Dynamic Energy Mapping Project Outline

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Abstract

This document provides an approach of adding the "time" dimension to an Energy Map. The approach is demonstrated with a model of a conceptual urban setting created in CityEngine based on the extracted topological and density pattern from an existing urban design project. The buildings in the conceptual model is then assigned an energy profile of certain DOE Commercial Benchmark Building Reference model based on its building type. Hourly energy demand profile of heating and cooling end use is then obtained from the EnergyPlus Reference models. The energy consumption data is classified into groups with consideration of building energy design context and the data distribution properties. A corresponding color coded energy profile is then generated and imported to CityEngine. 8760 color coded 3D map images was then extracted from CityEngine with Python script. A data reading, ploting, color-coding calculation and a user interface for visualizing the images and dynamic data plot with sliders is implemented using Python and related packages. The tool is anticipated to provide decision support for community energy management and planning, demand-side strategy design and district system sizing.

The document will also briefly discuss one of the testbed for data classification and visualization.

1. General Introduction
    1.1. Definition of Energy Map: energy related geo-database
    1.2. Why "time" dimension is important for an Energy Map
        1.2.1. Development of supply side requires better understanding of the demand side
        1.2.2. Community Energy Planning and District system design requires a more detailed picture of the energy temporal behavior on community level
    1.3. General Description of Dynamic Energy Map
        1.3.1. Dynamic Map holds 8760-hour meta data of energy demand and supply
        1.3.2. Dynamic Map has multi-dimensional graphical display of the meta data in conveying spatial-temporal pattern
            1.3.2.1. 1D: data plot for providing quantitative information
            1.3.2.2. 2D/3D: graphical display of spatial relationship of energy data
            1.3.2.3. 1D + 2D/3D: interactive graphical display of spatial-temporal pattern of energy data
2. Related Works
    2.1. Energy Maps without temporal dimension (grouped with field of application)
        2.1.1. Assessing renewable energy potential
            2.1.1.1. "Evaluation of Renewable Energy potential using a GIS decision support system", Voivontas et al., 1998
            2.1.1.2. "Spatial mapping of renewable energy potential", Ramachandra and Shruthi, 2007
            2.1.1.3. "Energy Potential Mapping: Visualizing Energy Characteristics", Dobbelsteen et al. , 2013
        2.1.2. Analysis or design support of existing energy infrastructures
            2.1.2.1. "Developments to an existing city-wide district energy network Part I: Identification of potential expansions using heat mapping", Finney et al. , 2012
            2.1.2.2. National Heat Map, `http://tools.decc.gov.uk/nationalheatmap/`
        2.1.3. Smart Management of energy system in a large urban scale
            2.1.3.1. "Smart Urban Services for Higher Energy Efficiency" (SUNSHINE) project (2013): energy consumption map, automatic alerts, remote control of public building lighting system.
    2.2. Dynamic Map
        2.2.1. History and Archaeology Instances of Dynamic Maps
            2.2.1.1. Pittsburgh Historic Map, `http://peoplemaps.esri.com/pittsburgh/`
            2.2.1.2. Europe History Interactive Map, `http://www.worldology.com/Europe/europe_history_md.htm`
        2.2.2. Animated Maps

2.2.2.1. “The Role of Map Animation for Geographic Visualization”, Mark Harrower and Sara Fabrikant

2.2.2.2. “Using Computer Animation to Visualize Patterns”, D Dorling and S Openshaw, 1992

2.3. Works on Visualization focusing on map design and information convey

2.3.1. “Data Visualization with Spacetime Maps”, Richard L. Brownrigg, 2005

2.3.2. “Effectiveness and efficiency of map symbols for dynamic geographic information visualization.”, Dong et al.

2.3.3. “Geographic Visualization: Designing Manipulable Maps for Exploring Temporally Varying Georeferenced Statistics”, MacEachren et al.

2.3.4. “Strategies for the Visualization of Geographic Time-Series Data”, Mark Monmonier, 2011

2.3.5. “Evaluation of Methods for Classifying Epidemiological Data on Choropleth Maps in Series”, Brewer and Pickle, 2002

2.4. Works on Technology regarding 4D visualization

2.4.1. “Web-based 4D visualization of marine geo-data using WebGL”, Resch et al. , 2014

2.5. Interface design of 4D visualization Case studies

2.5.1. “Web-based 4D visualization of marine geo-data using WebGL”, Resch et al. , 2014

3. Objective

3.1. Discuss the specifications / definitions of dynamic energy map

3.2. Evaluating some possible approaches to implement dynamic energy map

3.3. Presenting one major implementation approach

4. Methodology

4.1. General Work Flow

4.2. Simulation Setting

4.2.1. Source of benchmark models and default assumptions

4.2.2. Modified settings: urban environment context

4.2.3. Summary of input and output parameters

4.3. Model Setting

4.3.1. Software used in modeling and their general features (why choosing them)

4.3.2. Process of extracting building layout from Mellon Arena Project

4.3.2.1. Topological Pattern of the Mellon Arena Project

4.3.2.2. Building Type converting

4.3.2.3. Final Plan of the Conceptual Model

4.4. Data Collection and Analysis

4.4.1. Simulation Data Analysis of the benchmark models
  4.4.1.1. Distribution: Histogram, box plot
  4.4.1.2. Profile: Energy - Time plot
4.4.2. Potential Impact on system design or data visualization based on the analysis above

4.5. Temporal Data Aggregation
4.5.1. With CityEngine
4.5.2. With ArcGIS (ArcScene)
4.5.3. Comparison

4.6. Data Classification and symbol/color design of a dynamic choropleth map
4.6.1. Review of General Approaches: see 3.3
4.6.2. "Critical Values" or special cutoff values to be considered in the context of Community Energy Planning: need to look up (@@)
4.6.3. Final choices of classification method and symbol/color scheme and the implementation

5. Interface Design

5.1. Guidelines from interface design case study: See 2.5

5.2. User definition
5.2.1. Potential Users: policy makers, urban planners with the interest in executing community level energy strategies, researchers in energy related fields, public groups or individuals.
5.2.2. Target users for the current project: researchers in energy related fields
  5.2.2.1. Assumptions about the skill level and background knowledge
  5.2.2.2. How the assumptions influence design choices of the interface design

5.3. Goal Function of the interface
5.3.1. Revealing the spatial-temporal heating / cooling demand variation of the conceptual model by applying the Dynamic Energy Map on a conceptual urban setting

5.4. Major Operation Description
5.4.1. Navigate through dynamic map images with time sliders
5.4.2. Provide several default settings for choropleth map display
5.4.3. Provide a brief help window and documentation of the tool

5.5. Current Interface Design
5.5.1. General Layout
5.5.2. Navigation Function
  5.5.2.1. Overall navigation of year-round data
  5.5.2.2. Navigate and compare with default time steps: month, day, hour
5.5.3. Dynamic Plot

5.5.4. Implementation tools and strategy

6. Conclusion

6.1. Summary of the current approach in implementing the dynamic energy map

6.2. Limitations of the current implementation

6.2.1. Simplified building simulation assumption about urban environment

6.2.2. Lack of user choices for the stand-alone user interface as a result of its dependence on existing modeling softwares

6.3. Future Expansion of the project

6.3.1. Adding information of the supply side: residual energy, sustainable energy

6.3.2. Providing different interfaces for different user population

6.3.3. 2D and 3D compatible

The reason for providing 2D map together with 3D map is that 2D maps have the following good properties:

6.3.3.1. Better for region selection and spatial navigation than 3D map

6.3.3.2. Better for conveying spatial relationship that does not involve height induced variation

6.3.3.3. For larger scale display of city, state or nationwide, 3D building geometries becomes less significant in providing the urban environment context

6.3.4. Creating an on-line tool for better information share

6.3.4.1. Potential techniques: see 2.4

7. Acknowledgments