10]

Related work 2/2

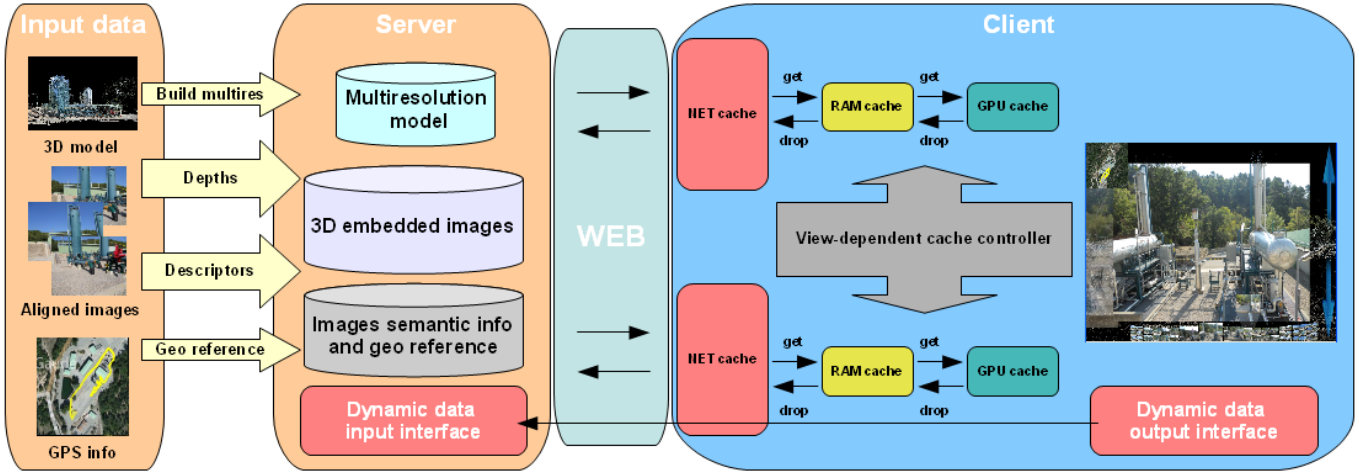
- **Our contribution**
  - Unlike the mentioned 3D photo browsers our system exploits state-of-the-art multi-resolution representations of the 3D model
    - Huge 3D massive models can be streamed and visualized
    - Scalability over limited hardware and network resources
    - Free-point-of-view navigation at interactive frame rates
    - Based on **Adaptive Tetra-puzzles** [Cignoni et al. 04] and **Layered Point Clouds** [Gobbetti et al. 04]
  - View-dependent/output-sensitive method applied to the image cache controller
    - Combined with pre-computed 6D descriptors for the images supports a fast and efficient navigation interface
    - Completing the system scalability
  - Combination, enhancement and application of SoA methods in a peculiar web-based environment
    - Very positive feeedback in terms of performance and user experience

Method: output-sensitive philosophy

- **We assume less data on screen (*N*) than in model (*K*>>*N*)**
  - Real-time data filtering problem
  - Best visualization at interactive frame-rates
- **We adopt this philosophy to access the 3D model, the embedded images and for the user interface**



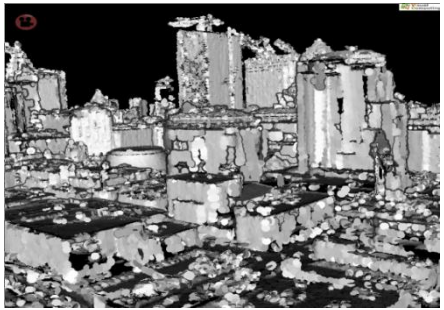
System overview

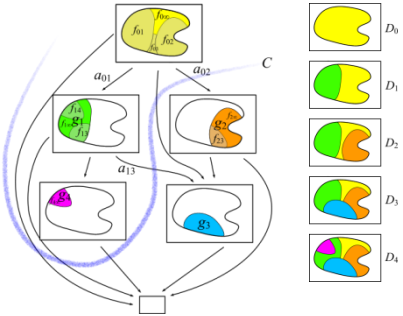


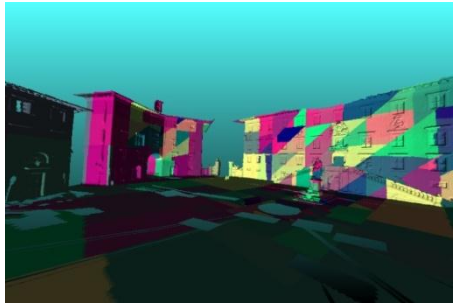
- **Server side pre-processing**
- **Data distribution**
- **Client side 3D navigation**

Server side pre-processing 1/2

- **Input data**
  - 3D models and related aligned images
    - SfM pipelines [Snavely 06]
    - Images to 3D alignement tools
    - GPS records
- **3D model out-of-core pre-processing**
  - A MR hierarchy over the samples is generated
    - reordering and clustering in fixed size patches
  - The hierarchical structure is split in a index tree and a point cloud (or triangles) repository
  - Dependencies between mesh modifications arranged in a DAG
  - Variable resolution representations of the model are obtained performing a *cut* of the DAG



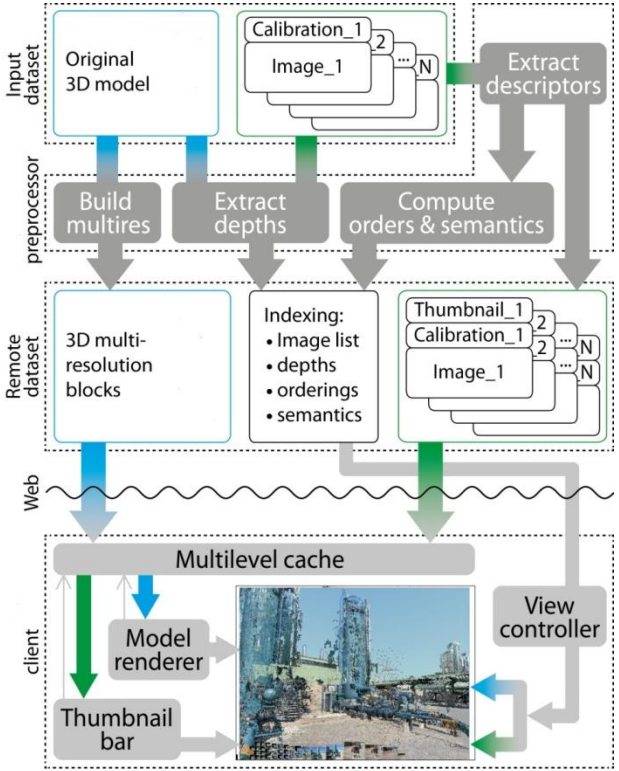




$$D^* = D_0 \oplus g_1 \oplus g_4 = f_{0\infty} \cup f_{02} \cup f_{03} \cup f_{13} \cup f_{1\infty} \cup f_{4\infty}$$

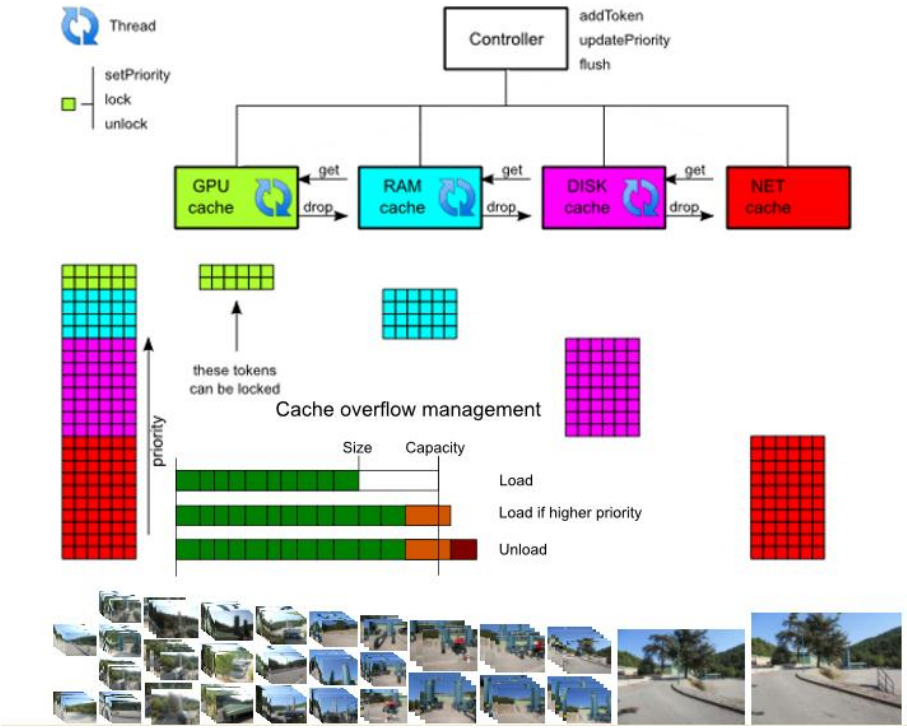
Server side pre-processing 2/2

- **Images out-of-core pre-processing**
  - An image depth is computed using the related 3D model depth buffer
  - A 6D descriptor is computed for each image as a weighted average (customizable) of:
    - Time of shot / Shot position / Shot orientation / Image color distribution / Spatial color layout / Image depth
  - **Image ordering and priority among images are pre-computed from these descriptors**
- **Geographical spatial reference frame**
  - RANSAC method comparing image data (GPS, exif,etc.) with the estimated 3D positions
- **The geo-referenced 3D model is a kind of "skeleton" where pre-existent and new images are embedded**



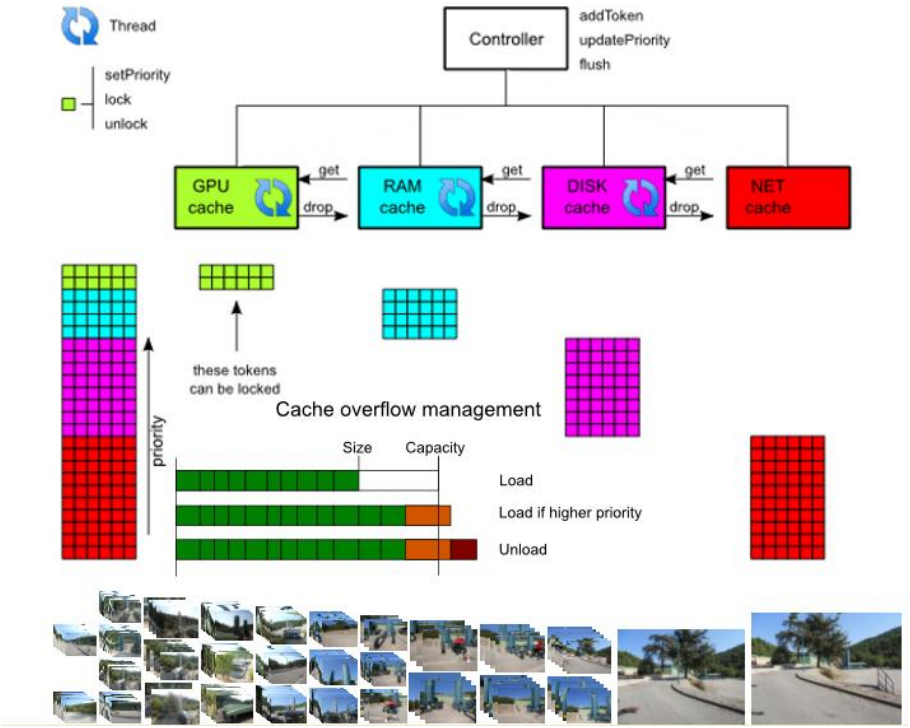
Data distribution 1/2

- **3D model and images repositories are stored in a server**
- **Priority-based/multilevel cache system**
  - 3 levels: http, (disk), RAM, GPU
  - 2 basic cache instances (3D model and images)
  - Different thread for each level (eg. blocking files and sockets)
  - Fixed size budget for each level (eg. RAM memory budget 50% of the system memory, etc.)



Data distribution 2/2

- **3D data data blocks stored as VBO**
  - VBO downloaded and rendered according with the current view parameters
    - GPU memory optimization
  - http persistent connection
    - Improves bandwidth usage and reduces network latency
- **Images stored as JPG**
  - Pre-computed priority-based respect to the current image
  - Good compression
  - Wide compatibility with different devices



Client: mixed 2D-3D navigation 1/3

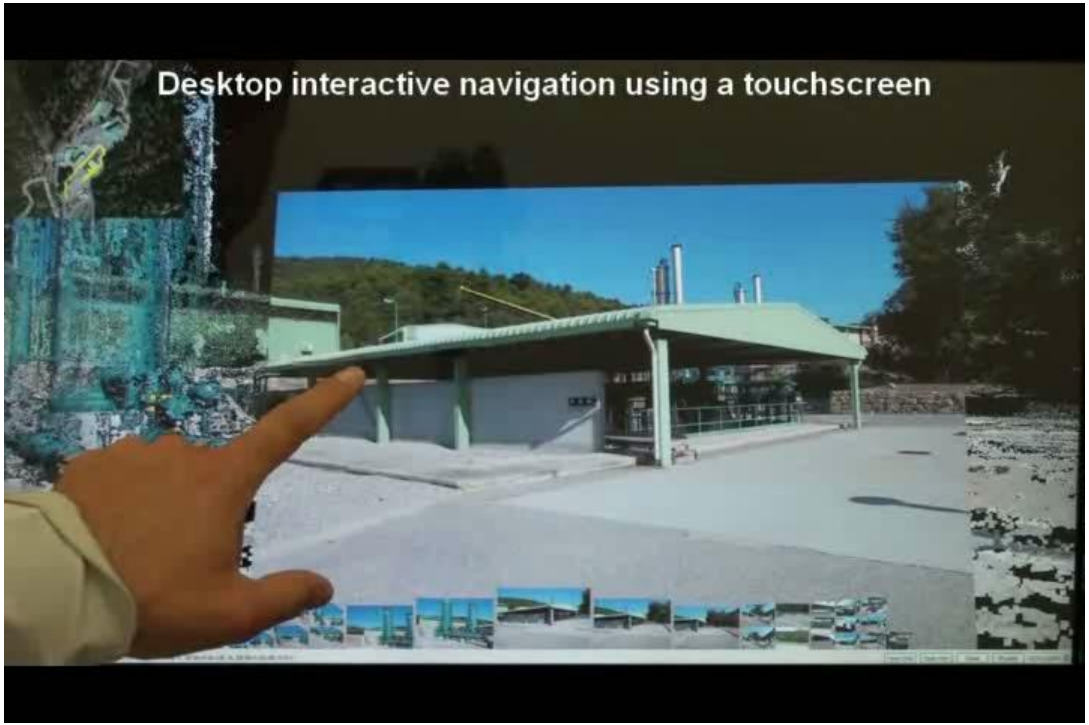
- **3D model rendering**
  - Model rendered as a kind of scenario “skeleton”
  - Performing real-time:
    - Selective (view-dependent) queries on the multi-resolution repository
    - Rendering by assembling and refining fixed size patches (thousands triangles/points)
  - Caching enables rendering with a single CPU call
  - Interactive frame-rate achieved

Client: mixed 2D-3D navigation 2/3

- **Images rendering**
  - Loading from network according with:
    - Current viewport
    - Image descriptor differences
    - Hardware capabilities
  - Images projected simulating their real shot parameters
    - Viewport parameters
    - Pre-computed depth
  - Focus on the real image appearance
    - Projection mode suggested by the system end-users

Client: mixed 2D-3D navigation 3/3

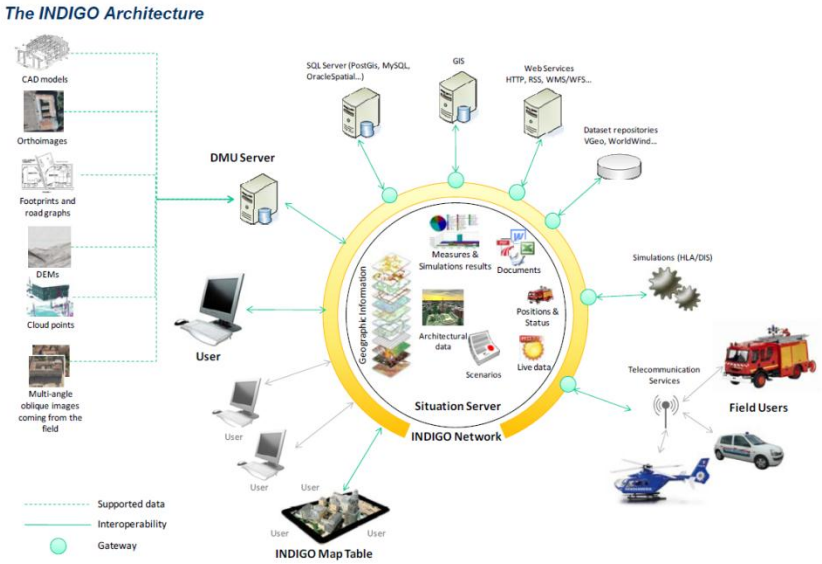
- **User interface**
  - 3D navigation
  - 2D image browser
  - Geo-minimap
- **Click-and-go**
  - According with the 6D image descriptors
  - Suggested images rendered according their 6D proximity with the current one
  - Free-point-of-view navigation



Interactive 3D navigation over the gas storage site of Geomethane in Manosque (France).

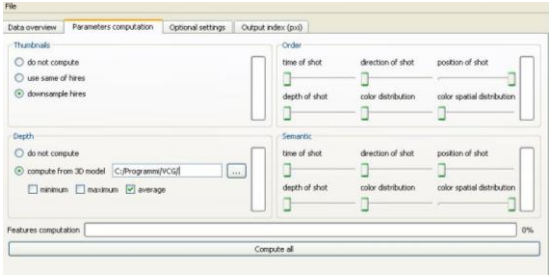
Results 1/3

- **Part of the Indigo framework**
  - **"Innovative Training & Decision Support for Emergency operations"**
  - Distributed architecture to simultaneous involve multiple actors
  - 3DNSITE integrates the global Indigo map capabilities adding a detailed, realistic and interactive 3D navigation for specific operational sites
  - Real end-uses and crisis managers involved



Results 2/3

- **Pre-processor module**
  - Data from SfM pipelines / In-house technology for 2D-3D alignement [Pintus et al. 11b]



3DNSITE Generator user interface

dataset	3D model			images		
	MSamples	Patches	Time	MPixels	Count	Time
Geomethane 1.2GB	7.5	464	2m23s	12	300	5m20s
Training building 151MB	0.5	32	11s	12	60	41s
Stockholm Tegelbacken 457MB	1.5	196	59s	5	150	56s

Dominant value for the real cases is the shot position – For the training area is instead the shot direction

Results 3/3

User	Hardware performance						Network		
	Device	Multires fps	No multires fps	Connection	RAM MB	RAM GPU	Peak MB/s	Startup s	Average KB/s
Manager1	whiteboard	172	16	Ethernet	1024	256	11	0	700
Manager2	laptop	70	9	Wireless N	512	256	600	0	600
Manager3	netbook	35	3	Ethernet	512	256	3.6	3	400
Agent1	netbook	26	2	Wireless N	512	128	0.6	6	220
Agent2	tablet	26	1	Wireless N	1024	256	0.59	6	470
Agent5	tablet	19	1	3G_HSDPA	1024	128	0.22	22	125
Agent6	tablet	8	1	EDGE-GPRS	1024	128	0.05	34	36

- **Client module**
  - Developed on the users profile (agents and managers)
  - Tested by real users
  - Scalability increase in importance for remote/tablet applications

Conclusions

- **Web-based system to interactively navigate a complex 3D environment during the evolution/simulation of a crisis**
- **Output-sensitive philosophy**
  - Combination and enhancement of already presented SoA methods in a web-based/crisis environment
  - It achieves scalability over limited network and hardware resources
  - It preserves a good interactivity
  - Integrated in the Indigo framework
    - Very positive performance measurements
    - Very positive user experience
- **Limitations and future work**
  - Dynamic dataset
    - 3D model
    - Images
    - Other data
  - Images streaming

Questions and contacts

- **CRS4 - Visual Computing Group**
  http://vic.crs4.it

- **ISTI-CNR - Visual Computing Lab**
  http://vcg.isti.cnr.it

- **Speaker: Giovanni Pintore**
  gianni@crs4.it

- **The Indigo project**
  http://indigo-project.eu/

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