Development of Geospatial Smart Cities and Management

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SUMMARY

The first section of this paper will provide an introduction to a unique cutting-edge 3D Geospatial Solution for local governments, governmental agencies and various industries. This section will be followed by an overview of successful case studies using the introduced solution.

The provided methodology and solution are based on high resolution intelligent, object-based 3D geospatial data for smart cities. Our data sets incorporate high resolution imagery, geometry, geospatial semantics, artificial intelligence (including deep learning), high-performance computing, computational fluid dynamics, simulation technologies, automation and topology. This solution is capable of displaying entire urban areas (city, towns, villages, etc.) and rural areas intelligently to users.

The system also allows for powerful analyses such as contour maps, noise pollution, flooding and so forth. This helps developers meet various demands related to smart cities such as utility management, green environments, resource management, urban planning and so forth.

The paper includes discussions of successful case studies in three countries, each one an excellent example of smart 3D geospatial data creation for smart city applications. These case studies are:

- Cerkes 3D Smart Data (Turkey)
- Read Sea Mega Tourism Project (Saudi Arabia)
- Orlando (USA) and Hannover (Germany) Case Studies

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1. INTRODUCTION

Smart projects require smart people, a robust IT infrastructure and knowledge. At present, the diversity, resolution and quality of geographic information systems are increasing, resulting in the emergence of rich information creation methods, such as:

- Artificial intelligence methods
- High-performance computing
- Computer graphics
- Image processing by computers

Thus, it is possible to integrate and obtain results that were not previously feasible.

There are a sizable number of software packages in the market for creating 3D representations of terrain and buildings, mainly using photo mesh (Tang, P., et al., 2010; Toschi, I., et al., 2017). None of these packages create object-based 3D representations using automated techniques (Biljecki, F., et al., 2015; Lafarge, F., et al., 2012; Remondino, F., et al., 2016).

Our approach, titled Citigenius, utilizes unique automated techniques to create object-based 3D representations. Citigenius data sets cover high resolution imagery, geometry, geospatial semantics, artificial intelligence, deep learning, automation and topology. This solution displays the entire city intelligently to users.

The paper includes discussions of successful case studies in three countries, each one an excellent example of smart 3D geospatial data creation for smart city applications. These case studies are:

a) Cerkes 3D Smart Data (Turkey): In April 2017, a 3D Smart City model of Cerkes, Turkey was produced using the proposed approach. The project area of roughly 27 km^2 was flown by an UAV for about 3 hours and 5cm GSD imagery was collected at 80% overlap and 60% sidelap. The 3D City model was created in 10 days' time by a single operator, the resulting output was comprised of:
   - 5cm GSD orthophoto,
   - DSM / DTM / Contours at ~10 cm precision.
   - 3D buildings (a total of 5,916 buildings),
   - 3D Trees (about 6,000), fences, power lines, and other planimetric features

b) Read Sea Mega Tourism Project (Saudi Arabia): During 2016-2017, Geo Tech Group has completed a comprehensive geospatial project covering an area of about 60,000 km^2. The project also included the development of 3D Geospatial Smart Data using 1.5m stereo satellite images, 0.18m stereo aerial images and smart 3D geospatial data using Citigenius.

c) Orlando (USA) and Hannover (Germany) Case Studies: Pilot projects were carried out in Orlando and Hannover to the proposed technology.

2. OVERVIEW OF CITIGENIUS

Smart cities offer excellent tools for public and governmental agencies. Smart cities are mostly based on 3D smart modelling of the city. Citigenius is a cutting edge geospatial solution by providing such smart geospatial data for local governments and governmental agencies. Citigenius methodology utilizes high resolution intelligent geospatial data for smart cities and it is based on a next generation photorealistic 3D virtual city model.

Citigenius is a great tool for developing smart and object-based 3D geospatial data, it incorporates Artificial Intelligence (AI), High Performance Computing, Simulation Technologies and Computer Graphics, with extensive measurement/editing and analysis tools.

Citigenius data sets cover:
- High resolution imagery
- Geometry
- Geospatial semantics
- Artificial intelligence
- Automation and
- Topology

The proposed solution provides 3D Geographic Information System tools allowing end users to perform innovative evaluation and analysis operations on virtual cities in addition to spatial operations, urban planning and simulations. This solution has the potential to introduce a new path in the field of Photorealistic 3D Virtual and Smart Cities due to its unique and innovative characteristics. With its ability to perform rich spatial analysis, urban planning and simulations, Citigenius serves to meet demands such as: energy efficiency, disaster management, improved quality of life and urban development management.

With the approach mentioned above, the process of knowledge creation is shortened, resulting in a more cost-effective path to new results, and the process of traditional data collection or information creation takes a serious turn.

As a future work we aim to integrate this smart 3D geospatial data with Building Information Management (BIM), which offers total management of GIS and BIM [Volk, R., Stengel, J., Schultmann, F. (2014)].

The proposed solution mainly covers the features listed below:
- Basic Features
- Integrated and Green Design

Each of these solutions are presented in subsequent sections. Moreover, extensive effort is spent to visualize the analyses results on web-based globe solutions such as CESIUM.

2.1 Basic Features

As mentioned above, Smart Cities uses realistic virtual city models. It is very important to provide new tools to better explore the potential of this type of data sets. Therefore, Citigenius introduces various new measurement solutions such as vertical area calculation (i.e. window area). Besides, some of the common measurements (such as vertical distance, slope, azimuth, horizontal distance etc.) are combined in a single tool to provide as much information as possible. In total, Citigenius offers almost 20 different measurement tools.

Basic features also include file operations, editing, geospatial queries and filtering functions that are very typical in GIS tools. However, we tried to extend such features with various cost calculation tools such as cut & fill, irrigation, road construction, tiling, asphalt removal etc. Citigenius uses high-resolution and very precise geospatial data, that is required for accurate cost calculation. The cut & fill feature can generate very detailed and accurate report as shown in Figure 1. The output presents precise cut and fill volumes, type of cut volume (soil/rock/clay if drilling is available), operational cost etc. Similarly, it is also possible to calculate almost exact costs to construct a new road by utilizing the high-resolution and seamless terrain data.

Figure 1. Cut & Fill Cost Analysis

As discussed above, Citigenius also generates detailed object geometry such as buildings. This type of output lets us to generate many calculations for buildings such as debris cost, thermal insulation cost or ice-load risk assessment. Our future goal is to generate more information regarding the building structure by using façade texture maps. We believe that machine learning techniques accompanied with several heuristics will help us to realize this goal.

Citigenius also introduces a revolutionary approach for rapid 360 degrees high-resolution panoramic image generation. In this approach as a first step dozens of high-resolution planar images are generated from an arbitrary view-point. At the second step these images are distorted and stitched to generate panoramic image as shown in Figure 2. To the best of our knowledge, there is no practical GIS solution that can generate such output in seconds.

Figure 2. Panoramic View (Çerkeş/Turkey)

Citigenius offers many more analysis and tools for various purposes ranging from insurance assessment to real-estate valuation. This paper focuses on Integrated and Green design tools offered by Citigenius, since the scientific efforts of this solution are mostly included in these tools.

2.2 Integrated and Green Design

Integrated and green design becomes a hot topic in the design community. This approach blends various domain-knowledge ranging from architectural to engineering. The idea is to build smart, green and efficient structures to ensure the sustainability of the cities. Citigenius aims to provide easy to use solution for urban designers to help them build smart cities. Our goal is to incorporate computational fluid dynamics, solar equations, high-performance computing and physics to bridge the gap between the CAD tools and GIS tools regarding building design. Therefore, urban designers will be able to perform most of the work by using real city data in a very short time.

Building orientation is quite an important issue since the future buildings must be energy-efficient as the world resources decreases day by day. It is possible to save significant amount of heating/cooling energy by just calculating the optimal orientation of the building considering the sun position and main wind directions throughout the year. Solar heat-gain, daylight gain, wind cooling effect and several more parameters are considered to compute the best orientation of the building. Semantic content such as windows, doors, construction material, floor plan (living rooms, bedrooms) etc. can also be used to improve the results of the analysis.

Citigenius has a built-in tool that determines the best orientation considering the parameters given above. Thanks to the enormous processing power provided by graphical processing units. It is possible to perform complicated solutions such as computational fluid dynamics in real time as shown in Figure 3. Figure 4 shows the optimum orientation of a sample building considering the heat gain and several other parameters. We prefer an iterative approach to determine the optimum orientation which starts with larger intervals and goes on with smaller intervals as shown in Figure 5. In this chart the minimum energy demand value gives us the optimum orientation. In this basic sample we determined almost 3% difference between the worst and best orientation considering energy gain, which is very significant considering the amount saved during the life-cycle of the buildings. It is certain that such simple design issues contribute a lot for the sustainability of future cities. In this sense, providing such a practical solution in GIS environment will help us to build green structures easily.

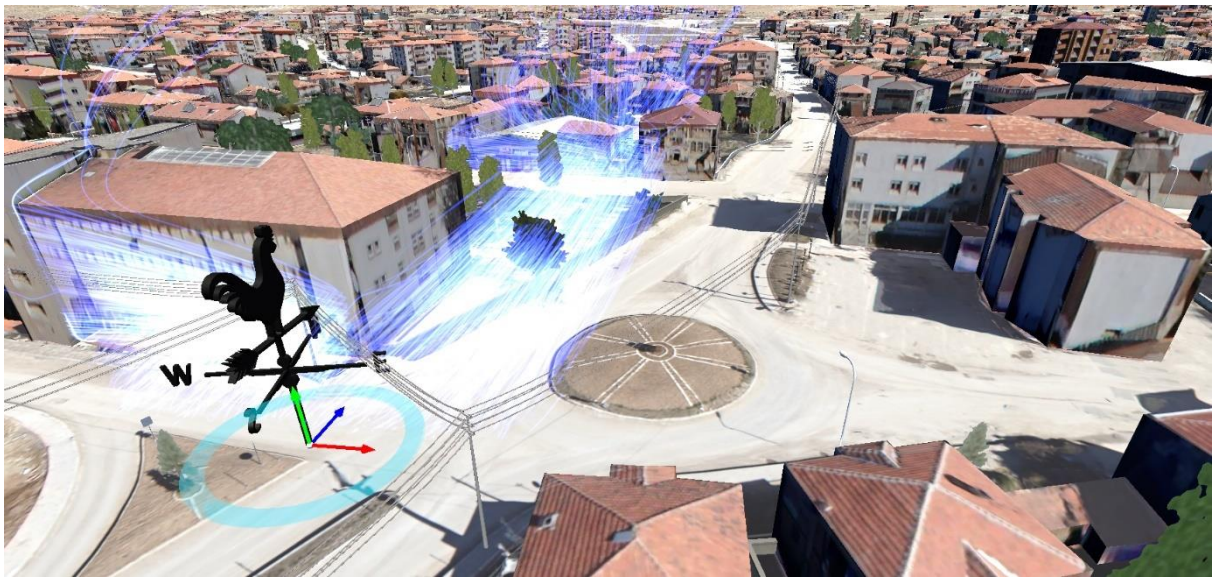

Figure 3. Real-time Wind Analysis in city-scale (Çerkeş/Turkey)

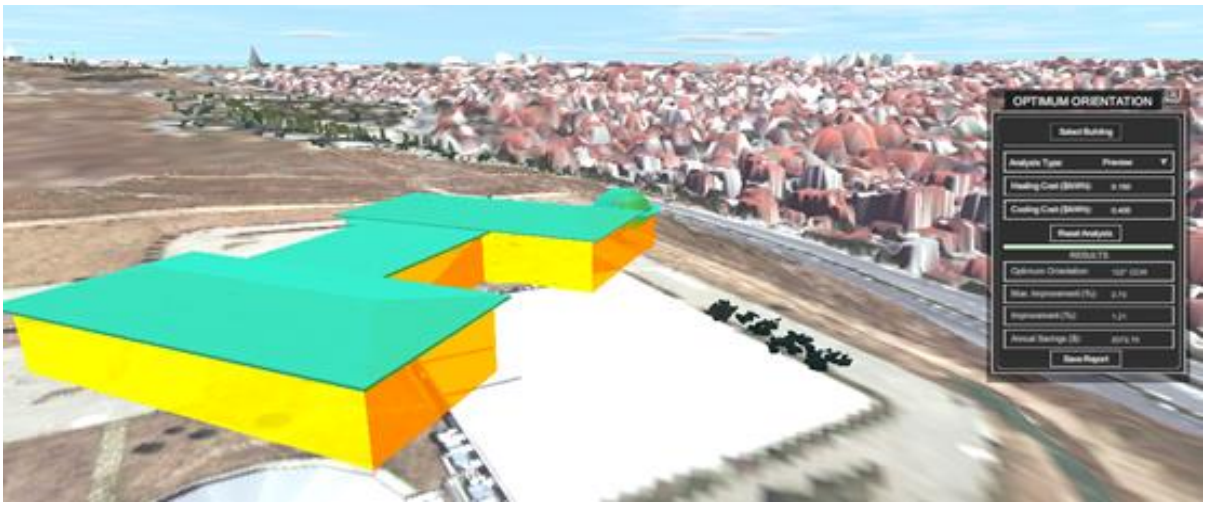

Figure 4. Optimum Orientation of a Building

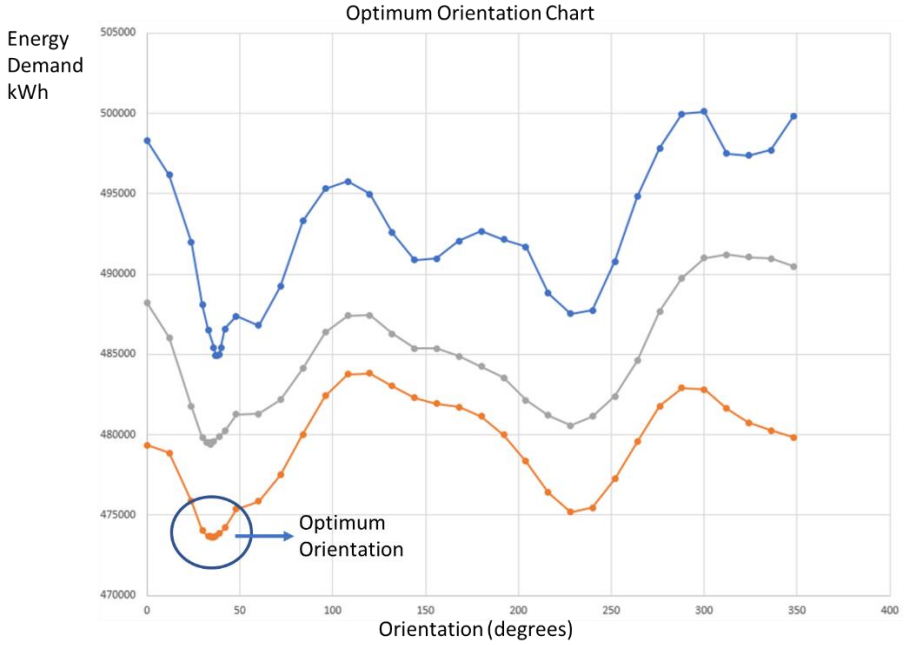

Figure 5. Optimum Orientation Chart

Such powerful design tools also include very accurate solar energy assessment solution. Shadow effect is also precisely calculated since each new building introduces a shadowing effect to the neighboring area. Thanks to the high-resolution geospatial data and 3 D object representation model, Citigenius is designed to provide minute-base detailed report regarding the shadow effect of each structure. The green design tools also address important environmental issues such as building carbon footprint assessment, local micro-climate

analysis. Last but not least, Citigenius capable of making very detailed analysis regarding the pedestrian wind comfort as shown in Figure 6.

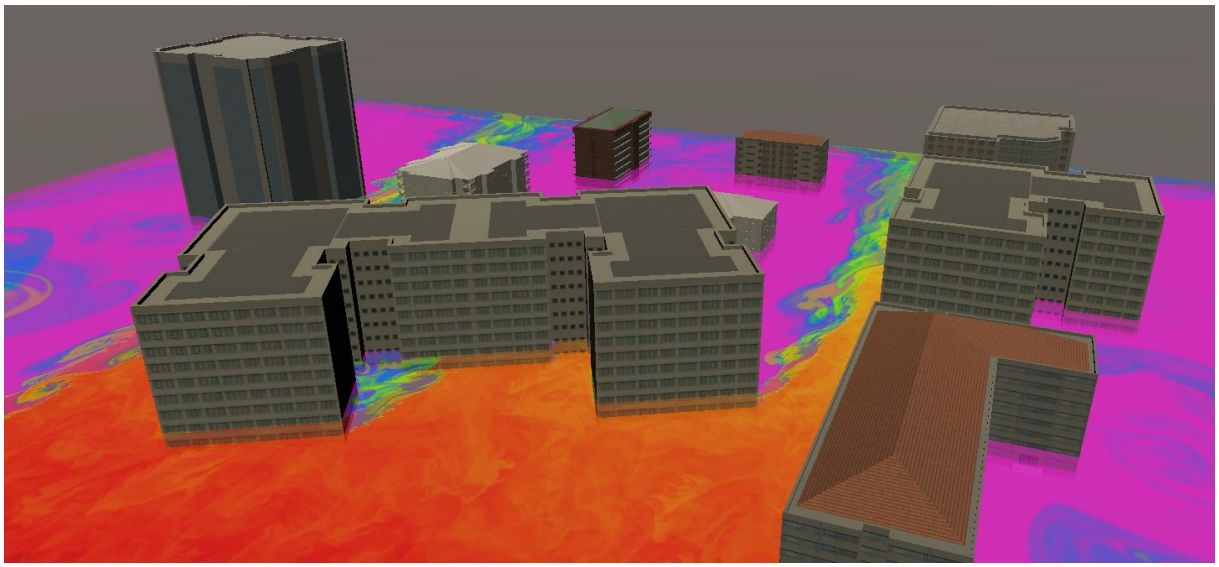

Figure 6. Real-time Pedestrian Wind Comfort Analysis

3. CASE STUDIES

The paper also discusses three case studies as excellent examples of smart 3D geospatial data for use in smart city applications. These examples are:

a) Çerkeş 3D Smart City – Turkey
b) Red Sea Mega Tourism Project - Saudi Arabia
c) Orlando (USA) and Hannover 3D Smart Cities

3.1 Çerkeş 3D Smart Project (Turkey)

Between the 3rd and 13th of April 2017, 3D SMART ÇERKEŞ, TURKEY (see Figure 7) was produced in 10 days by A SINGLE OPERATOR using the proposed solution. The project area, which is about 27 km^2, was flown by an UAV on April 3rd, 2017 for about 3 hours and 5cm GSD nadir imagery was collected at 80% overlap and 60% sidelap. A total of 40 GCPs were established in the national coordinate system based on ITR-1996 datum and used for Aerial Triangulation in order to create geometrically correct 3D stereo models. Following these steps, the 3D City model was created in 10 days' time consisting of:

- 5cm GSD orthophoto,
- 3D buildings (a total of 5,916 buildings),
- 3D Trees (about 6,000), fences, power lines, and other planimetric features
- DSM / DTM / Contours all to the precision of ~10 cm.

This solution displays the entire city intelligently to users. The system also allows for powerful analyses such as contour maps, noise maps, flooding and so forth. It is a good example of rich

and intelligent geospatial data compiled in a short duration. Some views of this smart geospatial data are provided in Figure 2. This software also generates automated meta data of objects as provided in **Error! Reference source not found.**.

Figure 7. The location of Cerkes and Project Area, Turkey (Left) and Project Metadata (right)

Figure 2. Some views of Smart City Example

3.2 Red Sea NEOM Project (Saudi Arabia)

We completed in February 2018 a major "3D Geospatial Data and GIS Project" in Saudi Arabia for Public Investments Fund (PIF). The aim of the project is to map entire area of the "Red Sea NEOM Project" considered for resort and tourism development. The project area is located in Al Madinah Al Munawwarah and Tabuk Regions, covering an area of about 60,000 km^2 including lands, islands and water as illustrated in Figure 9.

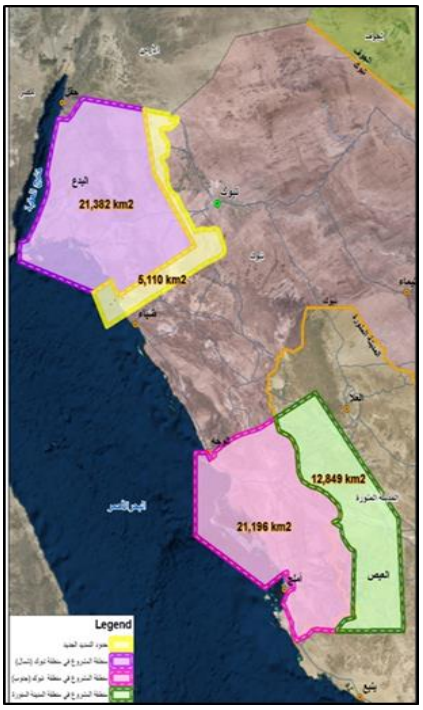

Figure 3. The PIF Geospatial Project Area

The scope of the project ranges from system design to mapping, and development of web-based geodatabase, 3D Geospatial data and applications as listed below:

- System design
- Data collection, processing and integration of existing information
- Establishment and operation of CORS
- 1/20000 scale mapping using stereo SPOT6 / SPOT7, determining land use / land cover of 28 classes and 2m contour compilation for the total project area
- 1/2500 – 1/5000 scale mapping using orthorectified GeoEYE imagery (rural areas)
- 1/1000 Scale topographic / cadastral mapping using 18cm GSD stereo aerial images (urban areas amounting to 18200 km2)
- Development of PIF Geodatabase, 3D Smart Geospatial data and Geoportal

We used stereo data of 18cm GSD for Al Bidi City within the project area. The data was processed via Citigenius and a smart model of Al Bidi was developed as illustrated in Figure 10.

Figure 10. Al Bidi 3D Geospatial data developed by Citigenius

3.3 Orlando and Hannover 3D Smart City Projects

We obtained sample oblique data of 10cm GSD for Orlando from Skyline Software Systems, Inc., (a leading provider of 3D earth visualization software and services).

We processed Orlando data via Citigenius and developed a smart model of Orlando as illustrated in Figure 11. In this example façade texture maps are clearer due to oblique imagery. It should be noted that texture mapping of the facades is done automatically following the extraction of 3D Building geometry. In this example further image processing is performed in order to improve texture map quality such as noise removal, resolution enhancement etc.

Figure 11. Orlando 3D Geospatial data developed by Citigenius

We obtained sample stereo data of 18cm GSD from Phoenics GmbH, a photogrammetric company in Germany. We processed this data set from Hannover City by Citigenius and developed smart town model as illustrated in Figure 12. This data set represents a relatively low side and forward overlap values compared to the previous examples. However, it should be noted that even in low lap amounts it is possible to generate 3D city models.

Figure12. Hannover 3D Geospatial data developed by Citigenius

4. CONCLUSION

The cutting edge Citigenius solution combined with aerial imagery using aircrafts, UAVs and so forth, makes it possible to develop smart geospatial data for smart cities in a nearly automated fashion. Thus, a smart geospatial base can be established in weeks rather than the years that would be required using traditional approaches and techniques.

Therefore, our approach will effectively serve:

- Object based 3D GIS Establishment
- Cadastral registration and Real Estate Value Assessment
- Environmental Management
- Spatial Planning and Landscape Planning
- Urban Transformation and Traffic Planning
- Energy Efficiency
- Disaster Prevention and Disaster Management
- Improving the Quality of Life (noise, air pollution, air flow, etc.).
- Urban Life Mobility Analysis (Business centers, streets, underground transportation)
- Infrastructure Construction and others.

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BIOGRAPHICAL NOTES (Kamil EREN)

K. Eren completed his Ph.D. study and post-doctoral work in Ohio State University – USA during 1975-1980. He joined Middle East Technical University (Ankara) in 1980 and worked there until 1985 as Professor in Geodetic Science. In 1985 and 1987, he carried out research in Germany as a Humboldt Fellow.

He joined United Nations as a Geodetic Expert in 1986 and served until 1994 training technical staff, designing and supervising numerous projects in geodetic surveys, digital mapping and GIS/LIS activities.

K. Eren founded Geo-Tech Co. in 1997 offering services worldwide on surveying & mapping, GPS, and GIS/LIS activities. During 1996-1997, he also served as Chief Adviser to the Prime Minister of Turkey for the privatization of government owned facilities and modernization of slum areas. In 2004, He was also appointed as Professor in Civil Engineering Department of Istanbul Kultur University (part-time).

Through the companies and University mentioned above, amongst others, K. Eren completed engineering surveys and mapping of Blue Stream Natural Gas pipeline (in Turkey / 500 km); National GIS project of Ministry of Interior / S. Arabia, establishment of National Planning Information System in S. Arabia, establishment of Geodatabase and GIS for Saudi Telecom / S. Arabia, establishment of the National Geodetic Network and CORS of S. Arabia, establishment of "Network Based CORS TR Project" for RTK coverage throughout Turkey.

He has over 30 refereed publications (articles, books and reports).

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