Interactive Visualization of Simulated Urban Spaces by using Procedurally Generated Content

Carlos Vanegas, Daniel Aliaga, Benes Bedrich, Paul Waddell

Outline

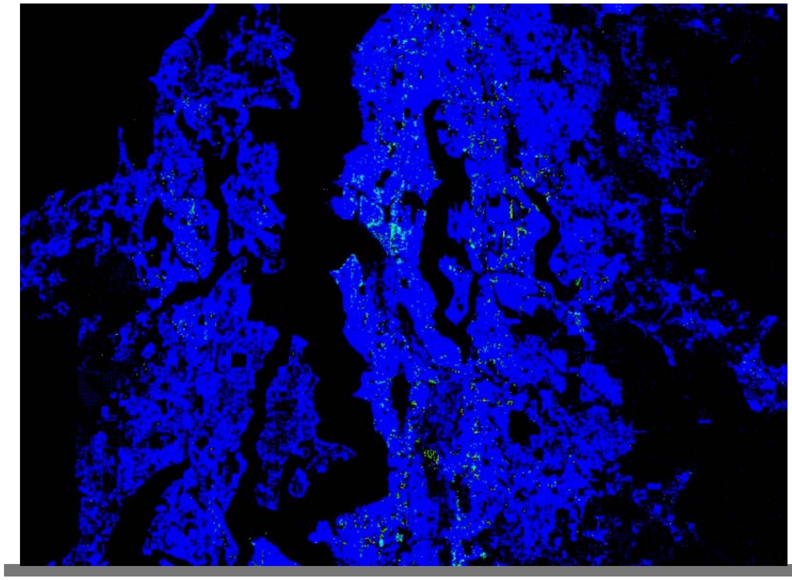
- Summary and Motivation
- Contributions
- Pipeline
  - Some Details
- Results
- Future Work

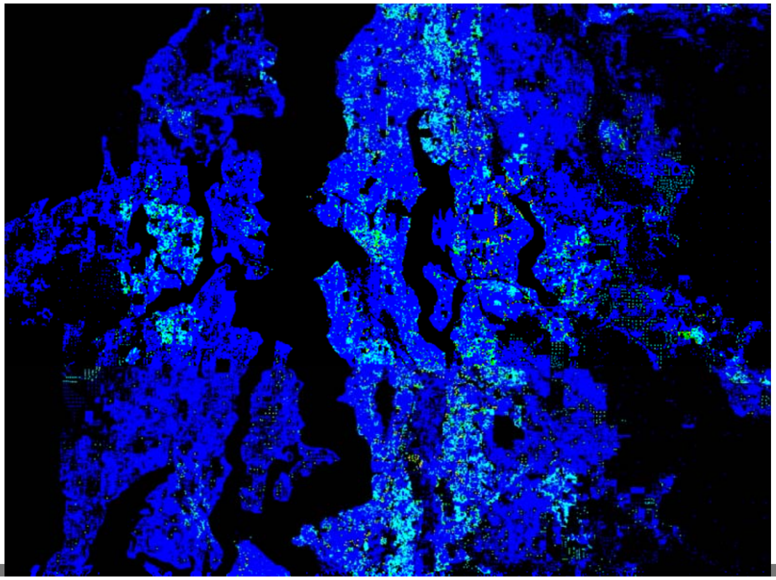
Summary

- Visualizing **simulations of urban spaces** is of significant importance to urban planning, emergency management, and content creation.
- We bring together **procedural modeling** and **urban simulation models** in order to **improve the visualization of data** resulting from simulated changes in urban activities and landscapes over time.

Motivation

- Traditional Visualization of Urban Simulation Data
  e.g. Number of households per parcel in the Puget Sound Area in 2000 (left) and 2030 (right)





A long time ago…

(Graphics Lunch September 2007)

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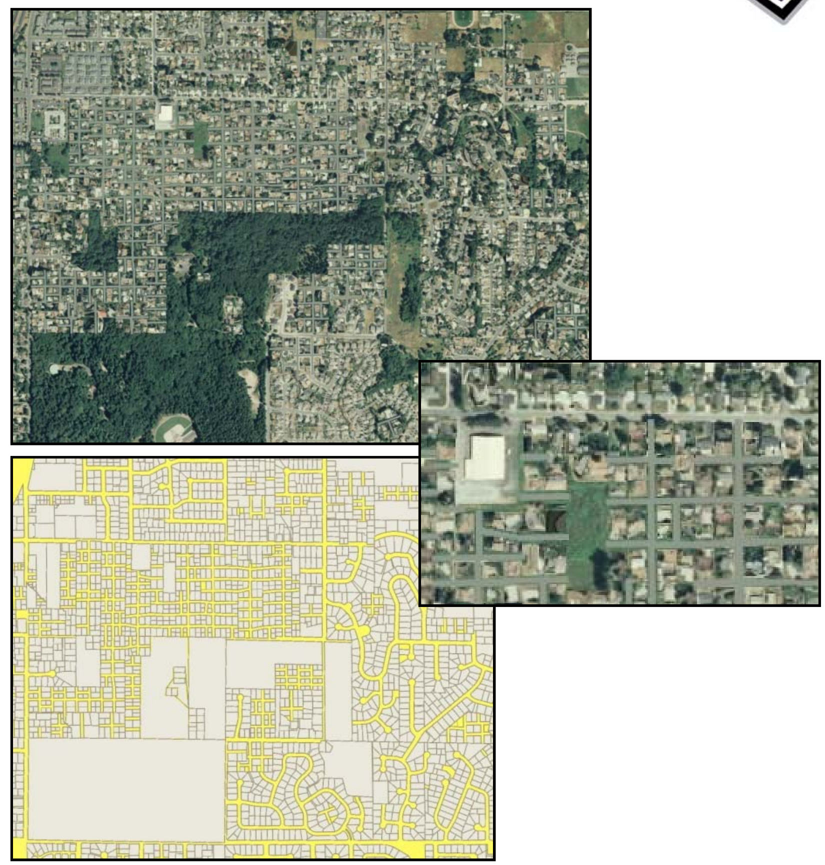
(Graphics Lunch September 2007)

Our Results Today!

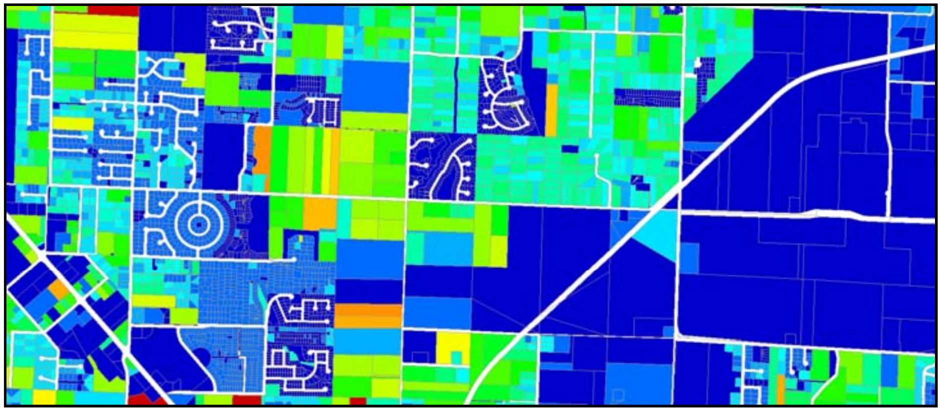


Our approach

- **Observation:** Interactive procedural techniques can be used to complement and enhance visualization of urban simulations

- **Goal:** Build upon existing visualization techniques of urban simulations and extend them by using specialized and interactive procedural content generation.

Our approach



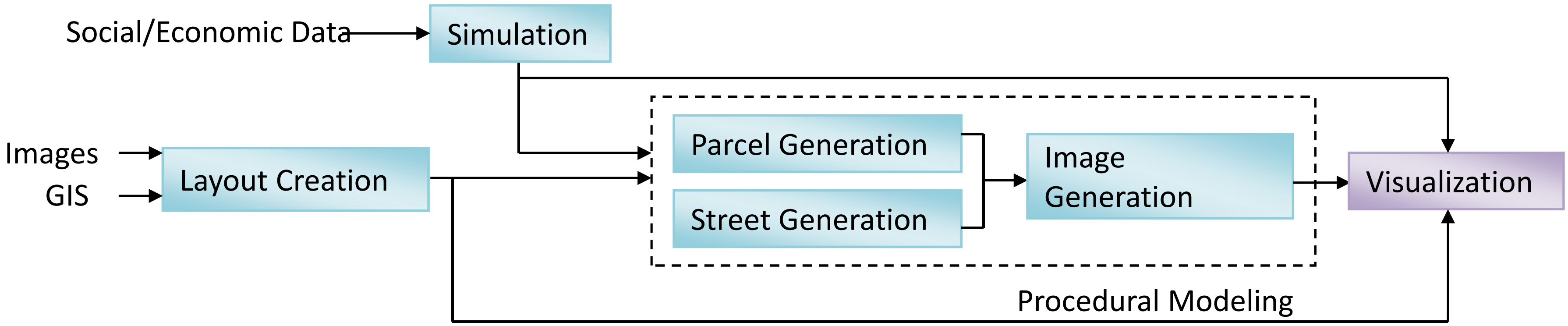
Basic existing approach to visualize Simulation Results

Our approach to visualize Simulation Results

Contributions

- An enhancement to the visualization of the results of urban simulations with inferred higher-level structural information that can be displayed separately or simultaneously with other visualization modalities.
- A set of interactive and automatic algorithms for generating a visually plausible urban layout from the data produced by an urban simulation.
- The demonstration of a specific case of visualization using about 200GB and 30 years of simulation results from the Seattle, Washington area.

Pipeline



Social/Economic Data
Simulation
Images
GIS
Layout Creation
Parcel Generation
Street Generation
Image Generation
Visualization
Procedural Modeling

Urban Simulation

- Our framework can be applied to various urban simulation packages
- We in particular use the publicly available UrbanSim simulation software (developed at Univ. of Washington)
- UrbanSim has become a standard tool for metropolitan land use and transportation planning, and is currently used or in the process of implementation for the simulation of numerous metropolitan areas in the United States and Europe

Urban Simulation

- UrbanSim simulates annual time steps, within which new residential and non-residential buildings are virtually constructed by developers
- Construction decision is based on expected returns on investment and subject to development regulations

Procedural Content Generation

- During the urban simulation, a variety of state changes occur in the simulated area
- Our system extracts these state values and uses the initial street and parcel information to generate:
  - Parcels Geometry
  - Street Geometry
  - New Parcel Images

Parcels

We seek to have parcels that obey the following properties:

- Parcels generally have egress (e.g., access to street); thus, this property should be enforced if so desired
- City blocks are usually formed by rows of one or two parcels (e.g., parcels share a backyard with the parcels on the other side of the block) and thus the subdivision should produce a similar arrangement
- The geometrical shape of a parcel is often a simple polygon and most often a four-sided one

Parcels

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Parcel and Street Generation (iterative form)

Let K be the desired number of parcels per block

FOR each city-block B to be partitioned

   Let P be the initial list of parcels in B

   Set P = {B} initially

   WHILE not enough parcels in B to hold the
          simulated population growth

      Get the parcel p' in P of largest area

      Compute the axes of the OBB of p' and choose one
          of them (A) such that Egress is maintained

      IF (N/|P|)< K

         Generate street geometry along A

         Add the geometry to the list of streets

      ENDIF

      Split p' along A, into p0 and p1

      Let P = P U {p0} U {p1} – p'

   ENDWHILE

ENDFOR
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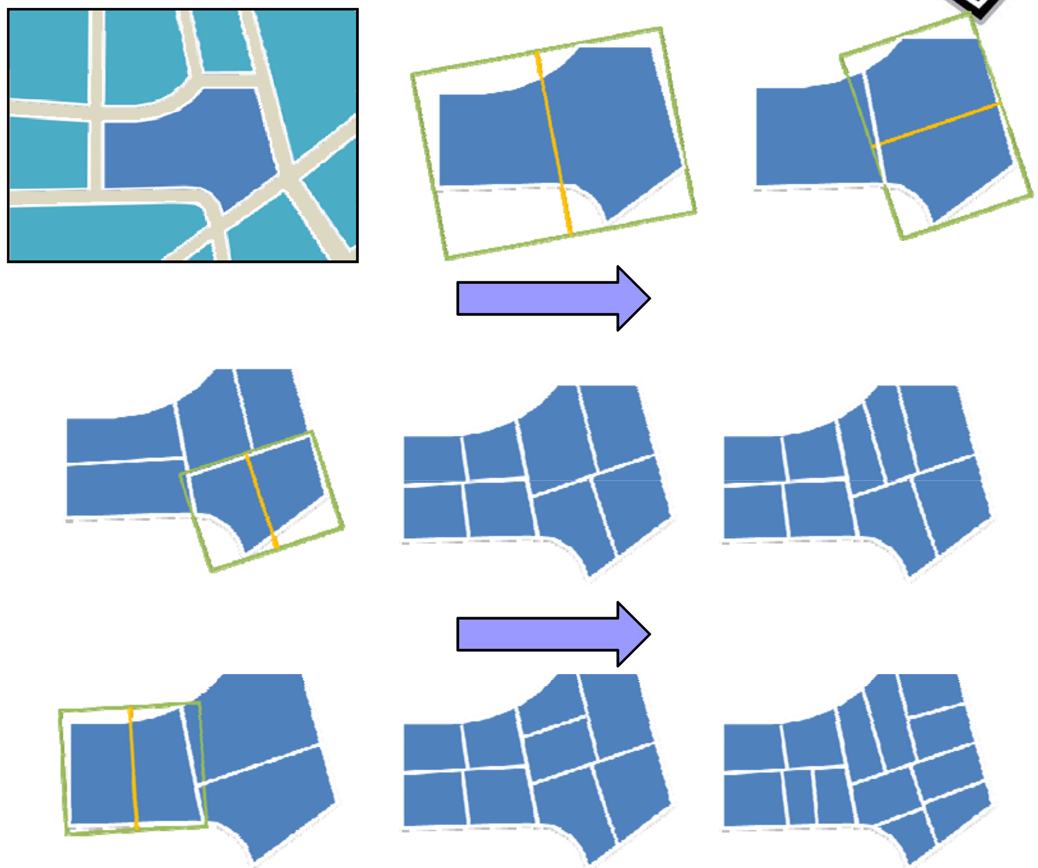


Streets

- Street generation is performed in parallel with parcel subdivision
- It enables generating a larger set of parcels, of more similar shape to nearby parcels, and with optional egress

Streets

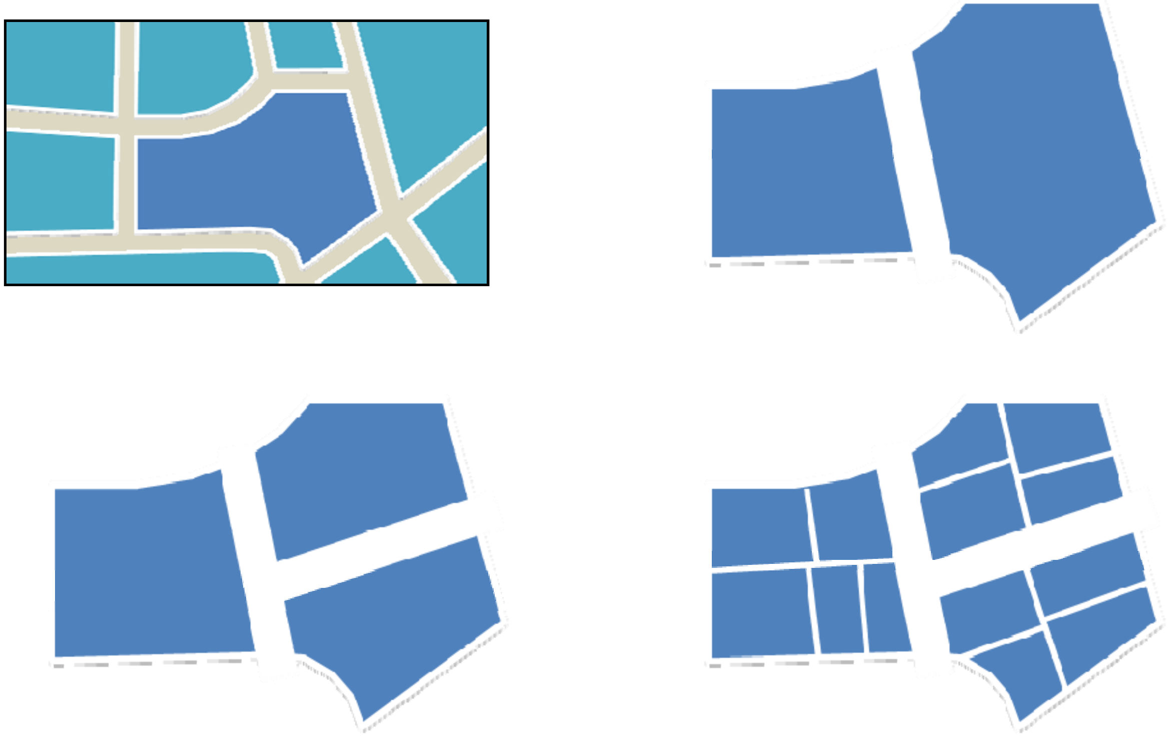
To generate streets we attempt to obey two additional properties:

- The overall shape of a parcel should be similar to those of other nearby parcels; in particular, we measure the aspect ratio of the parcels within a chosen maximum distance
- The number of parcels per city-block should be dictated by either a recommended value or by inspection of the neighbouring city blocks

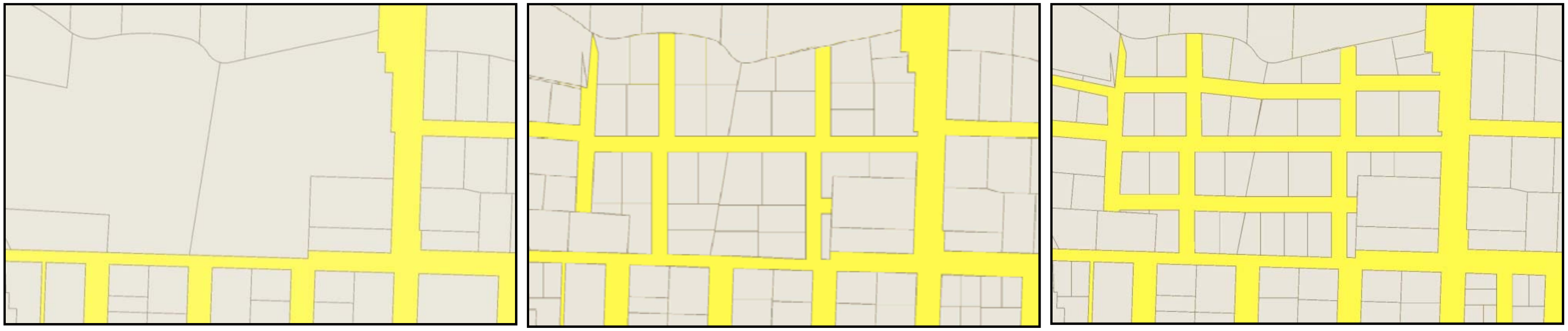
Streets

- Our initial recursive algorithm is extended to choose at each iteration whether the partition produces a street (and thus more city blocks) or generates more parcels (within the same city block)
- Further, the subdivision process chooses a partitioning that produces parcels of aspect ratio most similar to the targeted aspect ratio
- Our method uses the number of new parcels that need to be generated as a trigger to create new streets

Streets



Streets + Parcels



Example Parcel+Street Generations

a) Original area within the test dataset.

b) Using the data from the urban simulation and GIS input, we automatically compute a procedural subdivision of the area into new parcels and streets.

c) Additional streets are generated if necessary, in order to enforce egress rule.

Parcel Image Generation

- In the final step, we use a similarity-estimation method and an image-warping algorithm to generate plausible image content for each newly created parcel
- As there is no information available for the specific details of the future structures, reusing existing aerial views of parcels containing similar characteristics seems a plausible way of obtaining image samples

Parcel Image Generation

- To find the most appropriate existing (source) parcel image fragment to populate a new (destination) parcel, we define a **similarity metric** as the weighted sum of the similarity of simulation state values and similarity of geometric shape

Parcel Image Generation

- For simulation state values:
  - We use all or some of households per parcel, year built of the construction, and zoning classification
- For geometric shape similarity:
  - We compare oriented-bounding boxes (OBBs).
  - The OBB pairing that is most similar in area, aspect ratio, and respects the same side facing the street (assuming that information is available) is chosen.

Parcel Image Generation

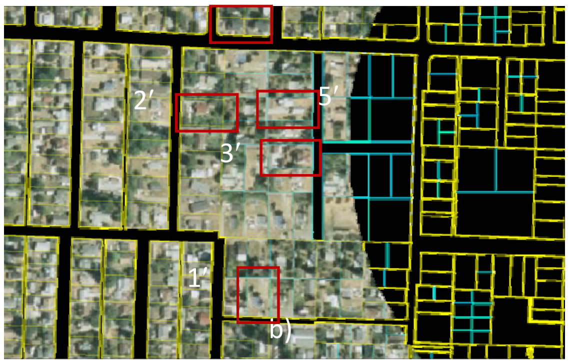
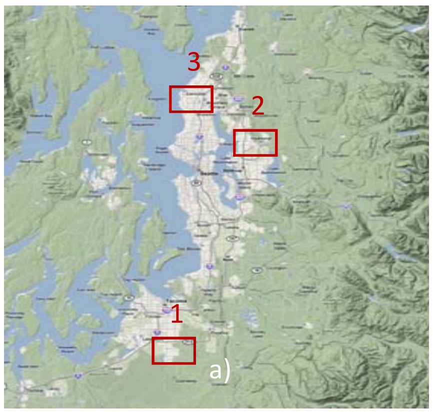
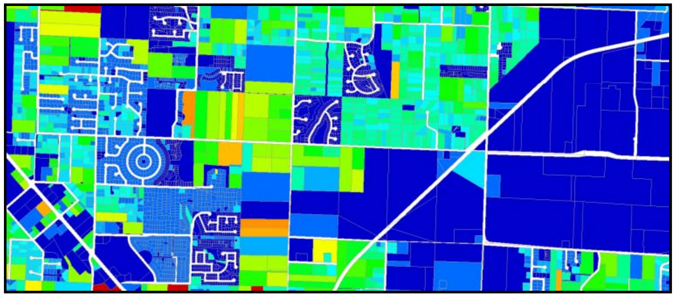


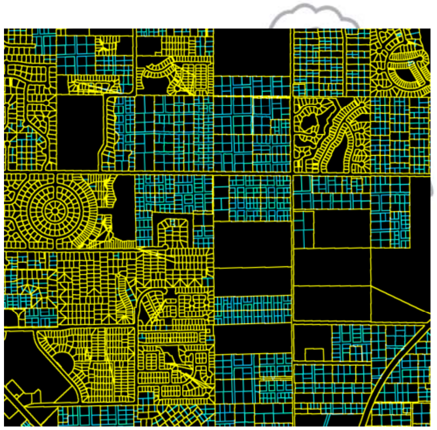
Figure 6. Images. a) Close-up of an original urban area from where parcel image fragments are extracted. b) Close-up of newly generated area and a highlighting of some of their (reused) image content.

Results



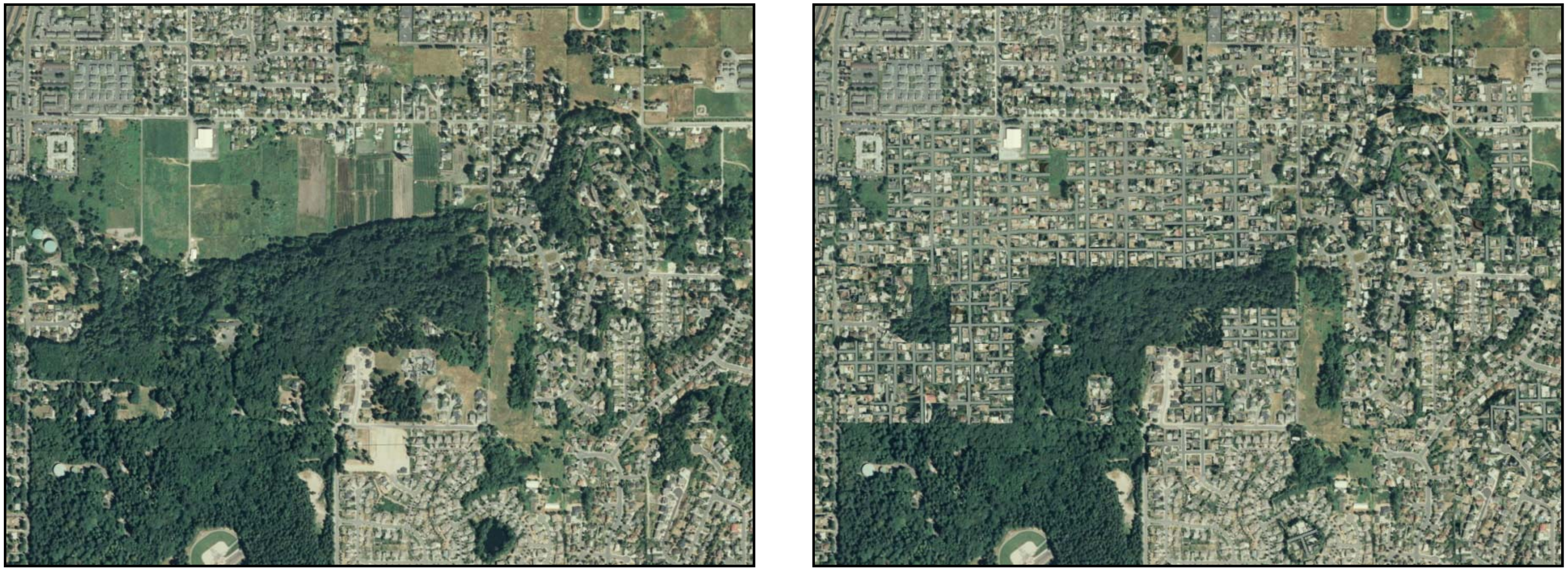
Results





Results

Results



Future Work

- Investigate producing synthetic 3D content for each of the parcels
- Support the explicit conversion of more rural areas to city as well larger-scale changes such as highway alterations, bridges, waterway changes, and so forth
- Another potential use of our approach is to incorporate the topologically-modified parcel geometry to the urban simulation itself, allowing:
  - The simulation to interact dynamically with the visualization engine as the simulation proceeds
  - Increase the realism of the simulation process