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Smugglers and Border Guards — Compact Visibility and Path Preserving Terrain Representations

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Outline



- Strategy
- 2 Achievements Representations
 - TIN
 - ODETLAP
- 3 Achievements Operations
 - Multiple Observer Siting Toolkit
 - Path Planning for Road Construction
 - Connected Components in Images
- 4 Future
 - Drainage
 - Productization



Achievements — Representations Achievements — Operations Summarv



Future



- LIDAR, IFSAR
- Increasing geo-related market:
 - GPS, mapping programs, ...)
- Increasing geo problems:
 - radio transmitter siting, surveillance
- This makes efficient representation more important.

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Achievements — Representations Achievements — Operations Future Summary



Strategy

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Look at this commercial product's smooth river valley.



Example, 2

Look at this commercial product's smooth river valley.



Aerial photo:



See the problem with the program?

Achievements — Representations Achievements — Operations Future Summary

Background 1



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- I've been doing efficient cartography, graphics, and geometry for 30 years.
- Worked at the Harvard Laboratory for Computer Graphics and Spatial Analysis, one of the founders of Geographic Information Science, while obtaining a PhD in Applied Math from Harvard in 1978.
- sabbaticals to UC Berkeley, Genoa (Italy), Laval (Canada), Commonwealth Scientific and Industrial Research Organization (Australia), National University of Singapore.

Achievements — Representations Achievements — Operations Future Summary

Background 2



- While on rotation as Director of the \$10M/yr Numeric, Symbolic, and Geometric Computation Program at NSF (2000–2002), I was the NSF lead for 2 rounds of a joint solicitation with the Defense Advanced Research Projects Agency (DARPA) Defense Science Office (DSO) called Computational Algorithms and Representations for Geometric Objects (CARGO).
- Previous funding from Army Corps of Engineers
- Current research is funded by NSF, and DARPA (GeoStar program) - \$1.2M over 3 years.

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Achievements — Representations Achievements — Operations Future Summary



Dperations Strateg



- Compact data structures for terrain elevation
 - represent elevation, slope sufficiently and efficiently
- Operations thereon
 - multiple observer siting
 - path planning to avoid them

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Smugglers and Border Guards



WR Franklin, F Luk, C Westort, M Inanc, Z Xie, D Tracy

Original 3595x3595 W111N31 Terrain: 12,924,025 d.f., Elev Range=2071



Compressed (7x7 Scoop): 791,267 d.f. (16x reduction), Mean abs error=1.7 (0.1%).



Smugglers and Border Guards on 16x

Compressed "Scooped" Terrain

Representation

Compressed: Shortest Smugglers Path Computed Avoiding All 324 Viewsheds of Optimally Sited Observers

Original: Joint Viewshed Computed for Same 324 Observers





Evaluation: Optimal Path from Compressed Terrain Tested on Original Terrain Viewsheds – 14 of 4767 Points (0.3%) Are Erroneously Visible

Achievements — Representations Achievements — Operations Future Summary



erations Strategy Future



- Pursue several representations and applications in parallel.
- Following promising leads, synergize (e.g., ODETLAP is initialized from TIN), and productize (e.g., ArcGIS DLL for multiobserver siting)

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Achievements — Representations Achievements — Operations Future

TIN ODETLAF

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TIN — Triangulated Irregular Network

Summarv



- Can process 10⁸ points on a laptop.
- Works in memory w/o needing to page data from disk.
- Inserts points incrementally, in order of importance.
- Could be used progressively to transmit the surface.
- Identifies ridge lines automatically.

TIN ODETLAP

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ODETLAP – Overdetermined Laplacian

- Overdetermined linear system:
 - $z_{ij} = h_{ij}$ for known points,
 - $4z_{ij} = z_{i-1,j} + z_{i+1,j} + z_{i,j-1} + z_{i,j+1}$ for all nonborder points.
- Fills contours to a grid.
- Fill missing data holes.
- Handles
 - incomplete contours,
 - complete contours,
 - isolated points,
 - inconsistent data.

TIN ODETLAP

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ODETLAP – Overdetermined Laplacian

RPI-odetlap.wmv

TIN ODETLAP

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ODETLAP – Overdetermined Laplacian

Evaluation Using Smugglers Paths







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- Compute viewsheds and smugglers' path on ODETLAP rep.
- Evaluate on original rep.

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Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Multiple Observer Siting

- Goal: Greedily site hundreds of observers on terrain to maximize their joint viewsheds
- Customizable: Observer and target heights above local terrain, radius of interest
- ESRI has produced an ArcGIS DLL toolkit an operational class configurable to perform siting simulations on any platform with a C++ compiler.
- Includes an ArcMap command application that runs on Windows, exercises the toolkit and demonstrates its capabilities.
- Both are functional and scalable.



Marquee Tool:

Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Multiple Observer Siting ArcGIS DLL — 1

Multiple Observer S	iting Toolkit		×
Observer Characteristics		Simulation Characteristics	
100 Effec	stive Radius (pixels)	50 Number of Observers Desired	
10 Obse	erver Height (m)	Enforce Intervisibility	
10 Targ	et Height (m)	10 Number of Tests for VIX	
255 Maxi linear Sign. 0.00 Decoret Alternative Input Options Use Existing VIX File Use Existing Observer Use Existing Observer Use Concealment File Use Concealment File	mum Signal Strength (max al Decay Type ar or exponential) ay Rate (bn / pixel) xponent s File none none	Dutput Options Virite Observers Shape File Virite Observer Count Image Virite Observer Count Image Virite Intervisibility Lines Shape File Virite Visibility Index (VIX) Data Fil Dutput c:\temp\	
		Cancel OK	

Dialog Box:

Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Multiple Observer Siting ArcGIS DLL – 2



Original Data

Resultant Multiple Observer Siting Map

Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

Siting and Path Planning



Will help terrain to be stored more compactly and retrieved more quickly by soldiers in the field. Site a group observers so as to maximize the amount of visible terrain. Use A* to plan a path through the terrain that avoids the visible areas while also minimizing the distance traveled. Use the visibility and the paths to evaluate terrain compression techniques.

Future work: A toolkit for the path planning.

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Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Summar

Path Planning Video

RPI-path-planning.wmv

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Path Planning for Road Construction

- Goal: Construct an optimal road connecting two points.
- Allowed: Material removal and deposition.
- Constraint: Max allowable slope is bounded.
- Objective function: Amount of material moved.
- Method: A*



Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Path Planning for Road Construction

Application to Representation Evaluation

Compute road (and its cost) on compressed rep, evaluate its cost on original rep, compare costs.





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Multiple Observer Siting Toolkit Path Planning for Road Construction Connected Components in Images

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Connected Components in Images



- We can find the connected components in a 19000x19000 image, whose pixels have been classified, in 25 secs.
- This may be synergistically useful to other teams.
- Here is a detail of the output.

Drainage Productization



Future

- pruning & combining representations
- globally optimizing representations and operations
- optimized coding

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Achievements — Representations Achievements — Operations Future

Drainage Productization

Summary



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- Problem: Local drainage regions trap water and inhibit long rivers.
- Solution: Use fast connected components.

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Achievements — Representations Achievements — Operations Future

Drainage Productization

Summar

Productization

 Hand off our most promising results to ESRI for productization.

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Intro hievements — Representations Achievements — Operations Future

Summary

Summary



Original Surface (320 KB) Compressed Surface (4071 Bytes)

Average Absolute Error = 2.451 Maximum Absolute Error = 25.822



Segmented Terrain



Smugglers Path