Virtual Cities of the Future and Past

Paul Cote
Geographic Information Systems Specialist
Harvard University Graduate School of Design
500 Design Students

250 Architecture      50 Urban Planning
100 Urban Design      100 Landscape
GSD Studio Culture:

75% of Student effort focused on one studio problem

100 Studios per year at the GSD

Focus on representing, understanding, modifying and evaluating places: Appearance & performance

Many Many Models are Made!!

An intense replica of the greater world of design
Studio Information Lifecycle

Start Semester Finish

Collect Information:  Synthesis / Study:  Presentation Materials:
- Site Photos  - Maps
- GIS Data  - Digital 3D Models  - Maps
- CAD Data  - Physical 3D Models  - 3D Models
- Documents  - Simulation Models  - Animations
- Process Understanding  - Presentation Documents  - Document ation

End of Term

Small Fraction
Suited for Re-Use

Bulk of Knowledge is Lost

Many Mysterious Presentation Documents

LACK OF PREDICTABLE ORGANIZATION AND DOCUMENTATION

Harvard University
Graduate School of Design
Information Lifecycle in Site Studies

Compile Data / Create Schema:
- Discover
- Transform
- Ideas &
- Information
- Structure

Information & Ideas
About Places & Processes
(In-House or Internet)

Author / Modify
- Regulation
- Groundplan
- Landform
- Circulation
- Buildings
- Vegetation

Visualize / Study
- Programmatic
  Capacity
- Streetscape, Shadows
  Views
- Coherence with
  Context
- Finance, Phasing

Evaluate:
Alternatives:
Performance & Impacts

Communicate:
Narrative, Graphics, Video

Collaborate / Share:
- Resources, Understanding, Procedures
  - Participate, Instigate
  - Exchange: between specialized tools
  - Exchange: Individuals & Enterprises to Shared Infrastructure

Paul Cote, 2008

Harvard University
Graduate School of Design
It Takes a Village of Specialized Tools

Many Specialized Tools

One-Way, Lossy Exchanges
GSD Handbook for Site Modeling in Context

Virtual Cities as a Mirror with Memory
The most authoritative information about an urban situation are collected and maintained by a host of administrative departments that employ a variety of data models and tools.
Collaboration of Administrative Domains

Understanding
Collaboration of Territorial Domains

5 Kilometers

1/29/2011
Collaboration of Territorial Domains

Understanding

Town A

Town / Campus B
If these alternate views of the city are expressed in common terms, much might be learned about urban mechanics and the probable consequences of decisions.
Necessity for
Shared Semantic Models
One-Way, Lossy Exchanges

Domain / Tool A
(e.g. GIS, RDBMS)

Domain / Tool B
(e.g. CAD / BIM)

Inputs

Outputs

Semantic Trash Bin
Real World Concepts:

e.g. Observations, Prescriptions, Rules

“The building meets the terrain along this line.”

Conceptual Information Model

e.g. UML (Unified Modeling Language)
Coherent Conceptual & Data Models

Conceptual Information Model

- **Kolbe & Groeger CityGML**

Technical Implementation

- **Binary Data Storage**
- **Programs & Business Logic**
- **e.g. Software tools: Proprietary or Open**

Business Processes

- Inputs
- Outputs
Shared Conceptual Models & Exchanges

Round Trip with Coherent Semantics

Domain Tool A

Inputs

Outputs

Domain Tool B

Inputs

Outputs

See: Stadler & Kolbe: Spatio-Semantic Coherence in the Integration of 3D City Models
## Community Based Standards Development

### Communities
- Engineers
- Tool Makers
- Content Creators
- Service Providers
- Users

### Industry Consortium
- Understanding
- Consensus
- Application Standards

### International Standards Organization
- Foundation Standards
  - Information Structure
  - Service Protocols
- Application Standards

---

**Participation**

**Assured Stable Environment**

**Lots of Interoperable Content!**

---

Harvard University
Graduate School of Design
Community Based Standards Development

Standards Organizations

- ISO
- W3C
- OGC
- KHRONOS
- buildingSMART

Encodings

- HTML
- GML
- CityGML
- KML
- COLLADA
- IFC
- BIM

Service Protocols

- SQL: structured query language
- HTTP: hypertext transfer protocol
- WMS: web map service
- WFS: web feature service
- WCS: web coverage service
Some KML, KMZ Collada Examples
The Virtual City Collective: A Forum on the Web

Virtual City Collective

Home

New! May 22 2010: See the new Greenline Station Workshop Site!

Also see: The Google Earth Trainset

Virtual City Collective is a prototype framework for organizing data in the Google/ Sketchup 3d warehouse. It is based on a couple of ideas:

- Your models look better when viewed in context of a greater massing model.
- While the Google-Sketchup 3D Warehouse has one level of granularity -- Buildings, a virtual city will should allow users to combine models in different ways to compose multiple elements into broader-scale models of places.
- Having a consistent spatial referencing system that works at different levels of detail will help people to organize and search for content.

http://groups.google.com/group/virtual-city-collective

Harvard University
Graduate School of Design
The Google Earth Train Set

Trying to understand the ways that a new transit line might be run through a neighborhood is somewhat difficult to do without understanding the measure of railways and specific streets. And it is difficult to assess the practicality or impracticality of a scheme without being able to represent the juxtaposition of these things in proper scale and also in the broad plan. It is also very difficult to communicate complex imaginary ideas about places without perspective drawings. These difficulties have traditionally made it difficult for people without highly specialized skills to participate as equals in the discussion of urban design alternatives. This Google Earth Train Set project provides a hint about how ordinary people may be able to explore and develop place-based ideas and to share and collaborate on creative urban design problems using free and easy-to-use tools such as Google Earth.

Viewing a Presentation

The context of this demonstration is the impending extension of a urban light rail project, Boston's Green Line, through East Cambridge to Medford and Union Square (all in Massachusetts, USA). There are several alternatives involving moving a beloved trolley stop across a large highway, or having the stop closer to the neighborhood, and running past

The Greenline Station Workshop

Station Modeling Workshop

The latest addition to the Google Earth Trainer
Model your Greenline Station!

The Greenline extension is coming! There will be 8 new stations located throughout Somerville, South Medford and East Cambridge. This site provides links to resources for visualizing the station locations and for many people to develop and share their ideas about the design of stations and their surrounding areas. Open this GreenlineStationWorkshop.kmz Google Earth Document (last updated May 28) in Google Earth to begin exploring these resources.

Visualize Station Plans and Elevations on Terrain
Executive Office of Transportation:
College Avenue Station Plan

Legend:
- Property Line
- Retaining Wall
- Fence
- Proposed Track
- Existing Track
- Land of Structure
- Area of Ridge
- Curb
- Tunnels
- Platforms
- Station Entrance
- Station Exit
- Service Areas
- Elevators
- Escalators
- Stairs
- Bicycle Storage

Figure 3.7-22
College Avenue Station
Modified Millennium Terminals
Alternatives 1, 2
Station Layout
Executive Office of Transportation College Avenue Station Plan
Executive Office of Transportation
College Avenue Station Elevation
GSD6447: Virtual Cities as Public Infrastructure

GeoWeb: Virtual Worlds as Public Infrastructure

Final Projects, 2010

The student projects linked below demonstrate a new mode of collaborative scholarship concerning the form of places. Over the course of the Spring semester at the Harvard University Graduate School of Design, nine students explored emerging conventions and tools that extend the capabilities of the world-wide web using spatial referencing and three dimensional models. Ideas concerning the past, present and alternative futures for places are shared via video and interactive three dimensional models. By providing free access to all of their source materials, each project demonstrates how the web can foster a refreshing culture of collaboration in the understanding of places. To view the syllabus and lecture notes for this course visit the course web site.

Over the course of the semester, each student collected documents, photographs, maps, and 3d Models related to their site. These were all brought together as an interactive presentation using the open standard KMZ format that can be loaded over the web and viewed in the world-wide context of Google’s Earth Browser. In many cases, the students developed original 3d models representing past or future scenarios using Google Sketchup. In other cases students incorporated existing 3d models made by others to create an urban mashup. Each project features a short web video that provides a quick introduction to the ideas that were explored and the resources created. Take a look at the videos. To examine the full project in interactive 3d with rich explanations and deep references, download the Google Earth and Sketchup files. Get inspired. Take this work and modify it to suit your own purposes -- and share your own ideas on the GeoWeb!!

The Projects

- A Mashup Laboratory for Boston’s City Hall Plaza
- The Highline: Past and Present Andre Biyohorse
- Kendall Square + MIT: Angela Ekvist
- Spectacle at Bryant Park: Past, Present and Future Jennifer French

Seaport Sandbox: A Cybernetic View of Studio

A Cybernetic View of Studio

GSD2201 Site Representation and Research: Fall 2010
Harvard University Graduate School of Design
Instructor Paul Cote

This cybernetic approach to an urban planning and design studio examines the ways that information is organized, transformed and exchanged in the societal process of place-making. In this course, nine students discovered and organized resources, and developed new ideas about a place, and published their work such that the critical source and manuscript documents are available in a shape that can be understood and taken forward by others.

https://sites.google.com/site/sbseaport/

Harvard University
Graduate School of Design
Paul Cote, 2008
Toward Deeper Semantic Coherence
CityGML: Shared, Open, Coherent

Real World Concepts:

Conceptual Information Model

Exchange Encoding

Images from CityGML Spec

Kolbe & Groeger CityGML

UML (Unified Modeling Language)

GML3

Harvard University
Graduate School of Design

Paul Cote, June 23 2009
CityGML: Objects May Honor Specific Levels of Detail

Image from OGC CityGML Discussion paper, Kolbe, Groeger, Czerwinski
First Component Sub-Models of City GML

Fig. 24: Illustration of a water body defined in CityGML (graphic: IKG Uni Böhm).

Fig. 16: Nested DTMs in CityGML using validity extent polygons (graphic: IKG Uni Böhm).

Fig. 12: Example for vegetation objects of the classes SolitaryVegetationObject and PlantCover (graphic: District of Recklinghausen).

Image from OGC CityGML Discussion paper, Kolbe, Groeger, Czerwinski

Harvard University
Graduate School of Design  Paul Cote, NCFMT  2007
The GSD Metropolitan Model Repository: A Simple Relational Schema For Temporally Deep City Models

http://www.gsd.harvard.edu/gis/manual/metromodel/index.htm
Granularity and Identifiers

Goals:

- Provide a way of uniquely identifying parts of buildings at multiple levels of detail across diverse territorial domains
- Provide for retrieval of past, present and future views of the city through simple SQL queries on a simple relational database schema
- Support check-out and off-line modification of parts of the model without possibility of ID conflicts on check-in.
Existing GIS Layers: Parcels

Each town in the metro area has a parcels layer that forms a decent source of information about buildings. We alter the parcel ID by appending a 3 character territory code and an _P so that the parcel IDs are assured to be unique within a multi_town schema.

<table>
<thead>
<tr>
<th>Parcel Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
</tr>
<tr>
<td><strong>Territory</strong></td>
</tr>
<tr>
<td><strong>Parcel_ID</strong></td>
</tr>
<tr>
<td><strong>Owner</strong></td>
</tr>
<tr>
<td><strong>Year Built</strong></td>
</tr>
<tr>
<td><strong>Address</strong></td>
</tr>
<tr>
<td><strong>Stories</strong></td>
</tr>
</tbody>
</table>
Existing Layers: Building Footprints

Each town has a building footprints layer established from a photogrammetric survey.

<table>
<thead>
<tr>
<th>Footprint Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
</tr>
<tr>
<td>Unique ID</td>
</tr>
</tbody>
</table>
New Table: Abstract Buildings

The Parcels table can form a table of information about buildings. Unique Building IDs are created from Parcel IDs. This table has no geometry associated with it. Any building associated with a parcel are designated Building 0. This lumping is inaccurate, but sufficient for an initial buildings table.

Abstract Buildings

<table>
<thead>
<tr>
<th>Territory</th>
<th>Cambridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>Cam_P364234_B0</td>
</tr>
<tr>
<td>Owner</td>
<td>Harvard</td>
</tr>
<tr>
<td>Built Date</td>
<td>1870</td>
</tr>
<tr>
<td>Demo Date</td>
<td>Null</td>
</tr>
<tr>
<td>Address</td>
<td>49 Quincy St</td>
</tr>
<tr>
<td>Stories</td>
<td>5</td>
</tr>
</tbody>
</table>
New Layer: Building Massing Parts

Where individual building parts vary in terms of their attributes, they may be distinguished with unique IDs and individual build and demo dates, etc. The Building Massing Part IDs are formed by appending a Massing Part ID to the Building ID.
The Massing Parts Layer forms a complete model of every building in the metro area at a low level of detail (CityGML LOD2). Building parts may have more specific attributes from their parent Abstract Buildings.

*CityGML LOD 1 Buildings*
Using a 3D authoring tool, models of building exterior skins can be encapsulated as sketchup or collada models and placed into relational tables as georeferenced objects. Like Massing Parts, Skin Parts have unique IDs linking them to abstract buildings and may have more specific attributes.

*CityGML Generic City Object or External Link
3d Building Skin Parts

Skin parts and massing parts for a given building may have independent dates. The Model field holds a Binary Large Object that can be downloaded to a 3d authoring tool for editing.

Building Skin Parts

<table>
<thead>
<tr>
<th>Shape</th>
<th>Multipatch / COLLADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Sketchup or Collada Blob</td>
</tr>
<tr>
<td>Part_ID</td>
<td>Cam_P364234_B0_S1</td>
</tr>
<tr>
<td>Owner</td>
<td>Null</td>
</tr>
<tr>
<td>Build Date</td>
<td>2001</td>
</tr>
<tr>
<td>Demo Date</td>
<td>Null</td>
</tr>
<tr>
<td>Built</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Relational Queries Create Views Based on Dates or Scenarios

Abstract Buildings
- Territory: Cambridge
- Building: Cam_P364234_B0
- Owner: Harvard
- Year Built: 1870
- Stories: 5
- Address: 49 Quincy St
- Year: Null

Building Skin Parts
- Shape: Multipatch
- Model: Sketchup or Collada Blob
- Part_ID: Cam_P364234_B0_S1
- Owner: Null
- Built: Yes
- Demo: Null
- Year: Null

Building Massing Parts
- Part_ID: Cam_P364234_B0_M1
- Owner: Null
- Built: 1998
- Demo: Null
- Address: Null
- Stories: 2

Cam_P364234_B0

1/29/2011
Current Built View
Handling Fictitious Future
Urban Design Schemes
Built and Unbuilt Schemes

The Built attribute is set to Yes for buildings that were actually built. Unbuilt buildings can be represented in the schema to allow experimentation with proposed scenarios.

<table>
<thead>
<tr>
<th>Building Skin Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
</tr>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Part_ID</td>
</tr>
<tr>
<td>Owner</td>
</tr>
<tr>
<td>Built Date</td>
</tr>
<tr>
<td>Demo Date</td>
</tr>
<tr>
<td>Built</td>
</tr>
</tbody>
</table>
Built and Unbuilt Schemes

The Built attribute is set to Yes for buildings that were actually built. Unbuilt buildings can be represented in the schema to allow experimentation with proposed scenarios.

![Building Skin Parts](image)

<table>
<thead>
<tr>
<th>Building Skin Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
</tr>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Part_ID</td>
</tr>
<tr>
<td>Owner</td>
</tr>
<tr>
<td>Built Date</td>
</tr>
<tr>
<td>Demo Date</td>
</tr>
<tr>
<td>Built</td>
</tr>
</tbody>
</table>
In order to create custom scenarios you must be able to turn on unbuilt buildings and to turn off other buildings that would otherwise render. This is accomplished by creating Schemes and entering part-specific rendering instructions in the Scheme Parts table. Because the Part IDs are distinct for Massing and Skin part models, the Scheme Parts table can refer to either type of part.

### Scheme Parts

<table>
<thead>
<tr>
<th>Part_ID</th>
<th>Render</th>
<th>Scheme-ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam_P364223_B0_S1</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Cam_P364223_B0_S0</td>
<td>No</td>
<td>1</td>
</tr>
</tbody>
</table>

### Schemes

<table>
<thead>
<tr>
<th>Scheme-ID</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flipped Gund Hall</td>
</tr>
<tr>
<td>2</td>
<td>Tank</td>
</tr>
</tbody>
</table>

### Building Skin Parts

<table>
<thead>
<tr>
<th>Part_ID</th>
<th>Name</th>
<th>Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam_P364223_B0_S1</td>
<td>Flipped</td>
<td>Unbuilt</td>
</tr>
<tr>
<td>Cam_P364223_B0_S0</td>
<td>Gund Hall</td>
<td>built</td>
</tr>
</tbody>
</table>

### Building Massing Parts

<table>
<thead>
<tr>
<th>Part_ID</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam_P364223_B0_M0</td>
<td>Gund Hall</td>
</tr>
<tr>
<td>Brk_P189-24-29_B0_M1</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Building Model Management

Schema

Abstract Buildings
- Building ID
- Attributes…

Schemes
- Scheme ID
- Name

Skin Parts
- Building ID
- Part ID
- Attributes…

Massing Parts
- Building ID
- Part ID
- Attributes…

Scheme Parts
- Scheme_ID
- Part ID
- Render
Unbuilt Scheme: Turn Gund Hall Around
View From Proposed Design Scheme
References

10 City Geography Markup Language
Kolbe and Groger, 2008

10 SPATIO-SEMANTIC COHERENCE IN THE INTEGRATION OF 3D
CITY MODELS
Stadler and Kolbe

10 Collada: 3D Asset Exchange Schema
Khronos Group

10 Town of Brookline Model Management System
Cote, 2007

10 Public Infrastructure for Virtual Cities
Cote, 2006

10 Integration of CAD, GIS, and Building Information Models in
Open Web Services
Cote, 2007

10 Building Interior Spaces Data Model for GIS
Penobscott Bay Media, BISDM.org
Lets Get it Together!

- Understand Open Exchange Specifications
- Target our conceptual and data models for open exchange
- Participate in standards development
- Demand open exchange capabilities in our tools
Credits and References

Find these links at www.gsd.harvard.edu/pbcote/talks/2010/geodesign_pbcote.pdf

- City Geography Markup Language
  Kolbe and Groger, 2008

- SPATIO-SEMANTIC COHERENCE IN THE INTEGRATION OF 3D CITY MODELS
  Stadler and Kolbe

- Collada: 3D Asset Exchange Schema
  Khronos Group

- Town of Brookline Model Management System
  Cote, 2007

- Public Infrastructure for Virtual Cities
  Cote, 2006

- Integration of CAD, GIS, and Building Information Models in Open Web Services
  Cote, 2007

- Building Interior Spaces Data Model for GIS
  Penobscott Bay Media, BISDM.org
Efforts to Develop Web Standards for Encoding and Exchanging City Models

Building Information Modeling Community:
- **International Alliance for Interoperability -- BuildingSmart** (Consortium of Owners, Engineers & Architects)
- **IFC** (Semantic and Exchange Standard for Building Information Models)
- **National BIM Standard** (social and institutional construction of BIM)
- **Open Floor Plan** Toward a simple standard for exchanging georeferenced floorplans
- **OASIS**

Geospatial Information Infrastructure Community:
- **Open Geospatial Consortium** (Architecture for Interoperable Web Services spanning diverse semantic schema)
- **CityGML**: Semantic and Exchange Standard for City & Landscape Models
- **Web Services Architecture for CAD, GIS and BIM** (edited by Yours Truly)

Game Development Community
- **Khronos Group** (Gaming Community Consortium)
- **COLLADA** (exchange standard for high-quality digital objects, includes materiality, lighting, physical behavior)