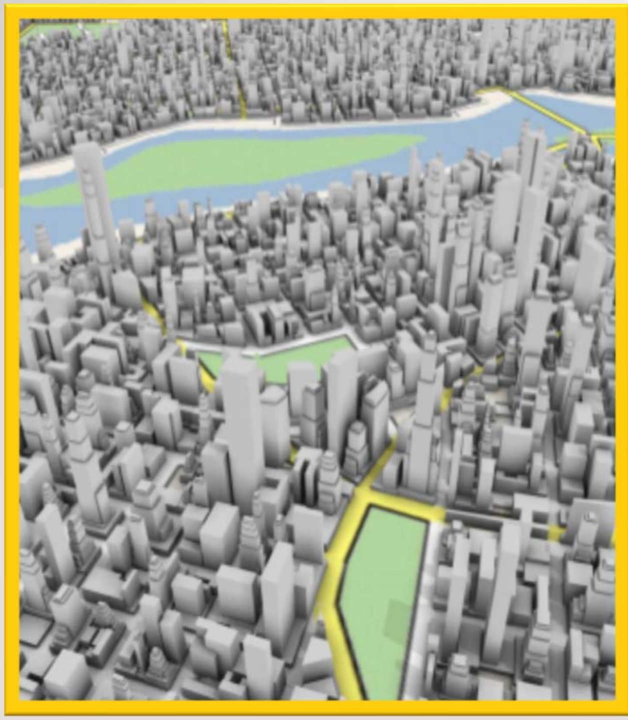

INTERACTIVE PROCEDURAL STREET MODELING

COMPSCI 289 PRESENTATION

BY JACK LIU

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INTRODUCTION

- Maps and visualizing urban areas is required by many industries.
- But drawing maps of large 3D urban environments is extremely tedious and time consuming.
- Solution: use computers to generate graphs of maps instead of manual drawing.

Downtown Portland, Oregon, USA

WHERE DOES IT FIT IN COMPUTER SCIENCE?

- Shift from paper maps to the digital age.
- Older maps are forms art.
- Several years of work for cartographers to draw maps.
- Computer vision and computer graphics.
- More specifically procedural generation techniques with the flexibility of user input.

INDUSTRY BACKGROUND

- Modeling bottleneck.
- Industries require fast and efficient creation of street models.
- Entertainment: advertisements, movies and games need city fly-throughs.
- Urban Planning: Help visualize projects, such as Britomart Train Station.

Map of changes to Auckland City Centre

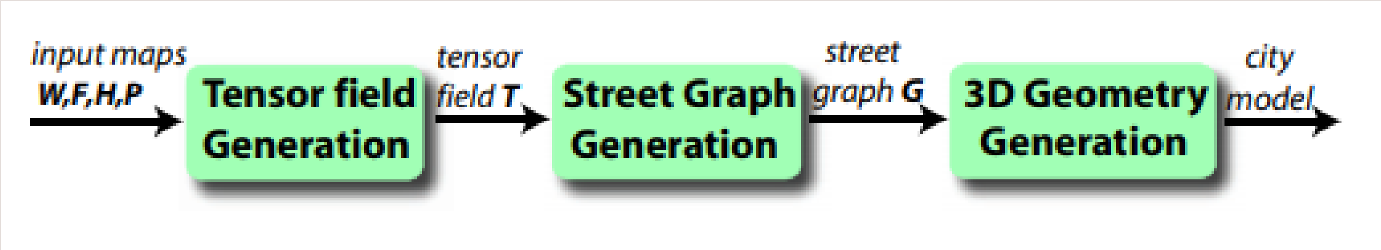
RELATED WORK AND ASSOCIATED TOPICS

- Roadworks construction and Civil Engineering.
- Distinguishing factor is scale: construction and engineering focus on building and geological details, factors like noise regulation, traffic density, vehicle pathing, soil density and legal details such as land ownership. Safety is key!
- Computer Science focuses purely on modeling and visuals. Make it look realistic.

3 STAGE PROCESS

Inputs are Images of maps; each is a discrete function defined on a grid, with range and domain.

- Binary valued water map **W**
- Binary valued park and forest map **F**
- Height map **H**
- Population density map **P**



3 Stage Modeling Pipeline Overview

TENSOR MATH

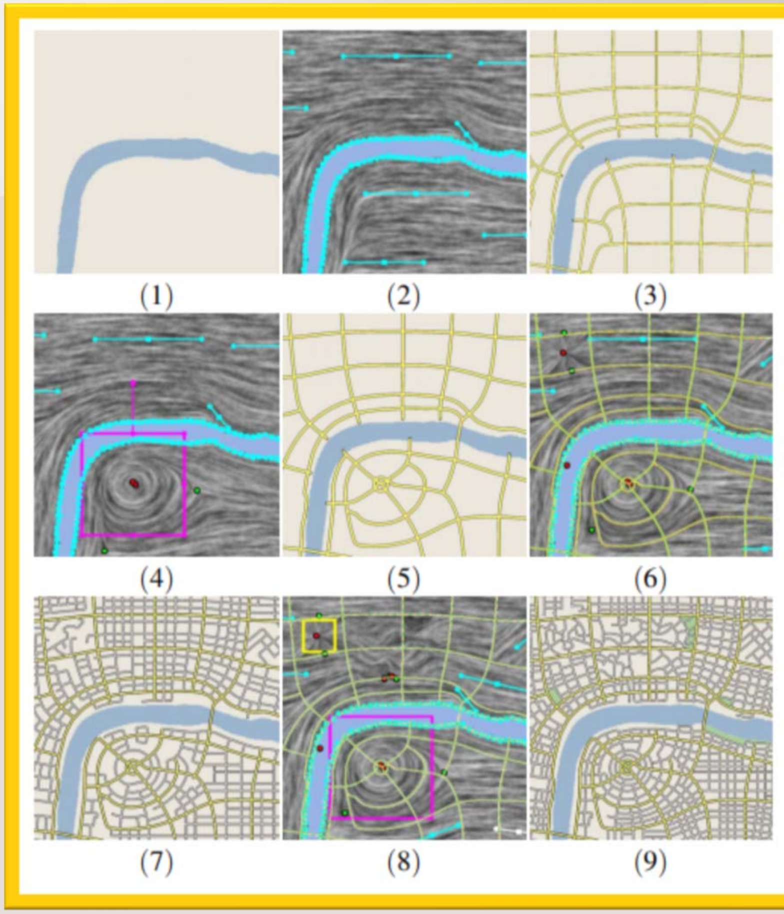
- In this research paper a tensors refers to a 2x2 (square) symmetric matrix in form:

$$R\begin{pmatrix}\cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta\end{pmatrix} \qquad R \geq 0 \qquad \theta \in [0, 2\pi)$$

- Tensors are algebraic objects that describe relationships between sets of algebraic objects in a vector space. Think points on a graph.
- Eigenvector is a nonzero vector that changes a vector by a factor, the eigenvalue.

MAP GENERATION PROCESS EXAMPLE

- 1) Load **W**
- 2) Place Major Tensor fields based on input image
- 3) Major street network generated from Tensor fields
- 4) User defines radial structure in tensor field
- 5) Radial structure results in changes to street graph
- 6) Add tensor fields for minor roads
- 7) Results in generated minor roads in street graph
- 8) User adds rotation noise fields to create irregular structures near top
- 9) Final result before 3D models added



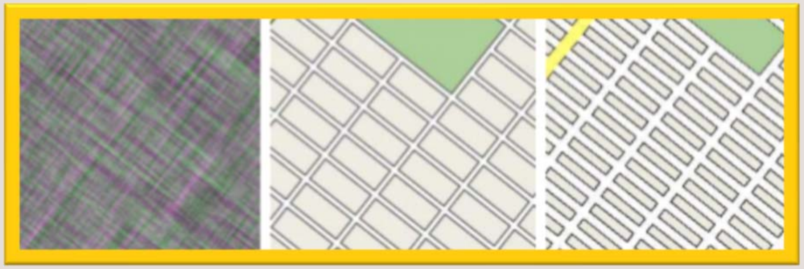
STAGE 1 TENSOR FIELD GENERATION

- User inputs tensor fields based on inputted maps
- E.g. Tensors placed to follow coastline as it is natural to design real roads to follow coastlines.
- Tools to modify tensor fields: Regular, grid, radial etc. For radial this is achieved by:

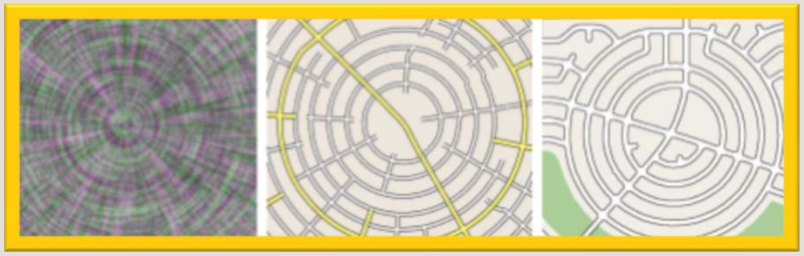
$$T(\mathbf{p}) = \begin{pmatrix} y^2 - x^2 & -2xy \\ -2xy & -(y^2 - x^2) \end{pmatrix}$$

- Pre-defined tensor fields to set boundaries e.g. respect topography of maps

STAGE 1 TENSOR FIELD GENERATION



Grid and radial streets generated from modified tensor fields

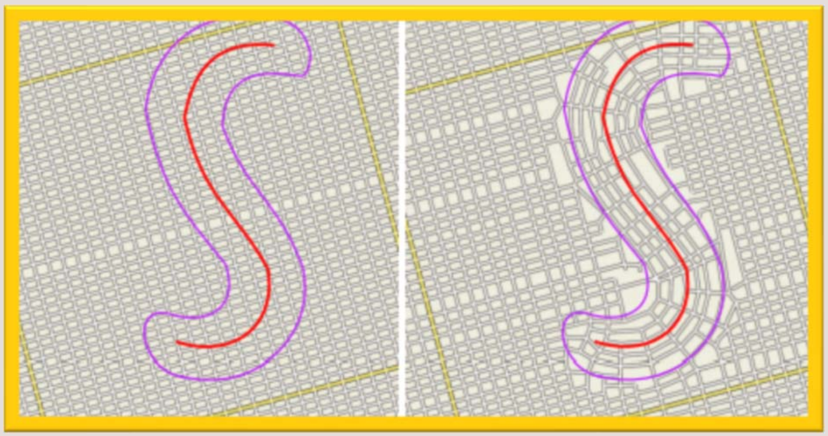


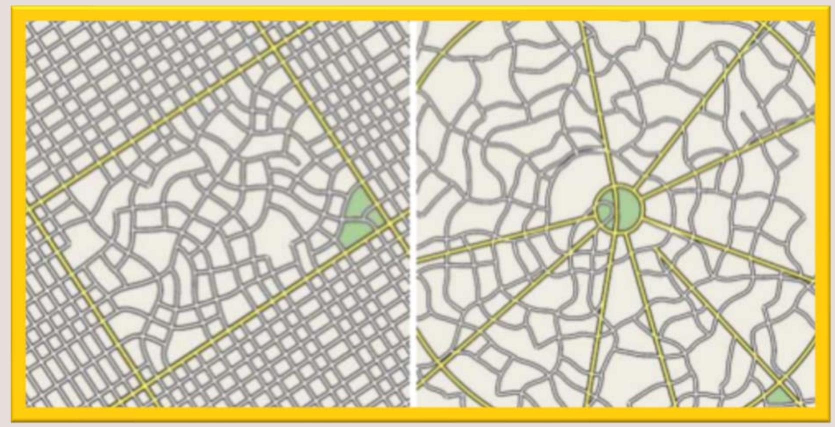
California Highway One. Major Road follows coastline due to boundary tensor fields

STAGE 1 TENSOR FIELD GENERATION

- Locally created tensor fields
- Real roads have irregularities for many reasons such as by design
- 3 scalar fields R1, R2, R3 modify minor eigenvectors of the tensor fields to generate noise in order to replicate irregularities in roads.
- By limiting a tensor field to certain values a brush tool can be replicated in the street generation

STAGE 1 TENSOR FIELD GENERATION

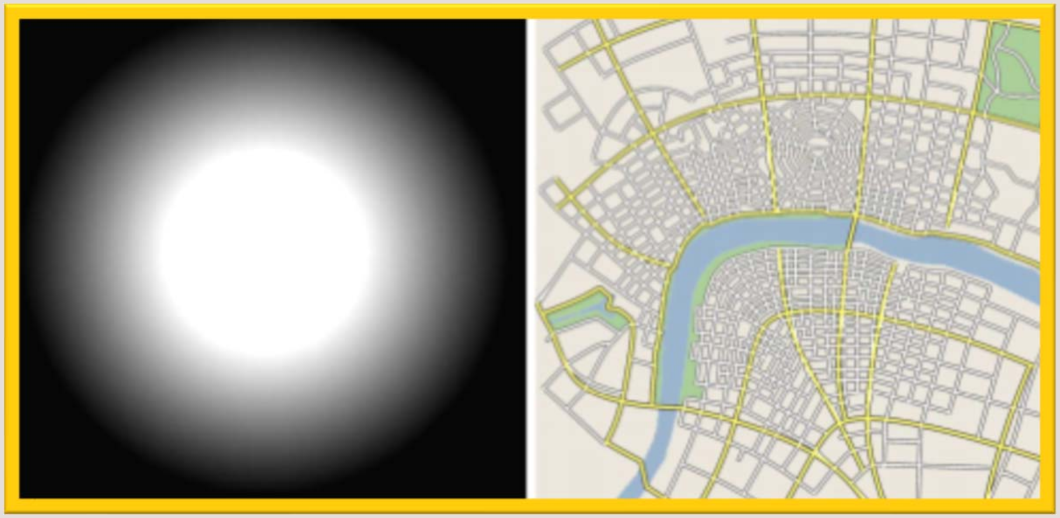




Example of ‘brush’ limiting tensor fields (left) and R values altering tensor fields resulting in noise (right)

STAGE 2 STREET GRAPH GENERATION

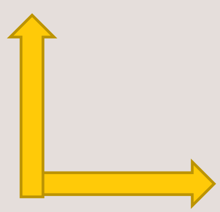
- Procedurally generate street network from tensor field
- Uses hyperstreamliness from tensors in the tensor field
- Algorithm is based upon the work of Jobard and Lefer 1997's evenly spaced streamline placement.



P is used to help generate street network from the tensor field

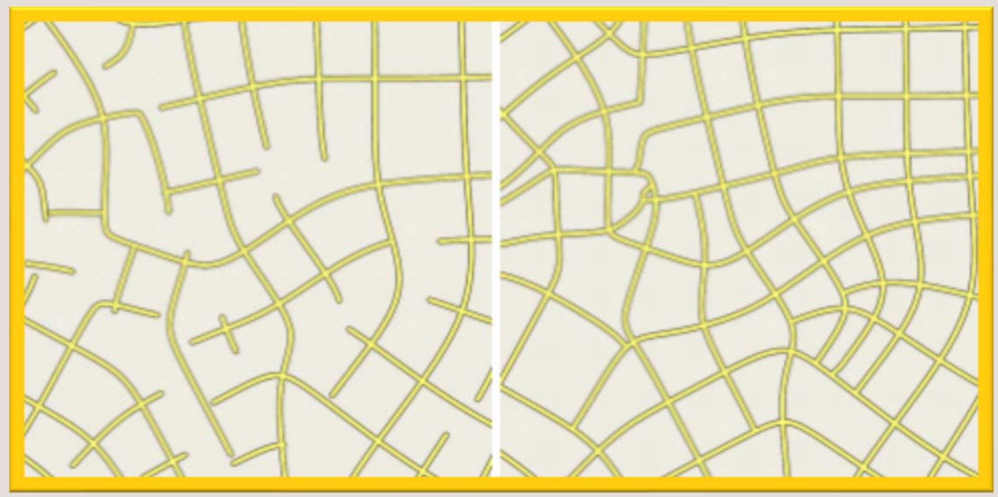
STAGE 2 MORE TENSOR MATH

- In this research paper tensor fields are continuous functions that associates every point to a tensor.
- Tensors have major and minor eigenvectors, unrelated to major or minor streets
- Hyperstreamline: tangents to an eigenvector field
- Hyperstreamlines are either major or minor depending on the eigenvector
- Orthogonal



STAGE 2 STREET GRAPH GENERATION

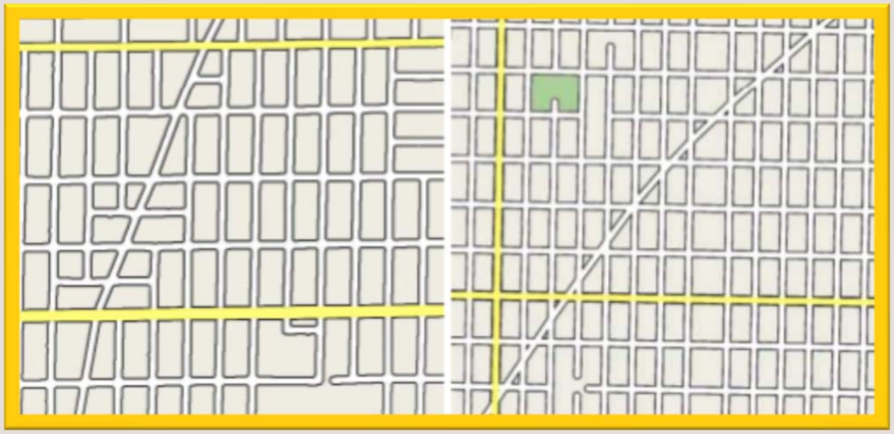
- original framework of Jobard and Lefer [1997] creates evenly spaced hypersteamlines.
- Many disconnected points is a problem for street networks
- Problem solved by continuing a hyperstreamline until it intersects another eigenvector



Left shows disconnected hyperstreams

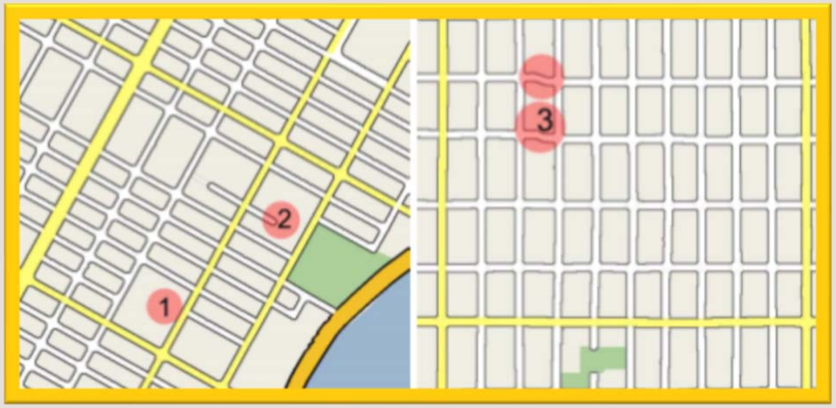
STAGE 2 STREET GRAPH GENERATION

- Additional tools for user to modify street network such as removing segments (eigevectors or hyperstreams), displacing or rotating hyperstreams etc
- Note worthy tool: Seed Point Creation, like seeds in generating random numbers e.g new Random()
- Real world Seed example from Chicago to add overlaying road



Map from Chigaco (left). Replica procedural map generation and seed point creation (right)

STAGE 2 STREET GRAPH GENERATION



1) Removed Hypserstreamline
2) Edited Hyperstreamline
3) Displaced Hyperstreamline

Map showing cracks in Missouri (left) with generated cracks from rotating hyperstreamlines (right)

DISCUSSION

- Possible for maps to be procedurally generated with user input.
- Possible for realistic and detailed maps to be procedurally generated in an efficient and effective time period
- Previous research on hyperstreamlines and tensor field visulaisation as aided in this paper. Jobard and Lefer [1997] evenly spaced hyperstreamlines placement. Tensor field visualization van Wijk [2002] and Zhang et al [2007]
- Aids future research on procedural generation of fracture patterns, plants and leaves, as well as modeling of cracks, bark and crystalline structures.

FUTURE

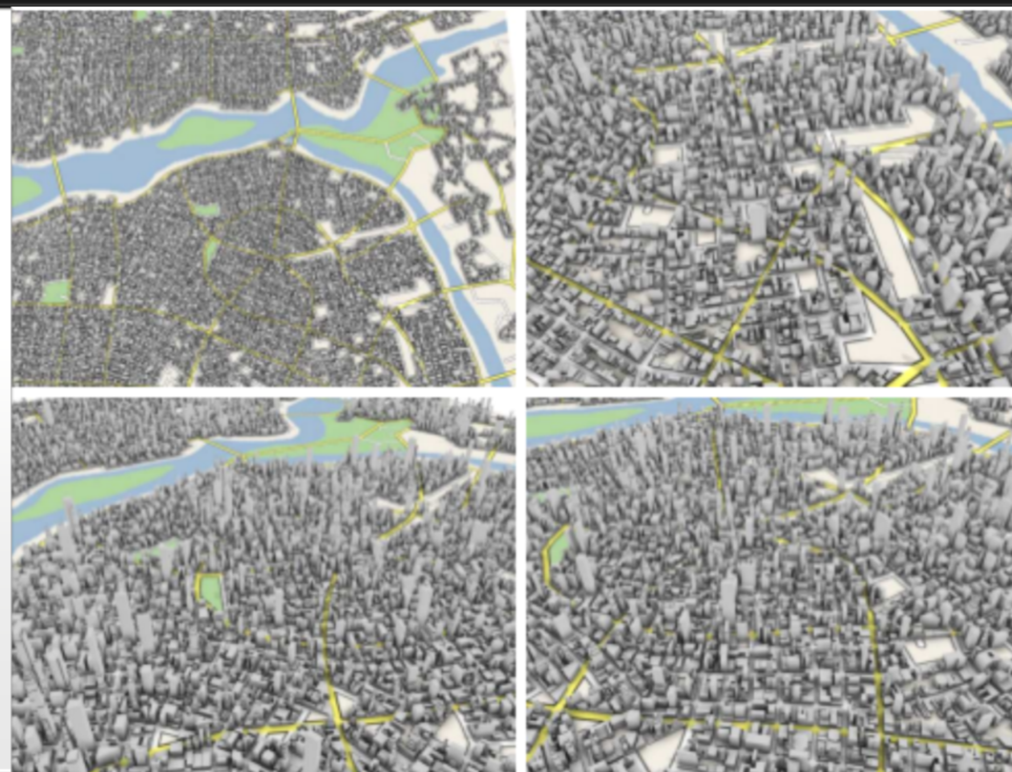
- Procedurally generated maps that are detailed and realistic can now be created in a shorter timeframe. Example of maps like Taipei in next slides can be created in roughly an hour. 3D models Fly-ins of virtual cities possible.
- Pros: Visually detailed maps that are generated fast and efficiently. Modifiable due to use of tensor fields as base. Advantage over graph-based software. Flexible due to user input.
- Cons: Single level spatial resolution (related to pixels and smallest viewable object). No ability to modify tensor field at different scales. Not 100% accurate.

STAGE 3: 3D GEOMETRIC MODELLING

Generated map for Downtown Taipei

STAGE 3: 3D GEOMETRIC MODELLING

Fly over of a 3D virtual city with generated maps



REFERENCES

- G. Chen, G. Esch, P. Wonka, P. Müller and E. Zhang, “Interactive procedural street modelling,” in Proc. ACM SIGGRAPH 2008, 103, 2008, pp. 1–10, doi: 10.1145/1399504.1360702.
- JOBARD, B., AND LEFER, W. 1997. Creating evenly-spaced streamlines of arbitrary density. Proc. Eighth Eurographics Workshop on Visualization in Scientific Computing, 45–55.
- VAN WIJK, J. J. 2002. Image based flow visualization. In SIGGRAPH ’02: Proceedings of the 29th annual conference on Computer graphics and interactive techniques, ACM, New York, NY, USA, 745–754.
- ZHANG, E., HAYS, J., AND TURK, G. 2007. Interactive tensor field design and visualization on surfaces. IEEE Transactions on Visualization and Computer Graphics 13, 1, 94–107.