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Dynamic 3D representation of information using low cost Cloud ready Technologies

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SCOPE

- 3D representation of objects and territories has been an everyday reality almost for everything
- Most software available can handle only static pre-processed data
- In Cadastre the Land Administration Domain Model (LADM) provides support for 3D representations; has been proposed as the framework on which a 3D cadastre should be based
- An implementation method for creating an API (Application Programing Interface) which can be used to 3D visualize large datasets (e.g., country-wide) with low cost and high precision is proposed
- Introduction of an algorithm to provide the ability to dynamically update elevation data so that accurate and time shifting representations can occur

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INNOVATIONS

- The 3D information can be viewed by many users and can be extremely detailed in terms of accuracy without the need of expensive software or hardware
- The elevation information changes, in terms of accuracy, at different scales while still maintaining its topology and thus providing smooth rendering when changing from one scale to another
- Innovative optimizations have been developed (Assembly Language) in order to accelerate commonly used routines thus contributing by lowering the minimum hardware requirements of the algorithm

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Existing virtual globe software

- Google Earth
- ESRI (ArcGlobe, City Engine)
- NASA World Wind
- Bing Maps 3D
- Earth3D
- CitySurf Globe
- Worldwide Telescope
- OpenWebGlobe
- more…

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ACCURACY

- Most of the current virtual globe projects have the concept of dealing with static data projected on a sphere
- A sphere is not a very good representation of earth
- Current virtual globes are focused in representing Earth as a whole planet thus not providing the accuracy needed for cadastral and topographic applications

➢ The proposed algorithm focuses on producing a 3D model based on a projected coordinate system so that it can easily be used for measurements

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ALGORITHM KEY PARTS

The proposed algorithm is a mechanism for merging elevation models of different levels of details (LoD) in order to:

- give a realistic visualization experience
- use as few points as possible so that the GPU, CPU and network utilization will be low
- dynamically change the model used according to the observer's position and viewing direction

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Process narrative

- Grid based technique dividing the area of interest into tiles

  In our study: Area of interest is Greece;

  tiles for 22 scales
- Each tile will have width and height equal to 512 pixels and 96 dpi

  An example: in scale 1:1,000 one pixel on the image equals 0.264 meters (1000 pixels) in reality
- Each scale is two times more precise than the previous one and two times less precise than the next one

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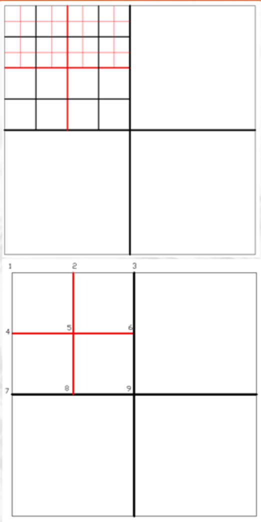
Process narrative

- The elevation model follows the same principle and is divided according to the image tiles
- Each tile has 4 rectangle sub tiles
- Following this structure it would be possible to dynamically add and remove tiles to recreate more dense or less dense DTMs resulting in realistic or less realistic visualization where not needed
- Each sub tile contains 9 points with X, Y, Z information
- The points are located at equal distances in such a way that each sub tile is divided into 4 rectangles of equal length



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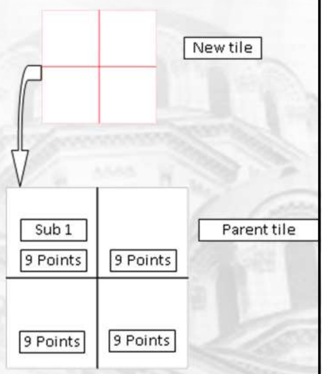
Process narrative

- A tile of scale id l contains therefore four tiles of scale id l+1 and sixteen tiles of scale id l+2
- When new data are available to the algorithm then these data should be used to update all tiles involved
- Assuming that a set of tiles of scale id l+1 is available while a new tile arrives of scale id l+2, the new tile will be rendered since it provides better quality than the existing tiles
- The parent tile and the sub tile (sub 1) at which the new tile corresponds is calculated
- The data of sub1 are being replaced by the data of the new tile



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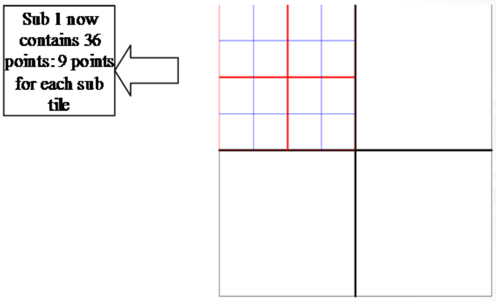
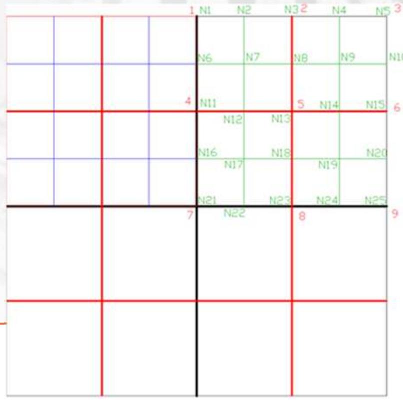
The other three sub tiles of the parent tile are being updated in order to use the new data where they have common points.



In case no common points exist dummy points are being calculated which contain the average values of the elevations that are used in rendering



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The process of updating point coordinates and elevation for sub tiles according to more accurate data is based on using the more accurate data to replace existing values where applicable and then use the average value of appropriate neighbouring points for all other cases.

Ni	Formula	Ni	Formula	Ni	Formula
N1	1	N11	4	N21	7
N2	(1 + 2) / 2	N12	(4 + 5) / 2	N22	(7 + 8) / 2
N3	2	N13	5	N23	8
N4	(2 + 3) / 2	N14	(5 + 6) / 2	N24	(8 + 9) / 2
N5	3	N15	6	N25	9
N6	(1 + 4) / 2	N16	(4 + 7) / 2		
N7	(1 + 5) / 2*	N17	(4 + 8) / 2*		
N8	(2 + 5) / 2	N18	(5 + 8) / 2		
N9	(2 + 6) / 2*	N19	(5 + 9) / 2*		
N10	(3 + 6) / 2	N20	(6 + 9) / 2		

Calculation of all nodes based on new elvation values

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Implementation steps

- The proposed algorithm contains five steps for the dynamic creation of a merged reality of all information acquired
- The steps are being executed serially but may spawn different threads which may complete at a later time
- Synchronization locking between different threads should be established in order to make sure that all the steps of the algorithm are being processed in the correct way and order
- These steps are being executed in a separated thread every quarter of a second and along with the rendering thread provide the mechanism for proper rendering and DTM update

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Implementation steps

- Step 1 : Load Data to Graphics Card
- Step 2: Update Render Tiles
- Step 3: Remove Data from Graphics Card
- Step 4: Calculate and Get Data Needed
- Step 5: Load Faces

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Step 1 : Load Data to Graphics Card

The first step is responsible for loading data that have been asked and received from other steps into the graphics card.

It is separated into two sub steps

a) **Update Pending Tiles and Load Data to Graphics Card**

In this step we iterate among the available scales (0 to 22). Scale 22 practically means that each pixel represents about 15 mm in ground space which is quite accurate in terms of topographic measurements.

b) **Calculate DTM and Choose data to render**

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Step 2: Update Render Tiles

- In this step the algorithm uses all the tiles that have been added to the Temporary Render List in order to replace the tiles in the Render List. This update takes place right after the current Render Process ends and before the next Render Process begins.
- The term Render List refers to a list that contains the tiles along with all the information needed in order to be rendered by the Render Process. The term Render Process refers to a separate process running usually on another thread that is responsible for rendering the result on screen as fast as possible.

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Step 3: Remove Data from Graphics Card

- In this step we iterate among the available scales (0 to 22).
- If a tile is marked for deletion then in case it contains valid data it uses the Restore Point to recalculate its DTM.
- Using the Restored DTM all neighbour tiles are being recalculated and marked in order to have its parents update their DTM as well.
- The parent tile updates its DTM based on the Restored DTM.
- The tile's parent uses the new DTM to update its neighbours so that the whole affected area will be updated.

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Step 4: Calculate and Get Data Needed

- In this step we iterate among the available scales (0 to 22) starting from higher scales (less precise) and moving towards smaller ones (more precise).
- Based on the observer's position the tiles needed for all scales that are near (Proximity testing) the observer are calculated.
- The algorithm checks whether the tile is in the Data List or already in the Fetch List at a previous iteration; in case it is not the tile is appended to the Fetch List.
- The term Fetch List refers to a list which is populated with the tiles that need to be asked from the Internet (or local storage).
- When a tile is fully downloaded then it is transferred to the Data List and deleted from the Fetch List, in order to be used for loading in the Graphics Card

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Step 5: Load Faces

The API supports the rendering of external faces so that real life representations may be visualized. In this step the faces are being transferred to the graphics card in groups of predefined quantity so that they do not block the normal flow of the algorithm

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CLOUD

- The rendering process takes place at the client's hardware with all the information being stored either locally or on the Internet
- All the necessary information is stored as tiles or organised in an indexed way that can be easily downloaded from any type of web server and with any kind of protocols (REST; SOAP) thus making it easy to be transferred to the Cloud
- The Cloud offers many alternatives when one wants to choose the best approach to support a service:
  - Platform as a Service (PaaS),
  - Infrastructure as a Service (IaaS),
  - Software as a Service (SaaS) or more.
- The solution is not bound to any technology or platform and may run at any data centre

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EXPERIMENTAL RESULTS

- An example was developed using C++, .NET, Assembly SSE2 (Streaming SIMD Extensions 2) and OpenGL (Open Graphics Library)
- The example provides real time navigation over a basemap with dynamically adjusted elevation according to the observer's eye position and elevation
- The density of the grid is adjusted so that the greater the distance from the observer, the less the density of the elevation grid
- The equipment used was a medium level PC

  Intel Core 2 Duo E8400 @ 3.00 GHz CPU and 3.25 GB of available RAM, graphics card NVIDIA GeForce 8400 GS 256 MB.
- The test lasted for 10 minutes with a typical user scenario where the user zooms and pans at a ratio of about once in 10 seconds

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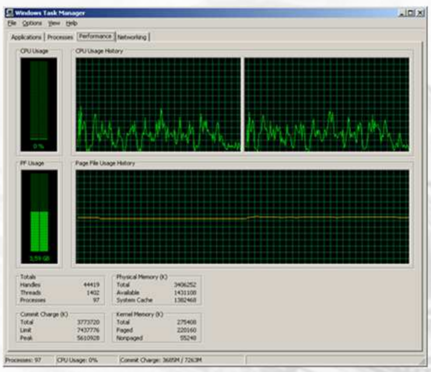
EXPERIMENTAL RESULTS

- The data were delivered to the client over the Internet through a Microsoft Internet Information Server -based web server
- The maximum CPU usage was about 30%, with an average of about 5%
- The maximum memory used was about 90 Mb with an average of about 75 Mb
- The user experience was very good with no delays



CPU usage diagram

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Dynamically adjusted DTM while approaching a hill

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Animation shows how the terrain is dynamically adjusted according to the viewer's position

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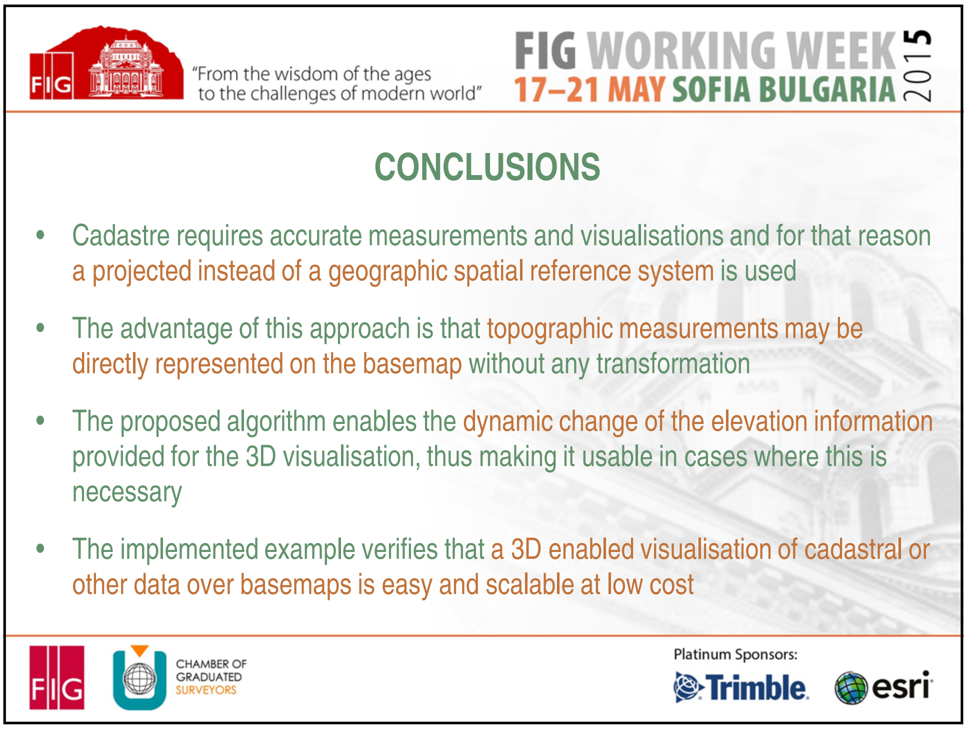
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CONCLUSIONS
• Cadastre requires accurate measurements and visualisations and for that reason a projected instead of a geographic spatial reference system is used
• The advantage of this approach is that topographic measurements may be directly represented on the basemap without any transformation
• The proposed algorithm enables the dynamic change of the elevation information provided for the 3D visualisation, thus making it usable in cases where this is necessary
• The implemented example verifies that a 3D enabled visualisation of cadastral or other data over basemaps is easy and scalable at low cost
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