Next Generation SMART Cities: The role of Geomatics

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1. Smart cities/spatial intelligence
2. Geomatics technologies: 3D/4D modeling
3. Example: SEC-FCL project
4. Conclusions, perspectives
Cities/megacities

Problem
- Urban growth is most rapid in the developing world, where cities gain an average of 5 million residents every month.
- City growth: Harmony among the spatial, social, economical and environmental aspects of a city and between their inhabitants becomes of paramount importance.

This harmony hinges on 3 key pillars:

Earth Environment  
Social Equity  
Economic Development

Balance through sustainability
Smart cities (6 axes model)
- smart economy, mobility, environment, people, living, governance

‘Smart’ city: Investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development, a high quality of life, with a wise management of natural resources, through participatory governance.
A lively and liveable Singapore: Strategies for sustainable growth
(Inter-Ministerial Committee on Sustainable Development, 2009)

Goals for 2030

- **Energy** – greater efficiency and diversification; reduce energy intensity by 35%
- **Waste** - towards zero landfill; improve recycling rate to 70%
- **Water** – towards self-sufficiency; reduce consumption to 140l per capita per day
- **Air Quality** – reduce annual mean for ambient fine Particular Matter to 12mueg/m3
- **Clean, Blue and Green Environment** – increase green park space to 0.8ha per1,000 population and more
- **Capability and Expertise** – Singapore as outstanding knowledge hub
- **Environment. responsible community** – part of people and business culture
Singapore CREATE program
(Campus for Research Excellence And Technological Enterprise)

5 research centers:
+ ETH Zurich (SEC-FCL: Singapore/ETH Center for Global Environmental Sustainability- Future Cities Laboratory)
+ MIT
+ Technion
+ TU Munich
+ Hebrew University of Jerusalem
SEC-FCL

URBAN METABOLISM

- Understand the city as a dynamic system
- Read and model this system in terms of Stocks and Flows
- Recognize Urban Stocks as basic elements of the urban metabolism and as locally available resources
What is the goal of the Simulation Platform?

a) Find new methods for better understanding of ever growing amounts of urban data
b) Make this knowledge available to decision makers, urban planners and stakeholders

What is the Value Lab?

The Value Lab is the physical collaborative environment where the new methods are validated and applied

Interface to the external world
SEC-FCL Value Lab Asia

- 3 x 82" Touch Display Wall
- 4 x 50" Mobile Touch Tables
- 4 x 4 Video Wall (40 Mpi)
Geospatial Technologies

Data acquisition: Many new platforms and sensors (space, aerial, terrestrial)

Data processing: Powerful computing devices („cloud processing“), fast/automated processing (on-line, real-time results)

Data administration & analysis: SIS technology

Data representation: Visualization (3D cartography), VR, animation

Data access and dissemination: Web-based technologies

Applications. Beyond mapping: Cultural Heritage, LBS, environmental monitoring, hazards, security, risk, business, tourism, simulation, animation (geogames, movies, TV), etc.
Geomatics technologies

+ GPS/IMU
+ DSMs/DTMs
+ 3D/4D city models
+ Facility management
+ Mobile Mapping Systems
+ Imagery: satellite, aerial, terrestrial
+ Maps, plans
+ Historic data
+ LBS, “smart” apps
+ Sensors in WEB 2.0
+ Sensors in smart buildings
+ GIS/SIS
+ Visualization/simulation/animation
Simulation platform – Research workpackages

Data Acquisition
- Inverse Procedural Modelling
  - WP16
  - Dengxin Dai
- Geo-spatial Data Infrastructure
  - Tao Wang
- 4D Singapore - Dynamic Modelling of Change in a City
  - WP9
  - Qin Rongjun

Modelling Techniques
- Automated Generation of Reality-based 3D City Models
  - WP1
  - Xianfeng Huang
- Mobile Crowdsourcing
  - WP10
  - Dongyoun Shin

Simulation Techniques
- Sensor Configuration for Improving the Reliability of Simulations
  - WP4
  - Maria Papadopoulou
- Augmenting Simulations with Measurements
  - WP7
  - Didier Vernay
- Pedestrian Movement and Health
  - WP6
  - Gideon Aschwanden
- The Economic Potential of the Built Environment
  - WP12
  - Eva Friedrich

City Theory and Models
- Topologies (Transgeometric Mapping of Urban Movements)
  - WP2
  - Vahid Moosavi
- The Quantum City
  - WP11
  - Chen Zhong

Interaction
- Urban Energy Studies
  - Matthias Berger

Visualisation and Analysis
- The Quantum City
  - WP13
  - Diana Alvarez
- Urban Visual Analytics
  - Zeng Wei
Reality-based modeling of cities

We use satellite, airborne and terrestrial imagery and laser-scans to develop new methods and software tools for realistic reality-based modeling of cities.

ETH Zurich via CyberCity Modeler
Required: **Models for landscape (terrain), buildings, infrastructures, vegetation, etc.**

**BIM – Building Information Models**

For individual buildings, but also for whole cities

*Contain*  - geometry

  - topology

  - semantics

  - appearance

*Used for*

Analysis of lifecycles of building stocks and flows:

Determining “flows”: 4D city models, updating, processes
Florence, Italy
Applications of 3D city models

**Traditional**
- environmental monitoring
- planning (buildings, roads, location)
- mobile communication, LBS
- energy (solar), natural hazards
- tourism, real estate
- architecture, landscape engineering
- monument preservation

**New**
- smart homes
- insurances (risk transports, etc.)
- 3D car navigation
- homeland security
- police, firesquad, traffic and crowd control
Singapore FCL – requested data

+ DTM, DSM at different resolutions
+ Master plans in vector format
+ Land use map, drainage pattern
+ Buildings: coordinates, building type, number of floors above and below ground, number of flats and rooms, roof type and shape, type of ownership, value (insured value/ market value), status of protection as heritage, life cycle of the lot/buildings, age
+ Thermal building data
+ Historical plans/cadastre
+ Census data 2010 with location
+ School catchment areas
+ Navteq road network
+ Trip matrices for tourists, Malayan commuters and lorries/heavy vehicles
+ Georeferenced post codes
+ Climate/weather data, temperature of ground at various depths, annual temperatures of rivers and ocean
Airflow around buildings
Multi-agent Transport Simulation with matsim
Central business district
Urban Modeling - Pedestrian Flow

By Eva Maria Friedrich & Gideon Aschwanden
Interactive 3D Augmented Reality of Urban Cities on Mobile Devices
Mobile
Social Sensing
(of individual user)
Imaging platforms

+ spaceborne images

+ Stratospheric platforms

+ aerial images

+ model helicopter/balloon images

+ terrestrial images
Singapore – 3D city models from satellite images
IKONOS, WV-2 stereos
Singapore – HRSI stereos

WV-2 Punggol

IKONOS Little India, Geelong
Building and Terrain Model – Little India
Overlay cadastral map

Rochor

3 clips
Punggol 3D
Aerial Sensing

Optical cameras (analogue, digital)
Laserscanners (LiDAR), GPS/INS
Radar, InSAR

Das Produktion Model
mit einer Optik und einer Focalebene
3D/4D City Models - CyberCity Modeler
3D Hamburg: Integration into Google Earth

Courtesy CyberCity AG
3D LANDMARKS for car navigation
Zurich Gockhausen in Google Earth
The problem of quality control – what is the accuracy and completeness of these models?

- How accurate are the models in terms of geometry, topology and texture (appearance/perception)?

- How do the different techniques compare to each other?

→ No quantitative studies!
SEC-FCL project – UAV over NUS campus

Prime Minister of Singapore Lee Hsien Loong, National Day Rally 2012, UAVs as a key breakthrough technology for the next 20 years: ”UAVs will have many uses in the future – civilian and military”.

AscTec Falcon 8
500 g load
max 20 min flight time
max 10 m/s wind speed
redundancy through 8 rotors
GPS, height sensor, compass, IMU
max. Total weight 1,8 kg
UAV photogrammetry
SEC-FCL project – UAV over NUS campus

Singapore – ETH Centre for Global Environmental Sustainability
Future Cities Laboratory (Simulation Platform)
SEC-FCL UAV NUS campus flight
Take-off and landing stations

- CREATE take-off
- Falcon roof landing

Education Resource Centre
CREATE Tower
SEC-FCL project – UAV over NUS campus

Singapore – ETH Centre for Global Environmental Sustainability
Future Cities Laboratory (Simulation Platform)
4x4 image block University Hall
NUS tennis courts, tennis balls
Data Processing
- Georeferencing: GCPs by GPS (datum)
  Image triangulation/bundle adjustment
- Model generation: DTM, man-made objects, natural features (trees, etc.)
  Photo texture: Roofs, terrain

Tree models
Problem: Model content definition
NUS Campus
NUS Campus: Model resolution
NUS Campus: Overview

Flyover geometry
Model view: University Town
Combination of
- 847 UAV images
- MMS point clouds
- terrestrial images
Singapore Mobile Mapping (flood simulation)
NUS (CREATE) building reconstruction raw data

UAV images  MMS laserscans
NUS building reconstruction
UAV images and MMS laserscans

Roof from UAV images  Wrapped point cloud  Complete Model
NUS CREATE) building reconstruction
From UAV images and MMS laserscans
Tree modeling from terrestrial laser-scans

Rain Tree

1. **Pointools Edit.** Separate point cloud of a tree from the whole scene
2. **Geomagic Studio.** Wrap the tree points into triangular mesh
3. **3ds Max.** Draw spline lines manually along the stems: skeleton of the tree
4. **3ds Max.** Generate columns along the spline lines using the tool “loft”
5. **3ds Max.** Texture the loft as stems and the left triangles as canopy, using images captured in the field.
Tree modeling from terrestrial laser-scans

Palm tree
Light pole models (900)
Multi-sensor data

(1) Vertical aerial UAV images at 5 cm footprint
(2) Oblique UAV images (in planning)
(3) Raw point clouds from MMS
(4) Terrestrial images from off-the-shelf cameras
(5) Ground Control Points (GCPs)
(6) Existing data (maps)

Output

3D hybrid site model, achieved by integration of these input data
NUS model - overview
CREATE building
Model view: Engineering section
Engineering section
GIS integration

Model geometry 576 MB obj/745 MB 3Dmax
Model texture 4.15 GB bmp/tiff
Potential UAV projects of Singapore Gov. Agencies

National Environment Agency (NEA):
- Real-time detection and tracking of oil spills
- Detection and 3D measurement of water pools where Dengue fever mosquitoes reside
- Micro-climate modeling, city hot spots

Urban Redevelopment Authority (URA):
- Building and tree (vegetation) models for smart city management

Public Utilities Board (PUB):
- DSM generation for flood modeling. Generation of 3D façade models for water entrance analysis

Singapore Land Authority (SLA):
- Base map data in 3D
- 3D change detection

NParks, Botanic Garden
- 3D GIS-based model, with tree health analysis (Garden management)
Detecting breeding grounds of Dengue mosquitoes
Thermal Imaging Test
Camera: FLIR, 640x480 pi, 14bit
Platform: Falcon-8

Daylight recording

Night recording
Night recordings

Missing fan. Car engine

Students at STARBUCKS
3D thermal building model

Point cloud

Thermal model
Schabolovskaya Tower
Built 1919-1922
Radio station for international connections of the young Soviet state
First version: 350 m high, with Lenin’s permission
After 1939: TV antennas
Today: Belongs to Russian State TV
 Restricted accessibility
 Transmitters for mobile communication
Network design:
80% | > b = 7.7m
- 20 images per strip
- 160 images in total
Final model, derived from laserscans
Modeling of junctions, examples
Moorea Island Avatar - Ecological modeling (mooreaidea.org)

**NATURE | NEWS**

Tropical paradise inspires virtual ecology lab

Digital version of Moorea will provide a way to experiment with an entire ecosystem.

Daniel Cressey

14 January 2015
Tetiaroa - Island Avatar

“Tetiaroa is beautiful beyond my capacity to describe. One could say that Tetiaroa is the tincture of the South Seas.”

Marlon Brando
Moorea 3D model
Conclusions

+ **New tools** available for documentation, analysis and dissemination of environment: Sensors, *processing software*, visualization, SIS, Internet

+ **Multi-sensor, multi-resolution approach** helps in getting results of better quality, completeness and higher level of automation

+ Perception of world and mapping is changing
  
  ➡️ **New concepts for 3D mapping/modeling** required

  Crowd-sourcing, Big Data, data mining, cloud computing