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Digital Photogrammetry

Geospatial City and Urban Environmental Development through Digital Photogrammetry & 3D/4D Visualization

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List of Acronyms

DEM	Digital Elevation Model
GPS	Global Position System
GIS	Geographic Information System
RS	Remote Sensing
UGIS	Urban Geographical Information System
DBMS	Database Management System
DSS	Decision Support System
DOM	Digital Orthophotoquad Model
DLM	Digital Linear Model
DRG	Digital Raster Graph
DPS	Digital Photogrammetry System
SPN	Shortest Path Analysis

1- Introduction

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant and other phenomena.

It can also be thought of as the science of geometry, mathematics and physics that use the image of a 3D scene on a 2D piece of paper to reconstruct a reliable and accurate model of the original 3D scene. With this in mind it is easier to understand the current expanded definition, which includes the science of electronics by using video and other synthetic means of reproducing 2D images of 3D scenes, and these images are also used to reconstruct reliable and accurate models of the captured 3D scene.

Photos are information about the imaged objects, but information without geometric reference is useless. The photogrammetry is giving us the 3-dimensional reference for our available information. Over long time analog and analytical photogrammetry has dominated the industry, both are proven techniques, but they require expensive instruments. Today even standard PC's are powerful enough to handle aerial or space images with the full resolution, so the digital photogrammetric applications can be handled on simple PC's. The only necessary hardware component beside the computer for digital photogrammetry is the image scanner if analog images have to be used. If the full accuracy range of the photogrammetry shall be used, special photogrammetric scanners are required because the desk top publishing scanners are limited to an accuracy of approximately +/-50µm, even if the resolution may be sufficient. The important advantage of the digital photogrammetry is the possibility of automation. Automatic image matching is today not too time consuming, it is much faster than the manual measurement of a Digital Elevation Model (DEM).

It is undeniable that the need of 3D geospatial information is increasing rapidly, especially in 3D urban planning & development, in which brilliant project visualizations & analysis are needed to pave an efficient way for town planning and public administration. Hence, this results the initiation of 3D geospatial city, which integrates various disciplines / technologies of geospatial information system (GIS) to cater the needs of various authorities and industries.

3D geospatial city – developed through digital photogrammetry and 3D visualization, is the ultimate answer on how one can administer a city effectively and transparently in terms of geospatial information management, with a good and interesting emphasis on presentation medium that can connect and increase the involvement of the public. With digital photogrammetry serves as the economical yet reliable input of geospatial data and 3D visualization as the tool to effectively construct-visualize-manipulate-explore-navigate 3D spatial analysis such 3D geospatial city deserve to be the best model.

This paper presents the use of UGIS in the urban planning and management, and the application of 3D and 4D and relevant technologies for modern urban infrastructure.

2- Description

Modern urban infrastructure needs a comprehensive and integrated information science and technology. Global Position System (GPS), Geographic Information System (GIS), Digital Photogrammetry and Remote Sensing (RS) and other spatial information technologies are it's core techniques. Products of digital photogrammetry and remote sensing are its basic information resource. The key tasks of modern urban infrastructure are urban planning and management, city modeling and constructing digital city. Urban planners and administrators use UGIS and RS Technologies both as a spatial database and an analysis and modeling tool.

This paper presents the use of UGIS in the urban planning and management, and the application of 3D and 4D and relevant technologies for modern urban infrastructure. It contains four sections:

A- The contents of modern urban infrastructure are introduced. Some advanced technologies such as 3D city model and cyber city with virtual reality (VR) environment for UGIS are outlined.
B- Traditional urban planning and management bases on 2D. Problems during the existing planning process arise because of lack of 3D functionalities to analyze and visualize the 2D/3D data. However, 4D techniques are information of resources of creating and analyzing 3D city model. Three dimensional digital urban model and cyber city constructed using DEM,DOM and associate techniques are present.
C- Example of application of integration of UGIS and digital photogrammetry and remote sensing in urban transportation is explored, and,
D- Some conclusions are made.

Digital photogrammetry is one of the most reliable technologies for digital mapping, orthophoto mosaic & DEM generation. It is also one of the most important input sources of geospatial data, and has been greatly utilized for object interpretation and object measurement. As the hardware & software technology grows stronger, digital photogrammetry technology is also advancing.

Basically, the 3D city model is an advanced DEM, which precisely describes the urban topography. Each building in the model is registered with its exact location in both plan and height positions.

The benefits of a 3D geospatial city are countless. The 3D maps and models are currently used in city and street planning, civil engineering projects (above and underground), environment, soil surveys, building permit processes, noise modeling, traffic simulation, and military defense applications. The 3D city model is being utilized to generate shadow diagrams, rendered images (still pictures of part of the model), video clips, internet publishing and 3D PDF documentations. One of the major purposes is to increase the effectiveness on information distribution to the public, through visualization dissemination.

A 3D geospatial city with digital photogrammetry and 3D visualization as backbone makes it possible to present complex problems in a reasonable and more convincing way, and are therefore suitable for public discussions / debate on the positive and negative consequences of a proposed urban development project. This is particularly important as 3D geospatial city provides the possibility of evaluating future works (building, civil, environmental or infrastructural projects) which are already in the design or drafting stage, to ensure that other existing buildings, facilities or services, as well as public sphere or the society norm of the city are taken into consideration. Members of the public can now deeply and actively involve in the urban development debate, because they can clearly see the visualized proposed changes.

3- General Analysis

Modern urban infrastructure needs a comprehensive and integrated information science and technology. Global Position System (GPS), Geographic Information System (GIS), Digital Photogrammetry and Remote Sensing (RS) and other spatial information technologies are it's core techniques. Products of digital photogrammetry and remote sensing are its basic information resource. The key tasks of modern urban infrastructure are urban planning and management, city modeling and constructing digital city. Urban planners and administrators use UGIS and RS Technologies both as a spatial database and an analysis and modeling tool. In the mean time, the composite application of spatial data and other professional data have also made a great progress, its applications will cover many fields, for instance, environmental monitoring and analyzing, resource investigation and exploitation, disaster monitoring and appreciating, modern agriculture, urban development and intelligent traffic, etc.

Integration of GPS, GIS and digital photogrammetry and remote sensing for urban planning and management, the following specific tasks that are required on a daily basis in most planning agencies and planners (Foreman and Millette, 1997):

1- Inventory and analysis of many types of spatial information, such as changing patterns of land cover and land use to support master plan development.

2- Administration of zoning bylaws, which required determining the location of a parcel in the relationship to established zoning districts.
3- Site plan reviews, which examine site conditions such as soils, slopes, ground water, utilities, setbacks, right of ways, and variances to ensure adherence to code.
4- Subdivision reviews that identify the potential impacts of residential development on community facilities and services
5- Permit tracking to identify the location of building permits issues to determine if development is conforming to master plans.
6- Property assessment based on listing requirements such as parcel size, location, address, frontage, building size, condition, and use.
7- Facility sitting, which involves identifying site conditions and proximity to particular land uses, utilities, and transportation routes
8- Infrastructure maintenance to set up a historical database and inventory of installations and provide for inspection and maintenance of roads, bridges, culverts, and sewer, water, and energy utilities.
9- Event reporting of crime, fire, and accidents to be for resource allocations of personal and equipment with a strong spatial rationale
10- Dispatching of emergency vehicles based on route optimization, given travel distance, road conditions, traffic patterns, and speed limits.
11- Vehicle routing for school buses, snowplows, wide loads, and hazardous materials to balance expedience against public safety
12- Disaster preparedness to preposition strategic materials, prepare evacuation routes, and identify high- priority facilities including hospitals, schools, and water supplies for emergencies.
13- Traffic analysis to identify origins and destinations of traffic at park hours to minimize traffic jam.
14- Legal notification for public hearings that require notification of abutters and land owners within a specific radius of a particular parcel
15- Acquisition and disposal of property for the purposes of condemnation, foreclosure, and right-of-way acquisition, This requires information on roads, buildings, land use, zoning, ownership, and adjacent parcel.
16 Tax listing, revaluation, and abatement programs for management of local land and tax base.
17- Redistricting and rezoning for schools and political representation

UGIS is just one of the formalized computer-based information systems capable of integrating data from various sources to provide the information necessary for effective decision-making in urban planning. Other information systems for urban planning include database management systems (DBMS), decision support systems (DSS), and expert systems. Current UGIS support efficient data retrieval, query, spatial analysis, and mapping. Planners can also extract data from their databases and input them to other modeling and spatial analysis programs.

When combined with data from other tabular databases or specially conducted surveys, geographical information can be used to make efficient planning decisions. UGIS allows planners to perform spatial analysis using geo-processing functions such as map overlay, connectivity measurement, and buffering. Spatial modeling is used more in strategic planning. General administration employs mainly data management and visualization. Finally, development control uses the visualization and spatial analysis functions of UGIS the most.

The more routine general administration and development control work of urban planning includes (Newton 1988):

• Management of land use record;
• Thematic mapping;
• Planning application processing;
• Building control application processing;
• Land use management;
• Land availability and development monitoring;
• Industrial, commercial, and retail floor space recording;
• Recreational and countryside facility planning;
• Environmental impact assessment;
• Land use/transport strategic planning;
• Public facilities and shopping area and accessibility analysis;
• Social area and deprivation analysis

Visualization, spatial analysis, and spatial modeling are the most frequently used UGIS functions in plan making. There are many advantages of using the data management, visualization, and spatial analysis and modeling functions of UGIS as scientific inputs to urban planning, (Webster, 1993, 1994). There are significant differences in the degree of UGIS use in the description, prediction, and prescription planning process geo-processing functions of UGIS as scientific inputs to urban planning, (Webster).

Different scales of planning require different data and techniques. Raster data are more useful for citywide strategic planning, because large areas are involved and high resolution is not required. The processing of raster data is much faster than that of vector data, especially in map overlay and buffer analysis. On the other hand, vector data are generally used for district and local action area planning because of the need for very highly resolution analysis.

There are many applications of UGIS in the land use, transportation, housing, land development, and environment sectors. Key examples include site selection and land suitability analysis. In contrast, network analysis and route selection are most frequently used in transport, and environmental planning and management use buffer and overlay processing. There is an increasing trend toward the integration of modeling in different sectors of urban planning (Goodchild, 1993).

The role of UGIS also varies in the different stages of the urban planning process. For example, UGIS is more useful in modeling and development of planning options than in the determination of planning objectives. The different stages in the urban planning process can be generalized as the determination of objectives, resource inventory, and analysis of existing situations, modeling and projection, development of planning options, selection of planning options, plan evaluation, monitoring, and feedback (Figure1). UGIS can only provide some of the data and techniques that are needed in the different stages of the urban planning process. Any UGIS also has to work with other databases, techniques, and models at different stages of the planning process.

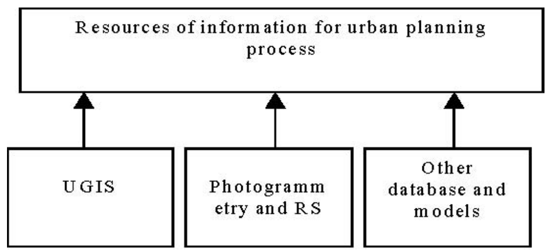

Figure 1. UGIS, RS and other database and models in planning process

4- Actualization

Photogrammetry and remote sensing image has created an urgent need for techniques for urban planning and management. These techniques have numerous applications in urban mapping, urban planning, and other geo-information engineering disciplines and application. However, traditional urban planning and management bases on two dimensions. Problems during the existing planning process arise because of lack of 3D functionalities to analyze and visualize the 2D/3D data. However, 4D techniques are Information resources of creating and analyzing 3D city model. 4D products contain digital elevation model (DEM), digital orthophotoquad model (DOM), digital raster graph (DRG) and digital linear graph (DLG). They have been widely used in Urban Geoinformatics to visualize model and to enhance the interaction of the decision-maker with data and image.

4.1- 4D and association enabling technologies for modern urban infrastructure

Digital elevation model (DEM) are nowadays important resource for many disciplines and are useful for generated digital products such as contour maps, orthoimages, and perspective views. The main incentive for the increasing popularity of DEM is the ability to generate them automatically from aerial and remote sensing image by image processing and matching techniques.
Digital photogrammetry system (DPS) is main technique for creating DEM

(figure2).

The orthoimage is created based on the DEM and the corresponding original image. According to the theory of digital orthorectification, the coordinates of the point projected on the original image are computed with collinear equations based on its ground control points. Height is interpolated from DEM. The orthoimage can be created from one or multi-images and resample of gray levels can be gotten by bilinear interpolation or other interpolation methods.

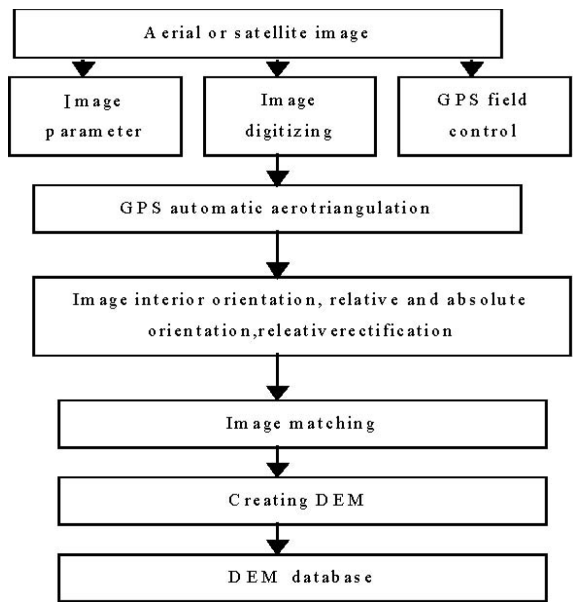

Figure 2. Creating DEM using digital automatic photogrammetry

With the rapid development of digital photogrammetry and remote sensing technologies, the amount of image data has dramatically increased, and has acquired more and more attention. Besides 4D techniques, modern urban infrastructure needs other new technologies such as 3D city model (cyber city) and urban geographical information system (UGIS).

4D and associated enabling technologies offer new and exciting opportunities to create 3D city model (Figure3, Figure4). Virtual reality (VR) technique can construct a 3D environment. Decision-makers and users can walk through 3D environment, see newly planned buildings and appreciate changes in the landscape.
The other associated technology is UGIS. The use of UGIS shifts from 2D to 3D modeling and analysis. Buildings and constructions are modeled with digital photogrammmetrical system (4D products) and linked to data in the UGIS. The 3D information is used to calculate volumes, distances, sound contours, shadowing, line-of- sight, etc.

Once the 3D city model has reached the status of well-engineered proposal, it will be converted into a form to be present to all participants in the urban decision-making process. This can be either through detail designing, DEM and DOM rending, or with very detailed and realistic scale models. The different variants and alternatives will have to be compared and their consequences and performances clearly outlined for each the different participants. The more realistic the presentation can be, the better the plan is communicated.

UGIS analysis involves the impact of the new design on its environment. The design is evaluate with respect to its exploration, maintenance, usability and environmental quality. Visual analysis is the main task at this stage of the planning process and a more realistic visualization will only improve the presentation of the plans. From this analysis of the planning process, the most important requirement for UDSS are possibilities for 3D analysis, a good visualization and interaction with the data.

4.2 Application of transportation of integration of GPS, GIS and RS

Transportation applications of GPS, GIS and RS have become increasingly popular in recent years. Sources of spatial data of transportation may be obtained from GIS, RS, GPS, and other databases. As the basic geo-spatial data, DEM, DOM, DLG, and other databases, they have been playing significant roles in urban transportation. For example, DEM is the carrier of any other geographic information and then is considered as the base of three dimension visualization even the virtual reality or digital earth. The integration of DEM, DOM and UGIS becomes the core part of spatial data infrastructure.

Transportation of application of Integration of UGIS and Digital Photogrammetry and Remote Sensing need a geo-spatial data framework. As we know, The GPS-supported fully by digital photogrammetric system (DPS) can promptly produce DOM, DEM, and DLG. The digital products with the unit of map sheet need to integrate a complete spatial database under UGIS environment.
According to the modern urban transportation needs and very fast updating, geo-spatial data transportation framework should include DEM, DOM, and several layers of DLG data. With DLG vector graphic data, at least the following are required:

A- Geodetic control network
B- Boundaries of administration regions
C- Road network
D- Waterbody
E- Geographic names and relative lettering
F- Underground-pipeline system

Modern urban transportation of integration of UGIS and digital photogrammetry and remote sensing should contain the following functions:

- Conduct check, roam and query within the entire spatial database
- Can cover vector graphic data onto image data and update graphic data using image data
- Can realize self-adaptive and multi-resolution display based image pyramid
- Achieve image and DEM's fundamental function such as 2.5D display, query, and roam, etc.
- Output visualization products with map sheet or given the range in term of user's needs

An example of application of transportation of integration of UGIS and digital photogrammetry and remote sensing is shortest path analysis (SPN). It is critical for route location models for determine the minimum environmental cost route (Tomlin 1997). Shortest path analysis in term of time, distance, and cost may all be relevant. The number of lanes, their height and width, and restrictions such as those on hazardous materials should all be incorporated into the calculations.
Other example of application of transportation of integration of UGIS and digital photogrammetry and remote sensing is that main road network information is collected and updated. Main road network information collected and updated is one of the most tasks in urban planning and management.

5- Discussion

It is undeniable that the need of 3D geospatial information is increasing rapidly, especially in 3D urban planning & development, in which brilliant project visualizations & analysis are needed to pave an efficient way for town planning and public administration. Hence, this results the initiation of 3D geospatial city, which integrates various disciplines / technologies of geospatial information system (GIS) to cater the needs of various authorities and industries.

3D geospatial city – developed through digital photogrammetry and 3D visualization, is the ultimate answer on how one can administer a city effectively and transparently in terms of geospatial information management, with a good and interesting emphasis on presentation medium that can connect and increase the involvement of the public. With digital photogrammetry serves as the economical yet reliable input of geospatial data, and 3D visualization as the tool to effectively construct-visualize-manipulate-explore-navigate 3D spatial analysis, such 3D geospatial city deserves to be in the best model.

The benefits of a 3D geospatial city are countless. The 3D maps and models are currently used in city and street planning, civil engineering projects (above and underground), environment, soil surveys, building permit processes, noise modeling, traffic simulation, and military defense applications.

6- General Recommendation

3D geospatial city provides an unbiased, realistic and economical platform for project presentation. Whether the projects are initiated by the government or the private sectors, the focus will be on the actual architecture and workability, rather than the key-players involved or excessive elaboration of the planned projects. However, One of the common challenges encountered is in the process of updating and synchronizing the old 2D base map features. The 3D development team always finds numerous digitizing errors from time to time, from the old 2D base maps. Since all detected digitizing errors will need to be traced back and rectified, the corrections procedures will take sometime and hence the 3D development schedule will need to be always revised. Compare to 2D works, 3D updating (modeling) needs more skills and time, especially in 3D visualization setup (photo-true texturing). Hence having a full-time dedicated development team is one criteria of the utmost importance. For instance, a 3D object needs further touch-ups after being built-up. Each of its surface texture (roofs and facades) must be matched exactly and accurately, by re-scaling the texture images and re-adjusting its resolution (pixel dimensions), fine-tuning its brightness, toning the overall appearances, testing the final outcome by rendering partly or the whole model. A few necessary repetitive attempts are needed and commons for 3D visualization works, in order to achieve the best and acceptable results. Besides, the consistency of the 3D base maps has to be monitored from time to time, to produce a truly reliable 3D city model. Therefore, each member of the development team needs to be persevering, consistent and sensitive to changes, on top of the basic skill set in 3D modeling. Since 3D geospatial city is multi-functionally useful and its potential is growing, there's a need for better systems coordination in the cities' administration, and this lies in the hand of the authority who governs the 3D city model. One of the workable solutions will be the development of a common documentation and standards repository by updating the city's current GIS metadata through internet. This will involve the collection of all data modeling documentations, object and feature catalogs used in various departments and divisions that utilize the 3D city model to offer services to the public.

7- Conclusion

With the development of modern cities, more and more advanced technologies are applied to modern urban infrastructure. 3D city model and 4D products generated from photogrammetry and remote sensing has constituted a decision support information system. This information has provided a new perspective to decision-makers, planners, government officials, and the public. In effect, techniques of Integration of UGIS and Digital Photogrammetry and Remote Sensing are being used as one of the key element by decision-makers for urban planning and, environment protection management. Additionally, the accessibility to 4D products, as well as digital image has afforded those entities and individuals who wish to utilize these data and image. Digital map and attribute information (control points, the depths of water, boundaries, place names, and natural and man-made features ranging from mountains valleys to oceans, lakes, rivers, and transportation networks of railways, super-highways, and gravel roads and etc.) can be provided by governmental website (WebGIS).

To this extent, research and development in new spatial data mining, infrastructure, standards, and widespread applications are all valuable to the urban planning and environmental management. We believe that creating UGIS, through 4D and associated enabling technologies are successful.

4D products derived from 3D integrating technologies used in UGIS have meaning for those entrusted with managing our urban resources and protecting urban environment.

High resolution remote sensing technique (high space resolution and high time resolution), 3DGIS, Web-GIS, Open GIS Standard, Data-house and Data exchange, Data sharing, and Object oriented technique are core techniques of constructing modern urban infrastructure. In this paper, some core techniques for modern urban infrastructure were explored, especially digital city model. I believe that those techniques can contribute to modern urban planning and management.

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