2D-3D Hybrid Data Modeling for Fire Evacuation Simulation

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Inhye Park, Hyeyoung Kim, Chulmin Jun
Dept. of Geoinformatics, The University of Seoul, Korea

Contents

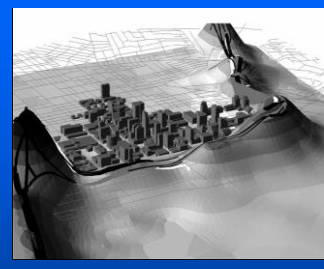
1. Introduction

Background

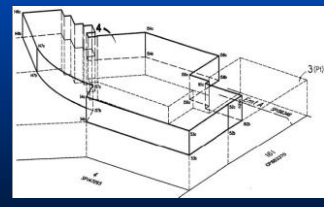
- With increase of ubiquitous computing applications, '3D GIS' is getting attention
- *3D models* are interchangeably used with *3D GIS*.
- 3D models : lack topological structure
- GIS : limited to 2D or 2.5D
- Need *'3D GIS'* to overcome these limitations!
- 3D GIS can be applied to evacuation.

Related Studies : 3D GIS

- Wang(2004), Brooks(2005),…
  - suggest combining of 2D GIS and 3D model, but they focus on 2.5D-based display of terrain data.



- Stoter(2006), Zlatanova(2004),…
  - suggest the topological relationships between 3D objects. but incapable of dealing with indoor spaces.



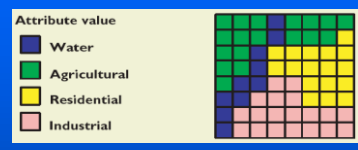
Outline

- A new 3D model is needed for geo-referenced indoor spaces.
- We propose a 2D-3D hybrid model that provides the functionalities of both models – *3D visualization + 2D topology*.
- *Vector-based* evacuation
  - Node-link based route guidance
- *Raster-based* evacuation
  - using CA (Cellular Automata) theory

2. Topological Structure for Indoor Location-based Systems

Vector-based Data

- Raster vs. Vector
  - Raster: Define objects as arrays of cells
  - Vector: Define objects as points, lines and polygons
- Vector-based Data
  - Simple features
  - Topological features



Raster

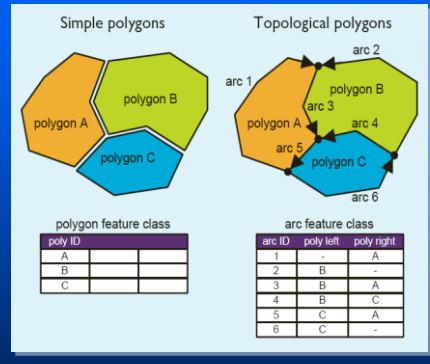
Vector

Simple vs. Topological features

Simple features	Topological features
■ Advantage with fast rendering performance ■ No constraints on relationship between objects ■ Isolated each other • Existence of gaps, overlaps and discontinuities	■ Advantages • Identify objects that are adjacent or connected to other objects • Relationship of network • Make spatial analyses possible property of spatial relationships that maintain adjacency and connectivity between geographic objects under transformation • Central concept of GIS allows geographic operations

Simple vs. Topological polygons

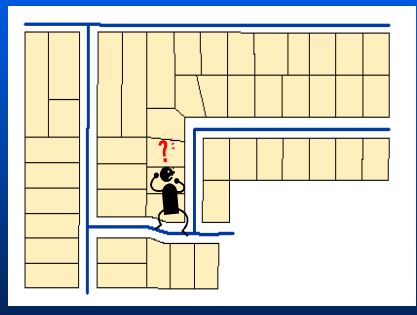
- Simple polygons
  - Perceived as isolated objects
  - A polygon can not be identified by another
- Topological polygons
  - Shared boundaries are stored only once
  - Adjacent polygons are identified by the boundaries



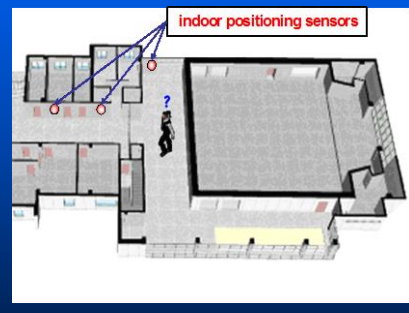
Simple and Topological polygons

Topology in outdoor and indoor

- Effectively used in location-based applications



Location-based services in outdoor spaces



Location-based services in indoor spaces

3. 2D-3D Hybrid Data Model

3D Model and 3D GIS

- 3D model and 3D GIS
  - 3D model
    - » Focused on visualization
    - » Can not be used in quantitative analyses or LBS
  - 3D GIS
    - » Topological relationship among discretely defined spaces
    - » 3D visualization functionalities

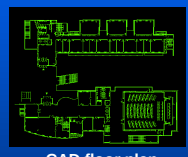
3D model

To build 3D GIS data models…

Need a method to combine advantages from both 2D GIS and 3D model

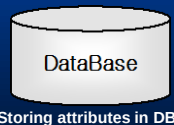
Combining 2D and 3D

- Create 2D GIS layers and isolated 3D spaces
- Use a database table as the linkage



CAD floor plan

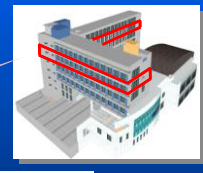
Converting to 2D vector layer



Storing attributes in DB

a. Creating 2D GIS layers from building floor plans

3D CAD–based model

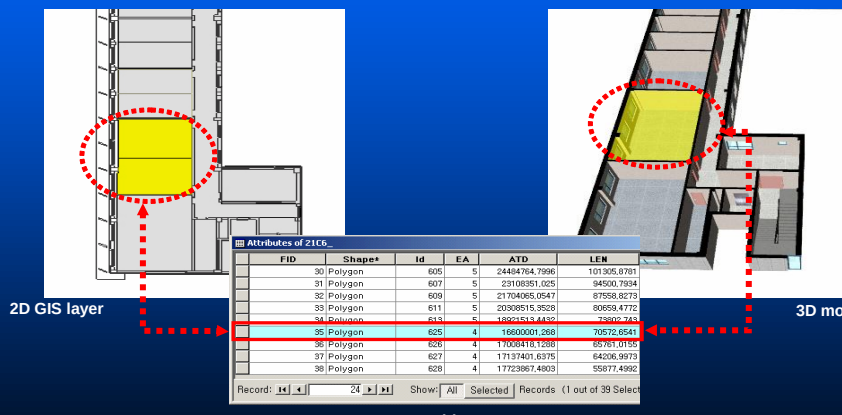


Isolating individual Spaces

b. Creating isolated spaces form a CAD-based 3D model

Combining 2D and 3D

- Identifying and invoking each other thru DB



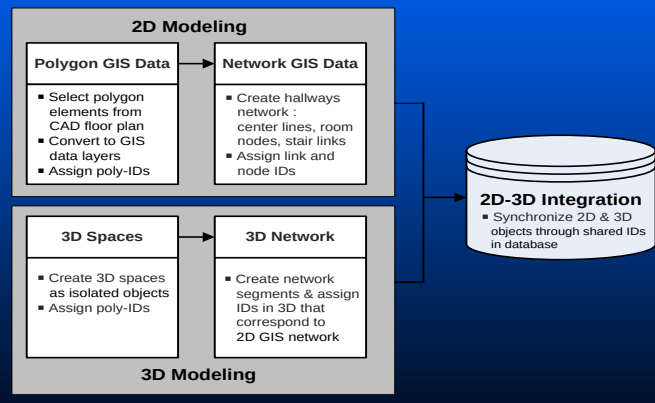
DB table

4. Vector (Node-Link)-based Model

4. Applying To Route Finding

Application Test

- Tested on a campus building
- Created network data both in a 2D GIS and a 3D model
- Linked the matching network segments through data table

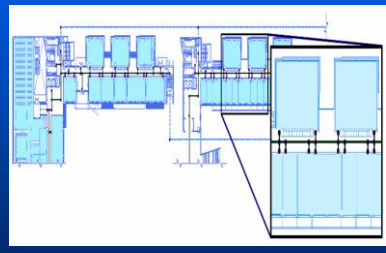


Data construction process for test

4. Applying To Vector-based Model

Network modeling

- 2D network modeling
- 3D network modeling



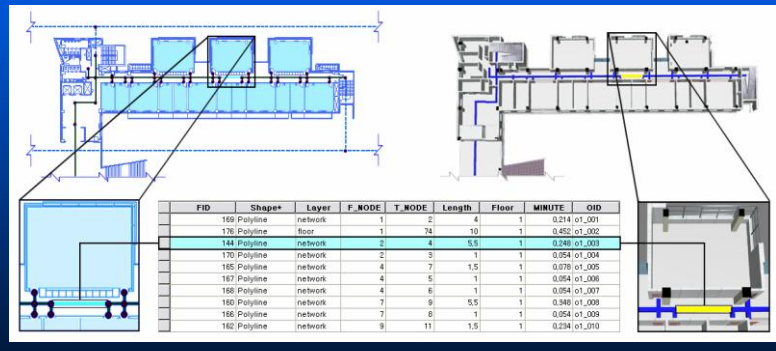
Network modeling in 2D GIS

Network modeling in 3D model

4. Applying To Vector-based Model

2D-3D Hybrid Data Modeling

- Linked the matching segments from 2D model and 3D model



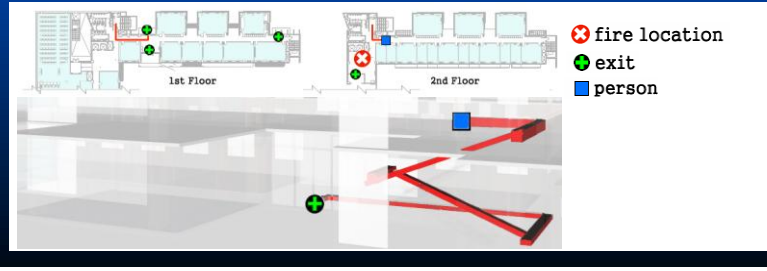
FID	Shape*	Layer	F_NODE	T_NODE	Length	Floor	MINUTE	OID
169	Polyline	network	1	2	4	1	0,214	o1_001
176	Polyline	floor	1	74	10	1	0,452	o1_002
144	Polyline	network	2	4	5,5	1	0,248	o1_003
170	Polyline	network	2	3	1	1	0,054	o1_004
165	Polyline	network	4	7	1,5	1	0,078	o1_005
167	Polyline	network	4	5	1	1	0,054	o1_006
168	Polyline	network	4	6	1	1	0,054	o1_007
160	Polyline	network	7	9	5,5	1	0,248	o1_008
166	Polyline	network	7	8	1	1	0,054	o1_009
162	Polyline	network	9	11	1,5	1	0,234	o1_010

4. Applying To Vector-based Model

Path Finding Results

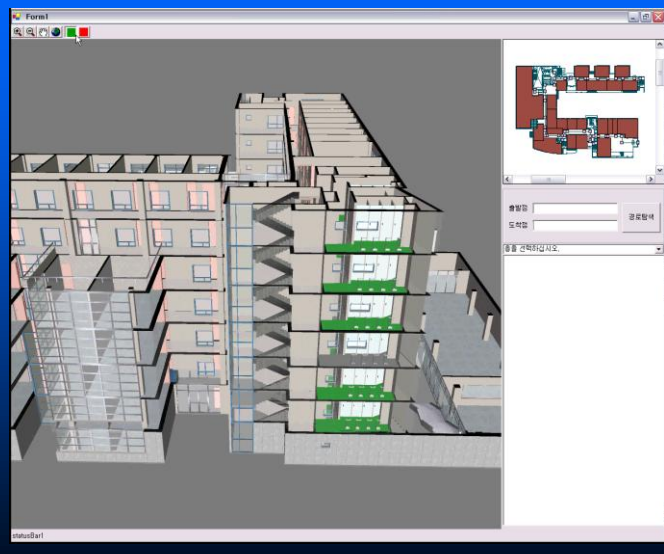
- Path finding between destinated starting point and destination

- The emergency evacuation case



4. Applying To Vector-based Model

Path Finding simulation

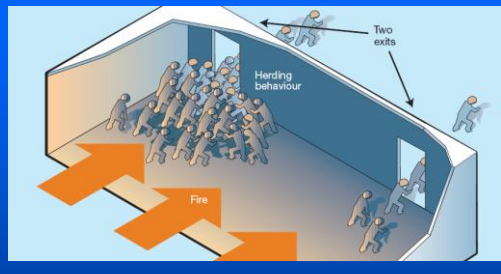


5. Raster (CA)-based Model

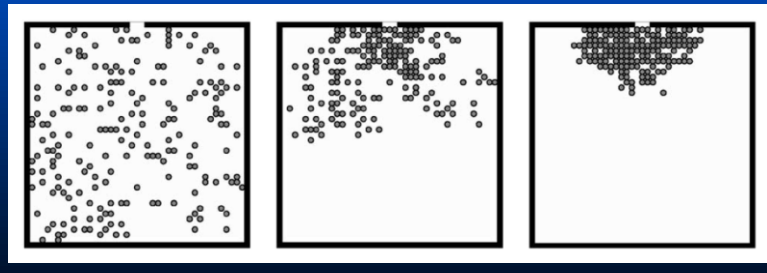
Short comings of node-link based evacuation models

- Typically, each room is mapped to a node, path mapped to a link
- Good for one person's route guidance under non-emergency conditions and fast computation
- Multiple persons' individuality is ignored and treated as a mass
- We should be able to model individual behavior during evacuation at finer resolution

Typical Evacuation Stages



(Low 2000)



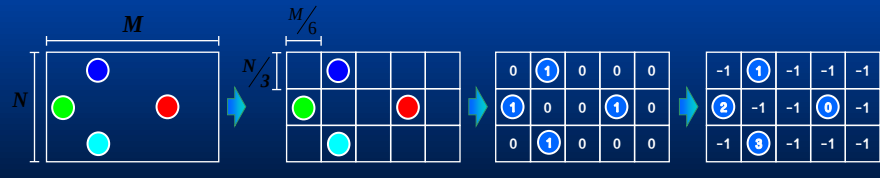
(Burstedde 2001)

CA (Cellular Automata)

- CA have been used for modeling complex phenomena
  - (eg. Fluid dynamics, biology and traffic flow)
- Evacuation is composed of pedestrians (multi-agents) with strong interactions and environment
- More complicated than traffic flow
  - research works are emphasized in evacuation time and human behavior

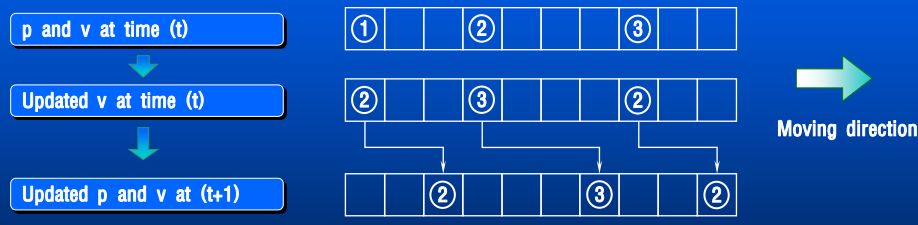
CA (Cellular Automata)

- Space and Time in CA
  - Represent continuous time and space *discretely*
    - » space : unit cell
    - » time : time step
  - Occupant existence is expressed in binary (1, 0)
    - » Other attribute values (*eg.* Velocity) -> real numbers



CA (Cellular Automata)

- Objects moving in CA

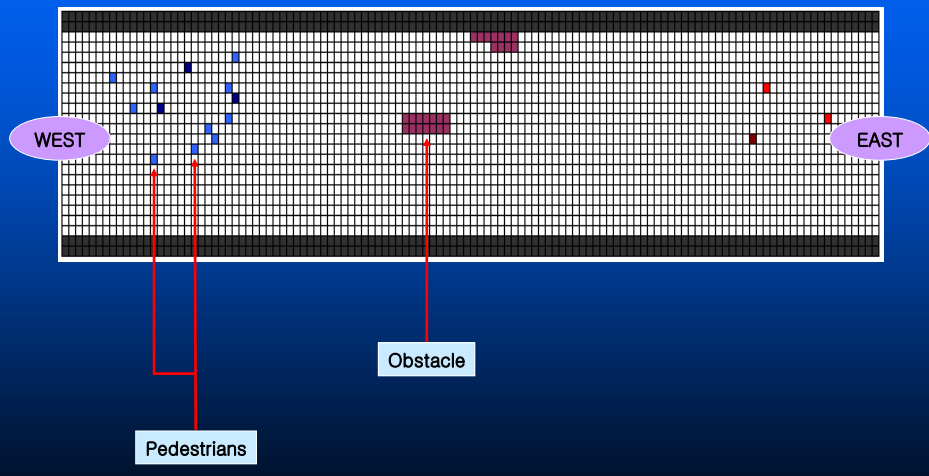


CA-based Simulation

- Hypothetic hallway simulation (bi-directional)

Direction	West <–> East
	• 500 ~ 2,300 persons/h
Pedestrian velocity	• Fast (2.0 m/s) : 30% • Normal (1.5 m/s) : 60% • Slow (1.0 m/s) : 10%
P_{noise}	• Fast : 0.090 • Normal : 0.045 • Slow : 0.005
Speed–reduce due to fore gap (P_{dp})	• 0.300
Direction–change in bump (P_o)	• 0.999
Direction–change in max speed (P_m)	• 0.200
Direction–change in < max speed (P_l)	• 0.500
Other pedestrian perception dist. (d_p)	• 30m

CA-based Simulation



Concluding Remarks

- This study proposed a unique procedure to realize the topological relationship in 3D model for indoor location-based applications.
- A method to build a 2D-3D hybrid data model was presented by linking the 3D and 2D counterpart objects from 3D model and GIS layer.
- We tested two evacuation cases.

Concluding Remarks

- More works to do…
  - Indoor positioning is required in 3D-based ubiquitous applications
  - With mapping the sensors and locating persons in our model, we can get the origin point for way finding.
  - Current 2D CA-model needs to expand to 3D with more human interaction factors

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Thank You!