Development of an ArcGIS ToolBox for Semi-Automated Urban Modeling

Elizah S. Dasari, Research Assistant
Northrop Grumman Center for HPC
Jackson State University
Jackson, MS 39204
(601) 979-1836
elizah.s.dasari@jsums.edu

Dr. Marvin D. Watts, Assistant Professor
Department of Computer Science
Jackson State University
Jackson, MS 39217
(601) 979-3302
marvin.d.watts@jsums.edu

Dr. Shahrouz K. Aliabadi, Professor and Director
Northrop Grumman Center for HPC
Jackson State University
Jackson, MS 39204
(601) 979-1821
saliabadi@jsums.edu
Overview

- Project Description
- Project Objective
- Background
- Model Development (v1.0)
- Model Development (v1.1)
- Future Work
Project Description

• Improve the blast damage predictions and calculation of evacuation distances for explosions in dense urban environments.
  – Develop a fast-running, easy-to-use software package derived from the ORNL VISAC (Visual Interactive Site Analysis Code) code.
  – Combine:
    • Updated correlation modeling for urban blast and fragmentation, with
    • Improved rapid geometry construction techniques and graphical results presentation.

• Create a version of VISAC optimized for responding to Improvised Explosive Device (IED) threats in densely populated urban areas.
Project Description

Generic Power Plant facility.

Generic Power Plant facility w/ transparency.

Interior of Generic Power Plant facility.

VISAC Facility Modeler.
units feet
visac name bldg1
visac ground 0.0
visac floors 0.0 20.0
visac sinkage 1.0
visac description Office building
/* Floors */
in bldglf.s1 rpp 8 103 162 402 -1 0
/* Walls */
in bldglw.s1 rpp 8 103 162 162.5 0 20
in bldglw.s2 rpp 8 8.5 162.5 401.5 0 20
in bldglw.s3 rpp 102.99 103 162.5 401.5 0 20
in bldglw.s4 rpp 8 103 401.5 402 0 20
/* Roof */
in bldglr.s1 rpp 8 103 162 402 20 20.5
in totalbldg1.s1 rpp 8 103 162 402 -1 20.5
in toptotal.s1 rpp 8 103 162 402 0.00 1.00
in sinkbldg1.s1 rpp 8 103 162 402 -1 20.5
visac total u totalbldg1.s1
visac toptotal u toptotal.s1
visac soil sinkbldg1.s1
/* Regions */
/* Floors */
regdef 5301 0 100 500
r bldglf.r1 u bldglf.s1
/* Walls */
regdef 5401 0 100 500
r bldglw.r1 u bldglw.s1
r bldglw.r2 u bldglw.s2
r bldglw.r3 u bldglw.s3
r bldglw.r4 u bldglw.s4
/* Roofs */
regdef 5501 0 100 500
r bldglr.r1 u bldglr.s1
/* Groups */
g bldg1 bldglf.r1 bldglw.r1 bldglw.r2 bldglw.r3
bldglw.r4 bldglr.r1

groundLevel 0.0
center 450.0 170.0
bldg1.txt
8.00 402.0 1.0 0.0 255 255 0
bldg2.txt
0.00 90.0 1.0 0.0 225 225 0
Project Objective

• Develop an ESRI ArcToolBox that:
  – Leverages commercial-off-the-shelf (COTS) software
  – Generates Open Geospatial Consortium (OGC) CityGML standard level of detail one (LoD1) and two (LoD2) building models from high resolution imagery and digital elevation models (DEM)
  – Supports blast analysis applications, specifically VISAC
Background

• Leveraging COTS software:
  – Feature Analyst
    • Automated Feature Extraction through Inductive Learning
  – ArcGIS ModelBuilder
    • Feature Fusion through Geo-processing
  – Feature Manipulation Engine
    • Feature Formatting through Semantic Translation
Background

• Generating OGC CityGML LoD1 and LoD2 building models from high resolution imagery and digital elevation models (DEM):
  – The OGC CityGML Encoding Standard establishes 5 well-defined consecutive Levels of Detail.
  – These Levels of Detail include differing accuracy and minimal dimension requirements.
  – Furthermore, they provide a means of identifying and categorizing the necessary data sources for creating building models.
Background

- 5 Levels of Detail
Background

• Data Sets
  – Mississippi Automated Resource Information System (MARIS)
    • Aerial Imagery
      – Coastal One Foot and Six Inch Imagery
      – One Meter Color Infrared Imagery
    • Digital Elevation Model
      – County 10-Meter Digital Elevation Model
Supporting blast analysis applications, specifically VISAC:

- Geometric information is stored by VISAC in text files compatible with the BRL-CAD format.
- VISAC uses a constructive solid geometry (CSG) approach to solid modeling.
  
  - An object is represented as a Boolean combination of simple primitive shapes.
- This is in contrast to boundary representation (BREP) modeling.
  
  - An object is represented by a set of surfaces (e.g. triangles) that are “stitched” together to enclose the object.
Model Development (v1.0)

• Feature Analyst v4.2
  • Automatic feature extraction tool for object-specific extraction from GIS imagery.
  • Feature extraction is dependent upon:
    – Input Bands (spectral class)
    – Input Representation (information class)
    – Hierarchical Learning Algorithm
  • Used here to process aerial imagery.
Model Development (v1.0)

- Feature Analyst v4.2 Workflow
Model Development (v1.0)

- Feature Analyst v4.2 Extraction

Input Aerial Image

Input Training Set
Model Development (v1.0)

- Feature Analyst v4.2 Extraction

- Initial Feature Extraction
- Clutter Removal
Model Development (v1.0)

- Feature Analyst v4.2 Extraction

Manual Clean Up

Detailed Feature
Simplify Building Tool

• ArcGIS ModelBuilder v9.2 Tool
  – Simplify Building
Model Development (v1.0)

• ArcGIS ModelBuilder v9.2
  – Model Inputs
    • 2D Building Extraction
    • Building Base Height
    • Building Roof Height
    • Thickness (walls, floor and roof)
  – Model Outputs
    • Roof shapefile with attributes
    • Walls shapefile with attributes
    • Floor shapefile with attributes
Model Development (v1.0)

- ArcGIS ModelBuilder v9.2 Model Workflow
Model Development (v1.0)

- ArcGIS ModelBuilder v9.2 Model Workflow
Model Development (v1.0)

- ArcGIS ModelBuilder v9.2 Model Workflow
Model Development (v1.0)

• ArcGIS ModelBuilder v9.2 Output
  – Mississippi Coast Coliseum and Convention Center
    • Biloxi, Mississippi
Floor with 1’ Thickness

Walls with 1’ Thickness

Roof with 1’ Thickness
ArcScene View of Model Output
ArcScene View of Model Output
ArcScene View of Model Output
Model Development (v1.0)

- Feature Manipulation Engine v2010
  - A spatial extract, transform, and load (ETL) tool for GIS data interoperability.
  - Readers and Writers
    - MultiReader / MultiWriter
    - CityGML
    - USGS DEM
    - Text Feature Store
    - Text File
    - Custom
  - Custom Transformer Development
    - Extrusion
    - Polygon Decomposition
Model Development (v1.0)

• ArcGIS ModelBuilder v9.2 Workflow Drawbacks
  – Redundant Data
  – Incorporating Terrain Data
  – Inaccurate Geo-processing
Model Development (v1.1)

• ArcGIS ModelBuilder v9.2 Workflow
  – Consolidate building and terrain features into a single Multipatch file.
Model Development (v1.1)

- ArcGIS ModelBuilder v9.2 Model Parameters
  - Model Inputs
    - 2D Building Extraction
    - Digital Elevation Model
  - Model Outputs
    - Multipatch file
      » Terrain data stored as a TIN
      » Building data stored as a Ring
      » Z-field used to store Height
      » M-field used to store Thickness
Model Development (v1.1)

• ArcGIS ModelBuilder v9.2 Workflow
Model Development (v1.1)

- ArcGIS ModelBuilder v9.2 Workflow

Building Footprint with Base Height from DEM

DEM Points with Erased Features
Model Development (v1.1)

- ArcGIS ModelBuilder v9.2 Workflow
Model Development (v1.1)

- ArcGIS ModelBuilder v9.2 Workflow

TIN With Building Footprint

Interpolated MultiPatch Building Shapefile from TIN
Model Development (v1.1)

- ArcGIS ModelBuilder v9.2 Workflow

TIN with Building Footprint Erased

Interpolated TIN as MultiPatch Shapefile
ArcScene View of Model Output
ArcScene View of Model Output
Future Work

• Upgrade ArcToolBox Toolsets
  – Feature Analyst v5.0
  – ArcGIS Desktop v10.0
  – Feature Manipulation Engine v2011

• Additional Input Data Sets
  – Oblique/Stereo Imagery (FA v5.0)
    • Building Height
  – Digital Surface Model
    • Differentiated Roof Structures
    • Building Height
  – Architectural Drawings (DWG/DXF)
    • Wall Thickness
    • Interior Space Details