Urban Grammar

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Urban Visualization

- Procedural creation of urban layouts for:
  - City planning.
  - Creation of virtual environments for games.
  - Emergency response training.
  - Fast prototyping.

- Urban Grammar deals with the modification of urban layouts.

Example: Stretch Lafayette

Data Representation

- Specification
  - An aerial view is marked up with lines denoting roads or boundaries.
- Parsing
  - The specification is then parsed to create a city grammar.
- Deriving
  - When the city is changed, the grammar is used to derive a new city image.

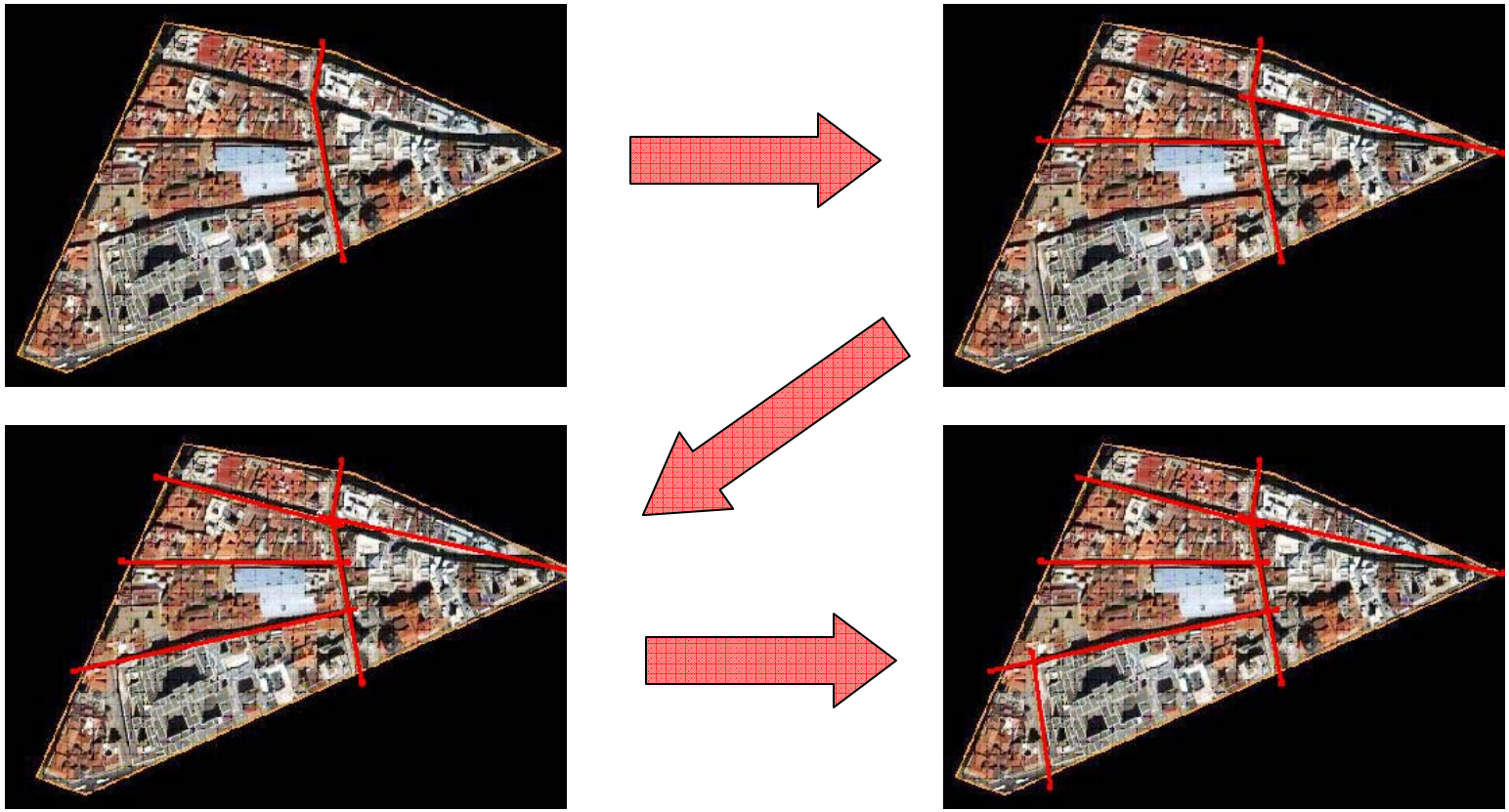
Urban Specification

- Specify an initial region that encloses the buildings you wish to include.

Urban Specification

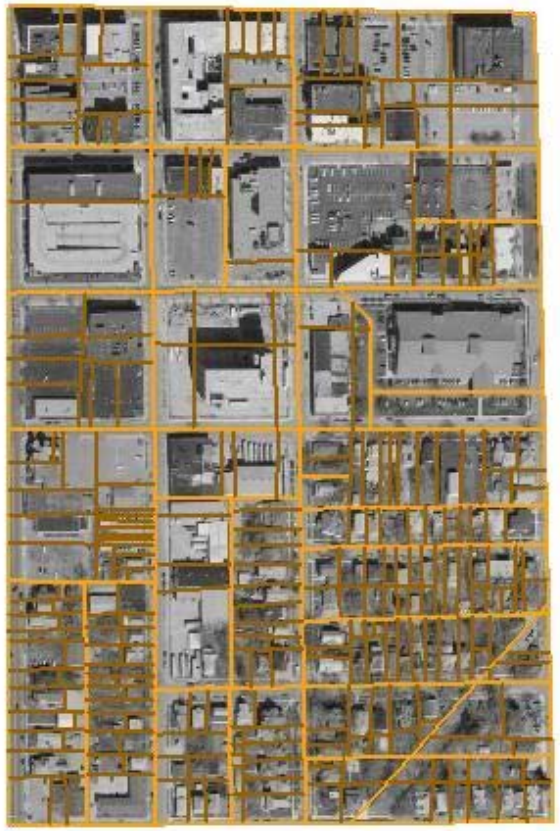
- Ideally, extract automatically from GIS database roads and other boundaries.
  - For now, we mark then manually in a top-down manor.
  - As you add edges you can see the tuples that are being created.

Urban Specification



Urban Specification

- Lafayette



Courtesy of Shweta Svaidya

Urban Specification

- Rome

Courtesy of Shweta Svaidya

Urban Specification

- Madrid

Courtesy of Shweta Svaidya

Urban Specification

- Buenos Aires

Courtesy of Shweta Svaidya

Urban Specification

- Paris

Courtesy of Shweta Svaidya

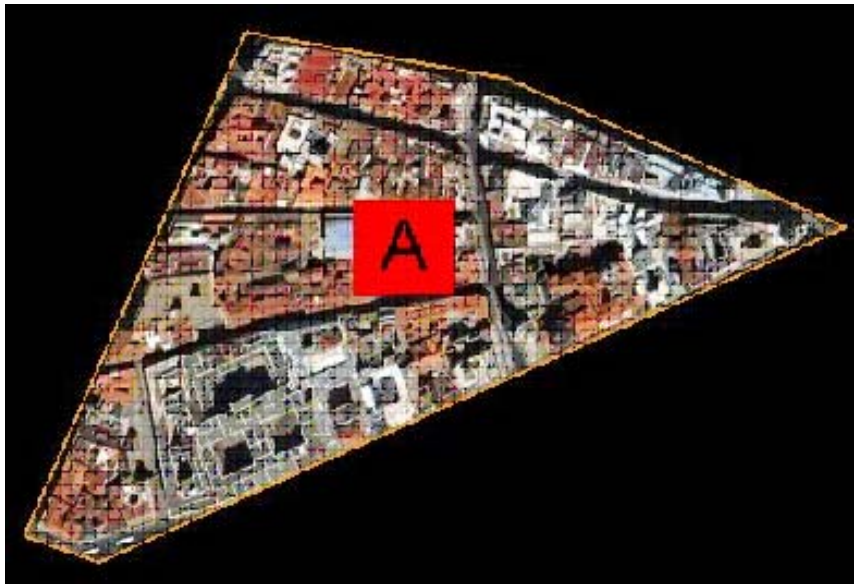
Parsing the City

- The top-down approach of marking up the city is key to parsing the city.
- Start by looking at the initial region and find a markup edge that splits the region in (approximately) half.
- Recurse on each of these regions and find edges that split them.
- Do this until all edges have been used.

Parsing the City

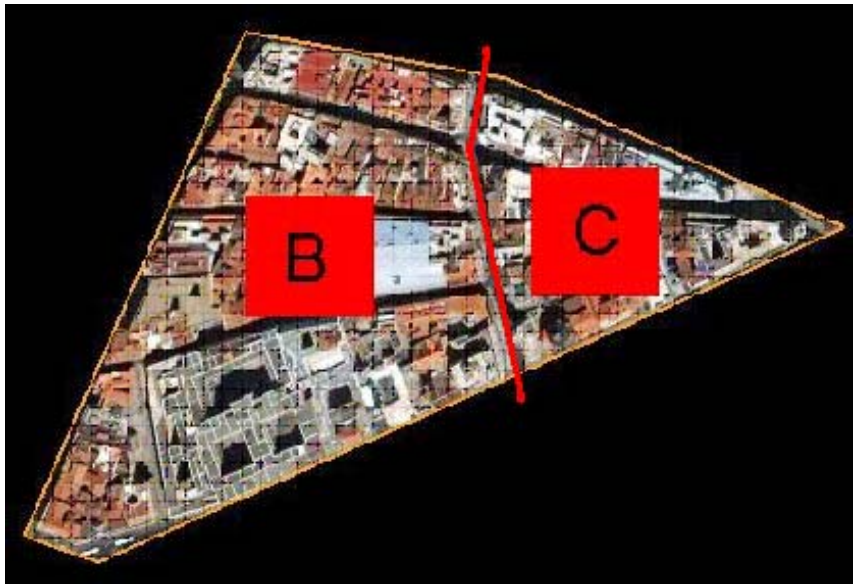
- When a tuple is divided, a rule is created.
  - The rule consists of the tuple's geometry, its location, and the line (partition) that divided it.
  - A rule has 2 children, either more rules or terminals.
- If a tuple cannot be divided anymore, it is a terminal (0 children).

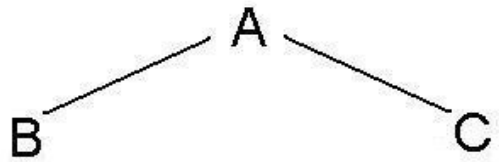
Parsing the City



A

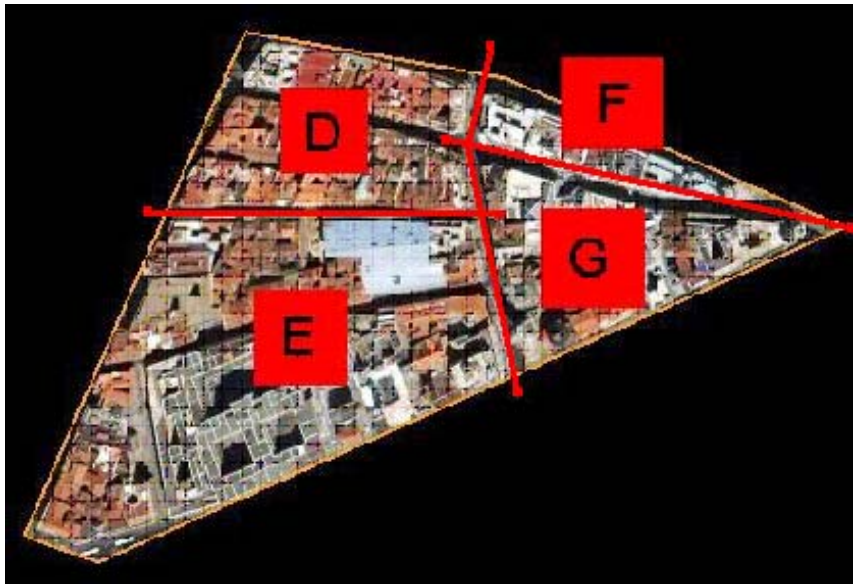
Parsing the City

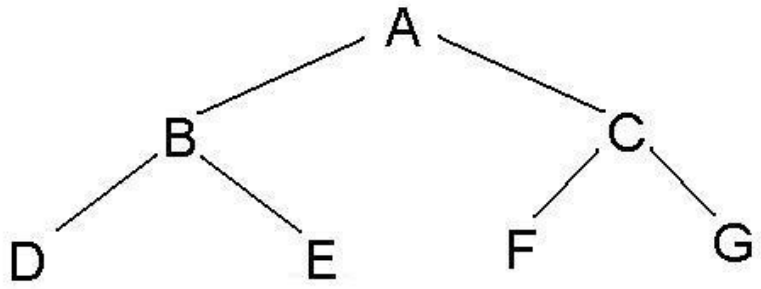




$A \rightarrow BC$

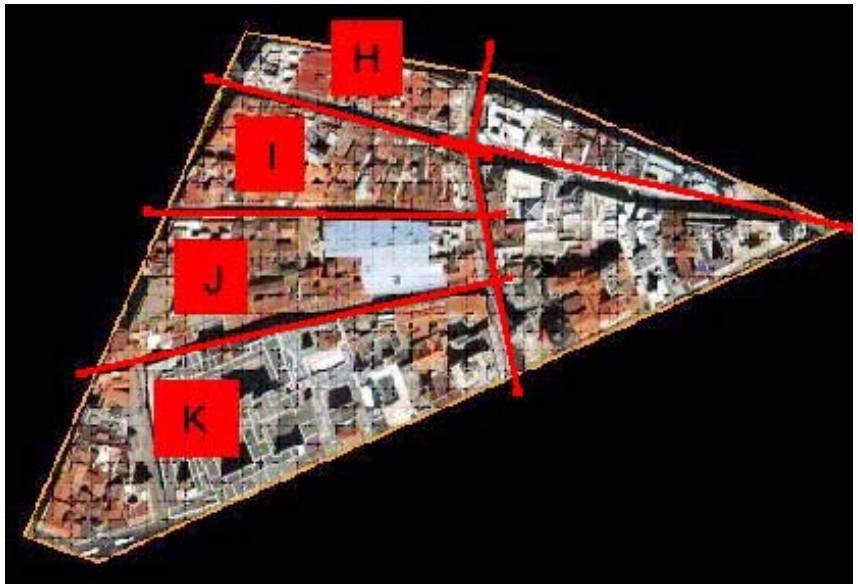
Parsing the City

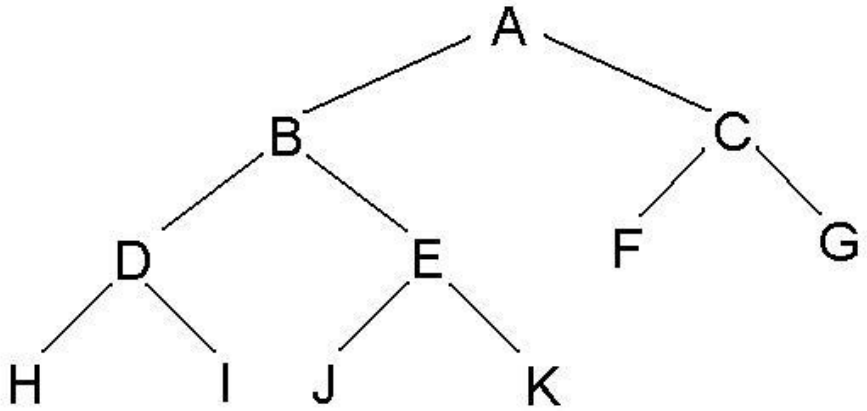




A → BC
B → DE
C → FG

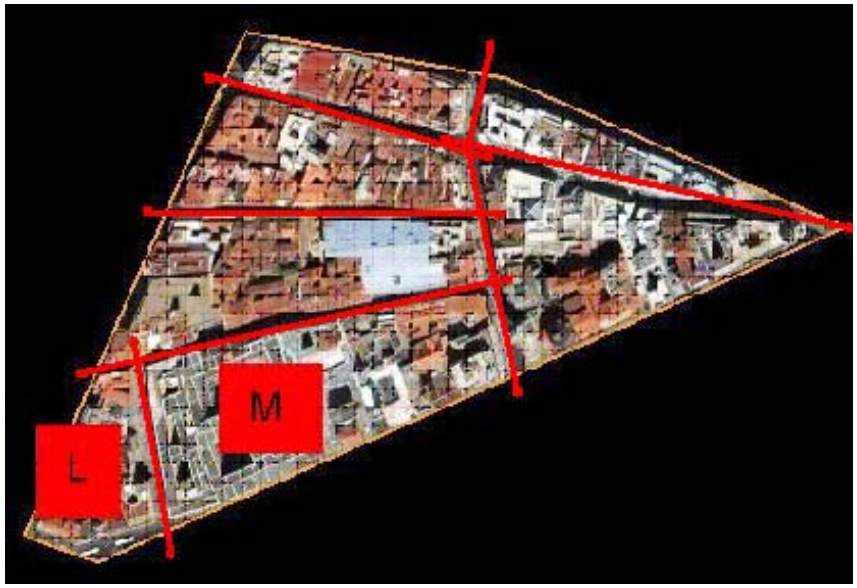
Parsing the City

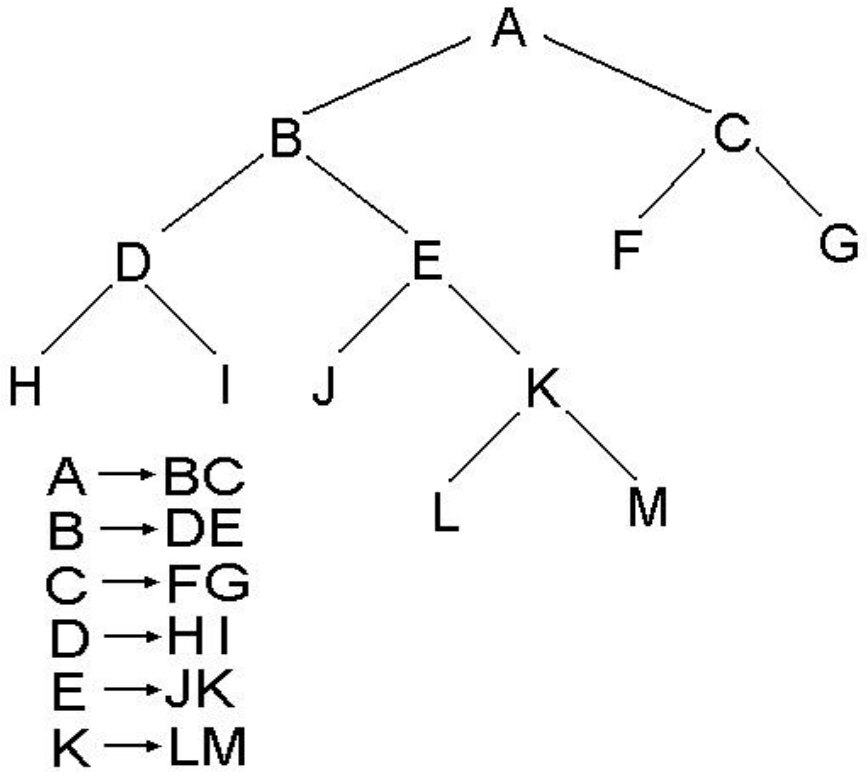




A → BC
B → DE
C → FG
D → H I
E → JK

Parsing the City



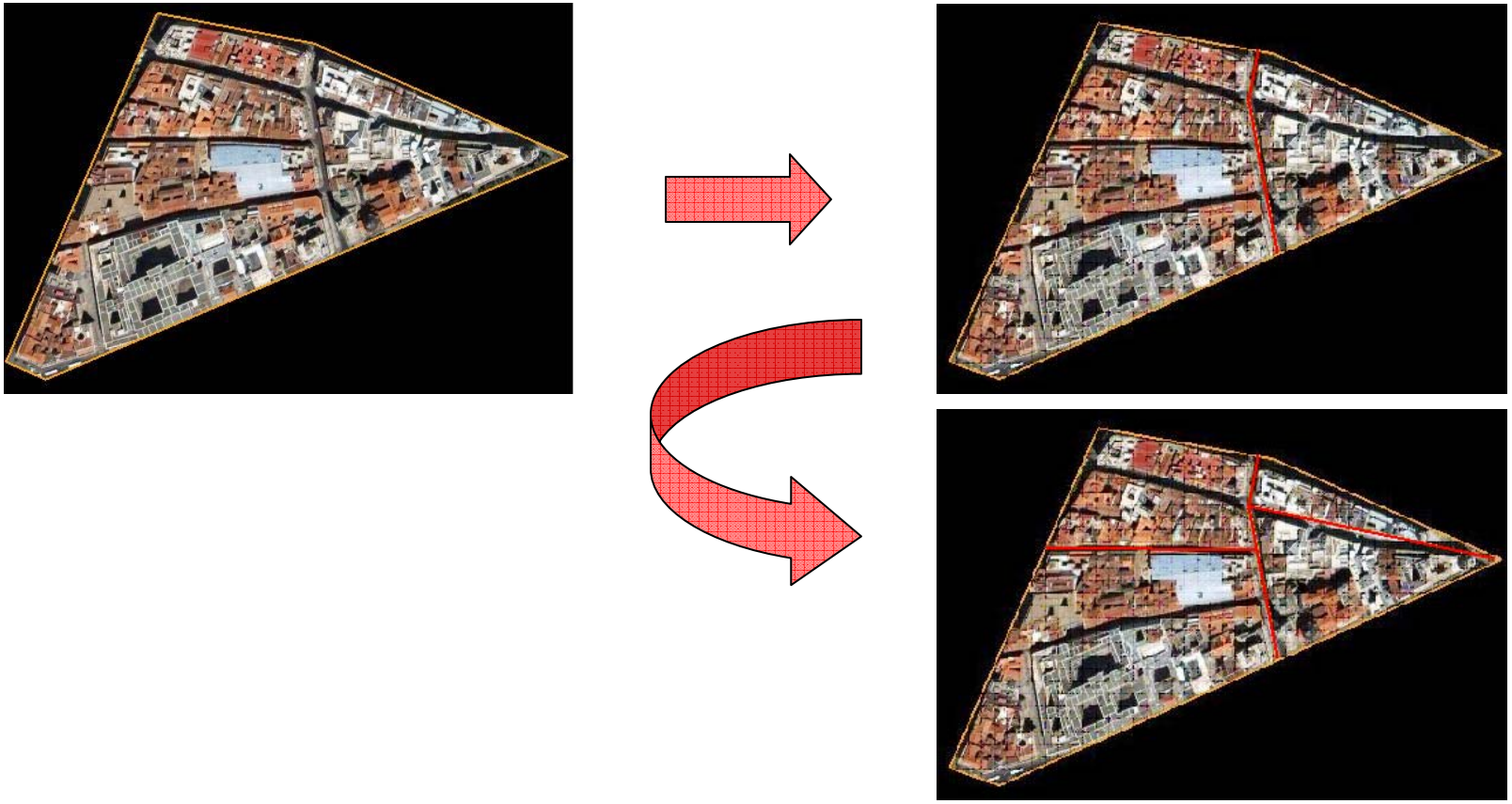


A → BC
B → DE
C → FG
D → H I
E → JK
K → LM

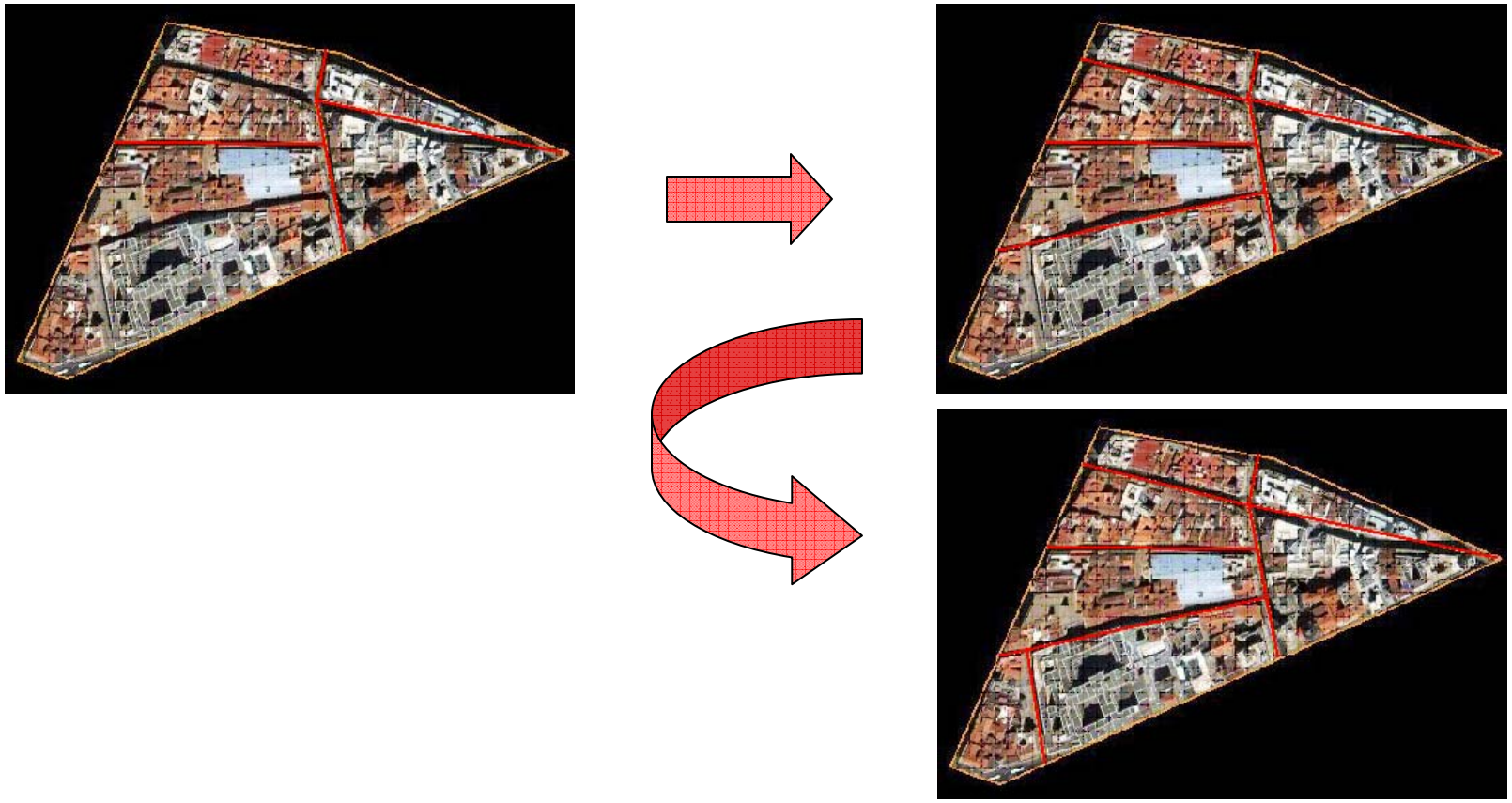
Deriving an Edited City

- If a region appears to have stretched or shrunk a significant amount, find the number of times to apply a rule so that distortion is minimized.
  - Note: an unmodified city's derivation should be the same as the original specification.

Deriving an Unmodified City

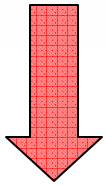


Deriving an Unmodified City



Stretch in 1D

Original

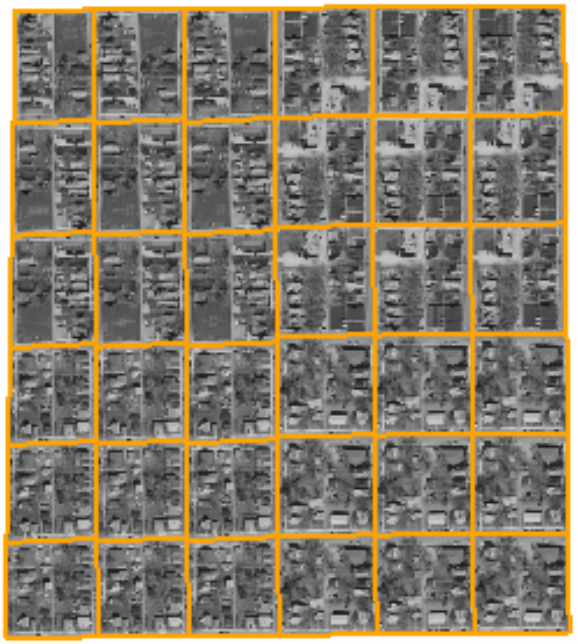


Scaled width by 3

Stretch in 2D

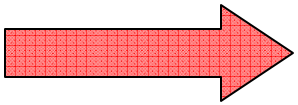
Original

Scaled by 3



Stretching Rome

Original



Scaled by 3

Reducing Distortion

- Granularity
  - If a region is stretched, we can choose to only apply the partition once.
  - This passes the work of further dividing the tuple onto the next rule in the tree.
- Terminal Matching
  - Find a terminal that best fits a given area.

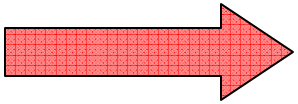
Granularity Example

- Original Method

Undivided Stretched Region

Original Region

Stretch



After application of first rule

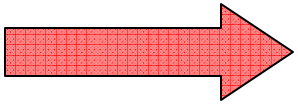
Result after application of next rules

Granularity Example

- Work pushed to terminal level

Original Region

Stretch

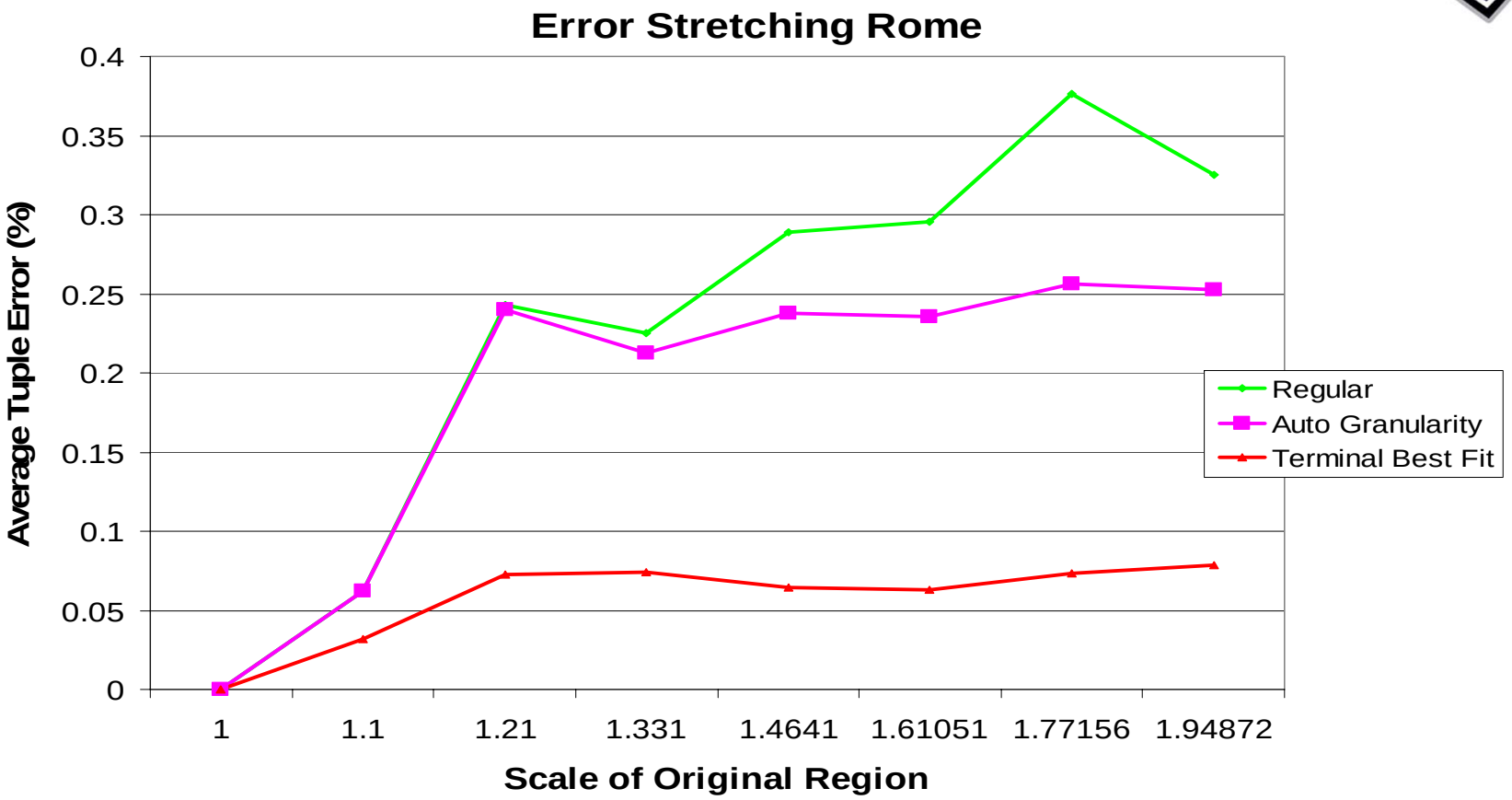


After application of first rule

Result after application of next rules

Comparison of previous method

Reducing Distortion



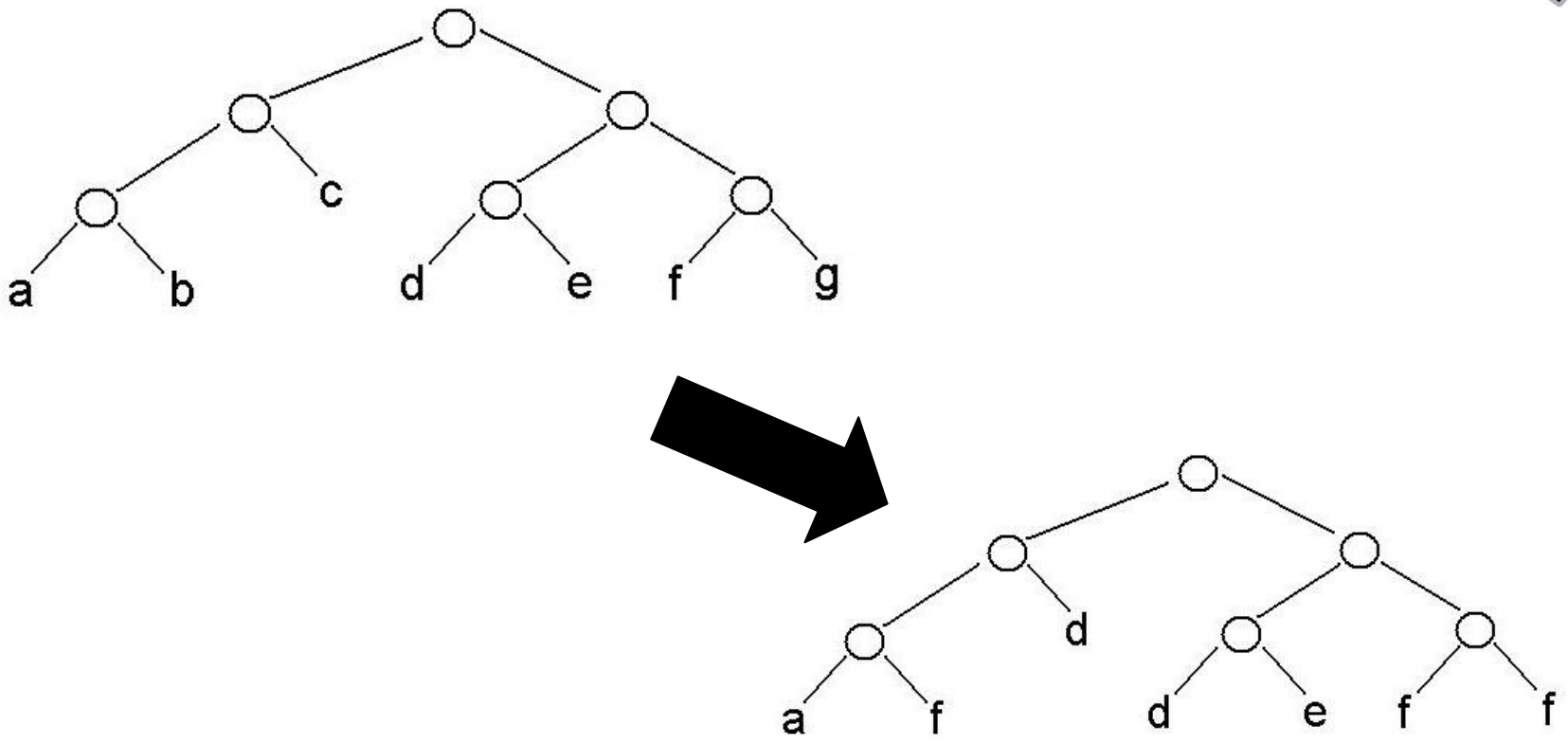
Urban Simplification

- Motivation
  - Want to have interactive rates.
    - For large cities we may have hundreds of thousands of terminals and hundreds of thousands of rules.
    - Displaying every unique terminal may tax the GPU.
  - Want to extrapolate interesting data from each city.
- Solution
  - These problems can be solved by simplifying the parse tree.

Terminal Simplification

- Group tuples that are similar to each other.
- Designate one (or more) tuples of the group to be used whenever a terminal is needed from the group.

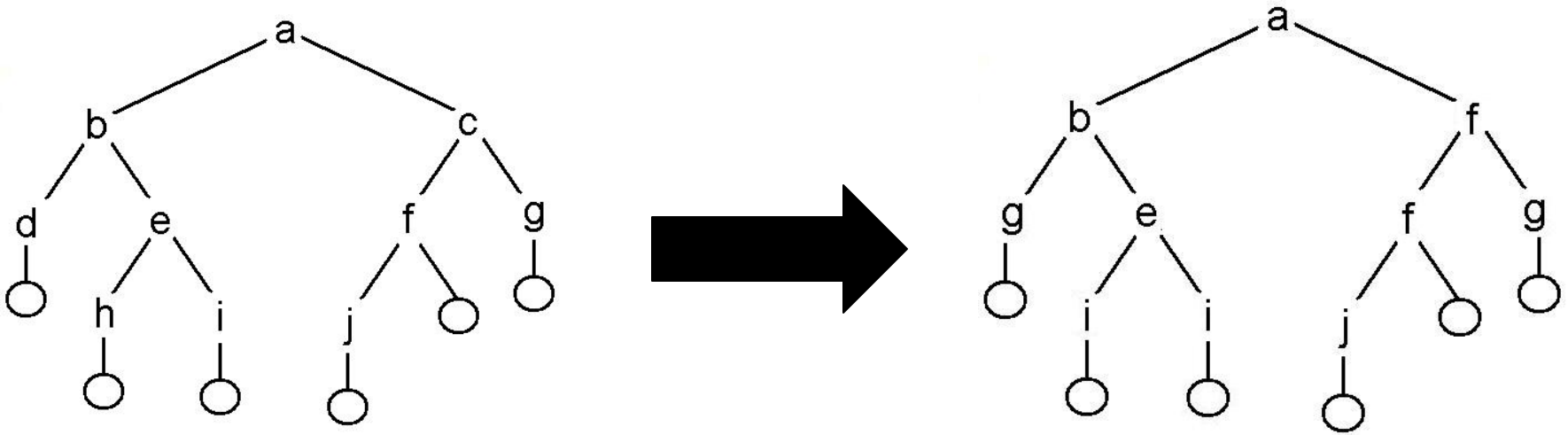
Terminal Simplification



Terminal Simplification

Procedural Simplification

- Combine rules that are similar.
  - Are the tuples similar?
  - Are the partition lines similar?



Procedural Simplification

1000 Rules

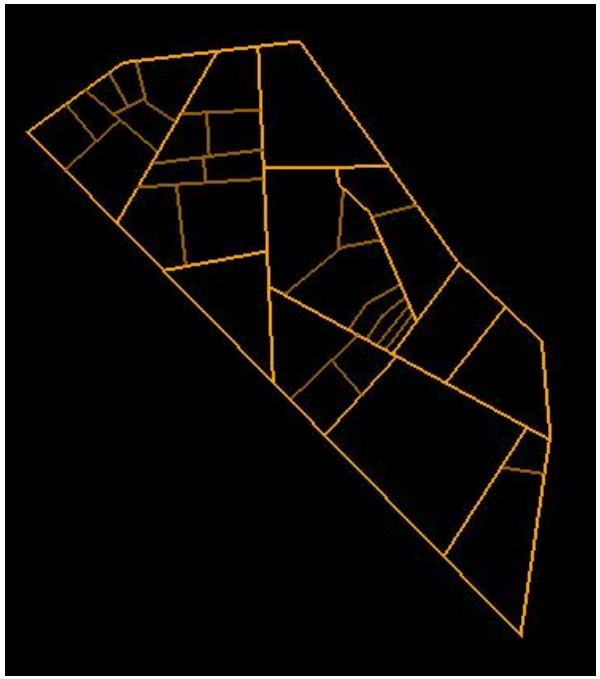
A → BC
B → DE
C → FG
…
X → YZ
…

5 Rules

A → DN
D → LK
N → TX
L → QR
Q → YZ

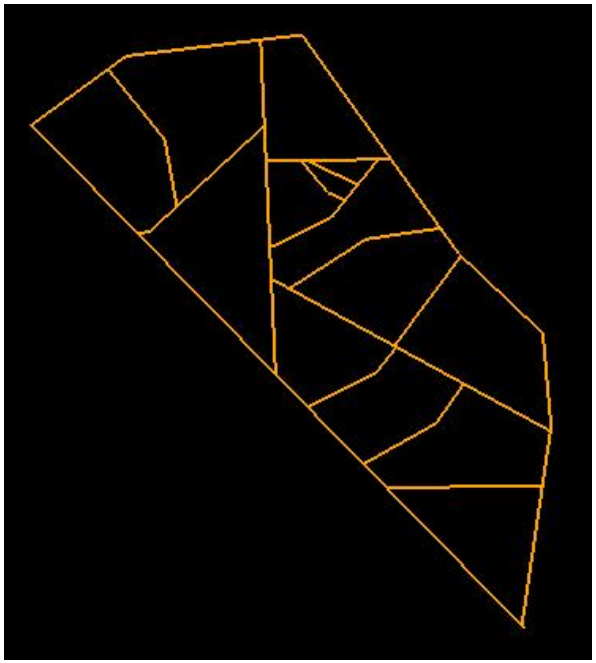
Procedural Simplification

30 Rules



Rome

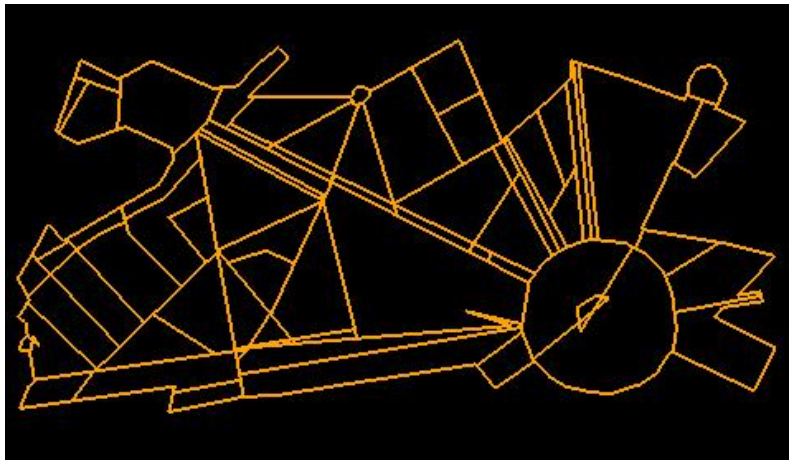
10 Rules



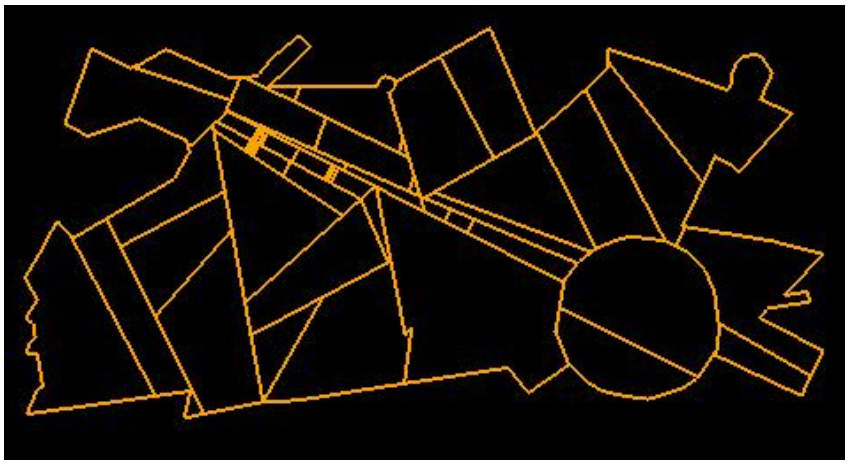
Procedural Simplification

Paris

77 Rules



19 Rules



Procedural Simplification

Buenos Ares

130 Rules

38 Rules

Tools

- Similarity Estimation
- N-gon mapping

Similarity Estimation

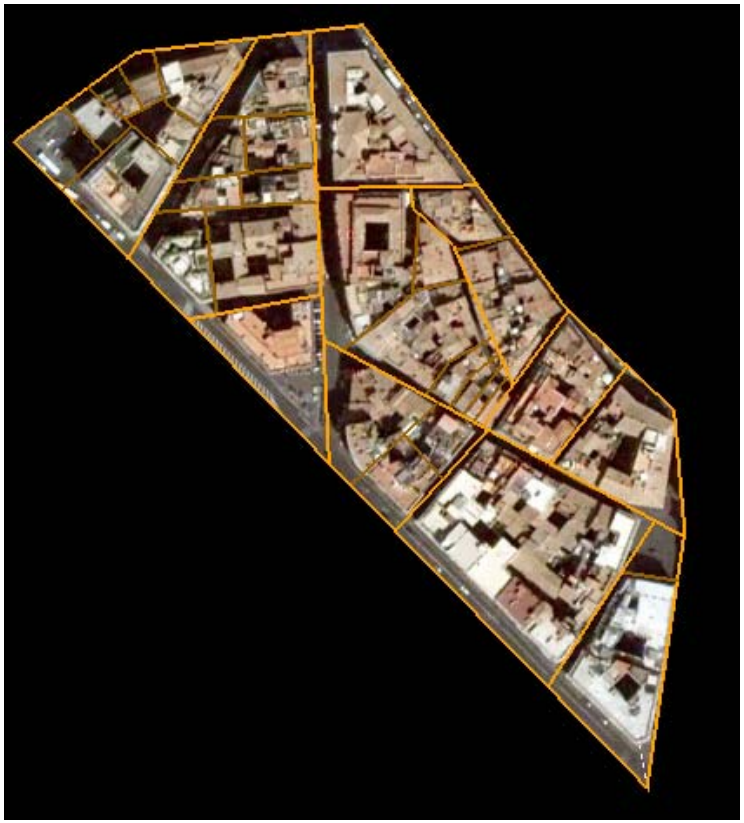
- Tuple similarity is a weighted combination of:
  - Shape/perimeter similarity.
  - Location similarity.
  - Size/radii similarity.

- Partition similarity is a weighted combination of:
  - Length similarity
  - Orientation similarity

Tuple Shape Similarity

- Use oriented bounding boxes.
  - Simplifies the computation to the comparison of two boxes.
  - Improved reliability over old method.

Oriented Bounding Box



Oriented Bounding Box

N-gon mapping

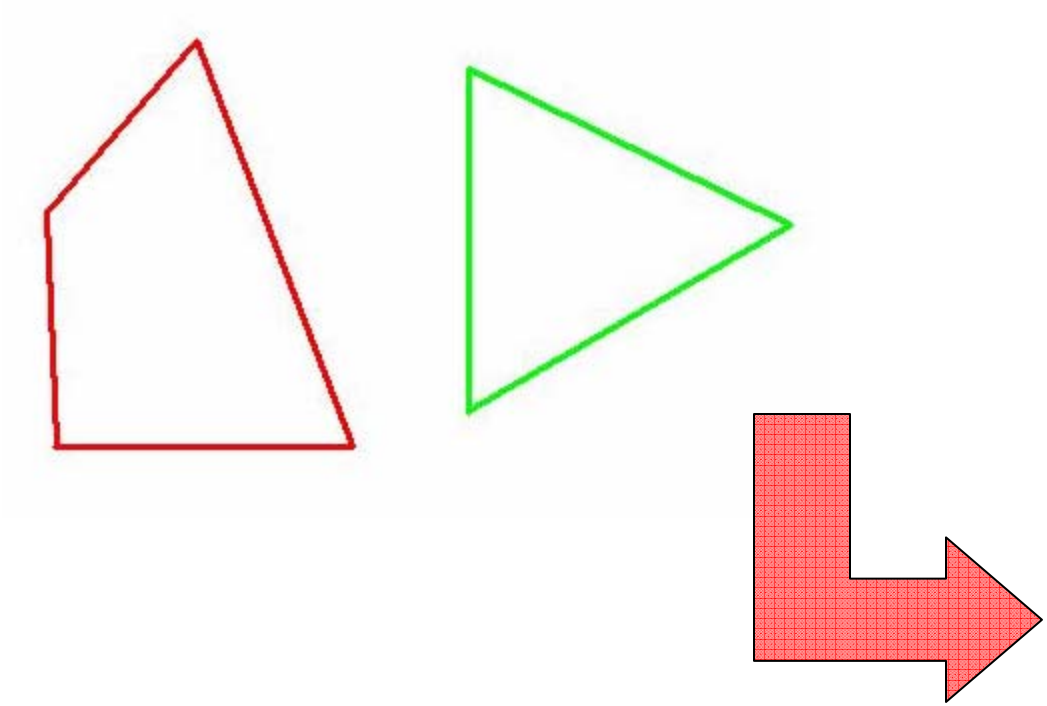
N-gon to M-gon mapping

- New tuples are derived that do not match the original tuples geometry.
- Can you map a hexagon to a square? Should this be allowed?
- Can we prevent tough cases by obtaining better derivations?

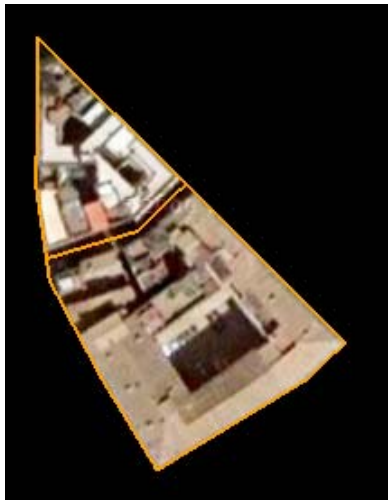
N-gon mapping

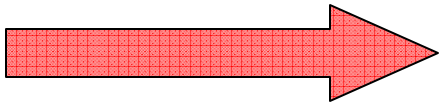
- Let N > M
  - Since the vertices of the n-gon contain the needed texture coordinates, only use those.
  - Map the M vertices of the m-gon plus (N-M) intermediate points.
  - Intermediate points are obtained by projecting the n-gon's vertices onto the m-gon's perimeter.
  - Rotate and scale to find a best fit.

Simple example

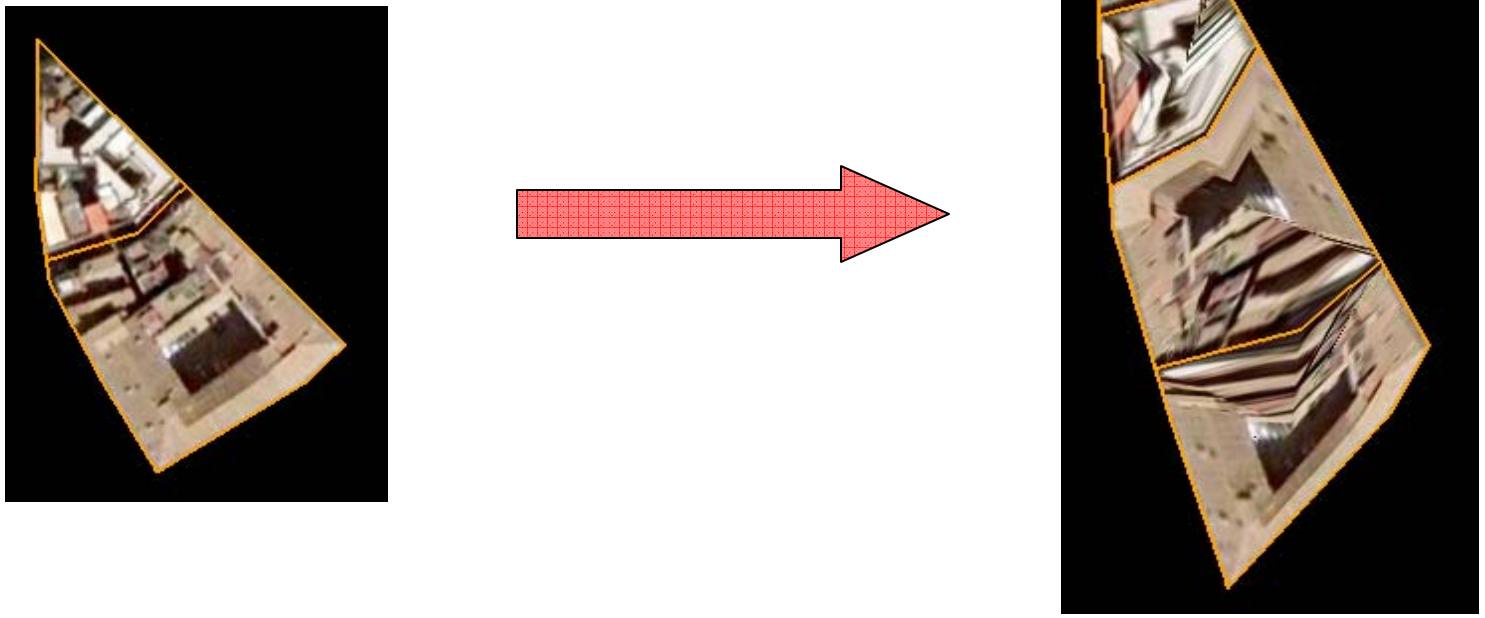


In the program

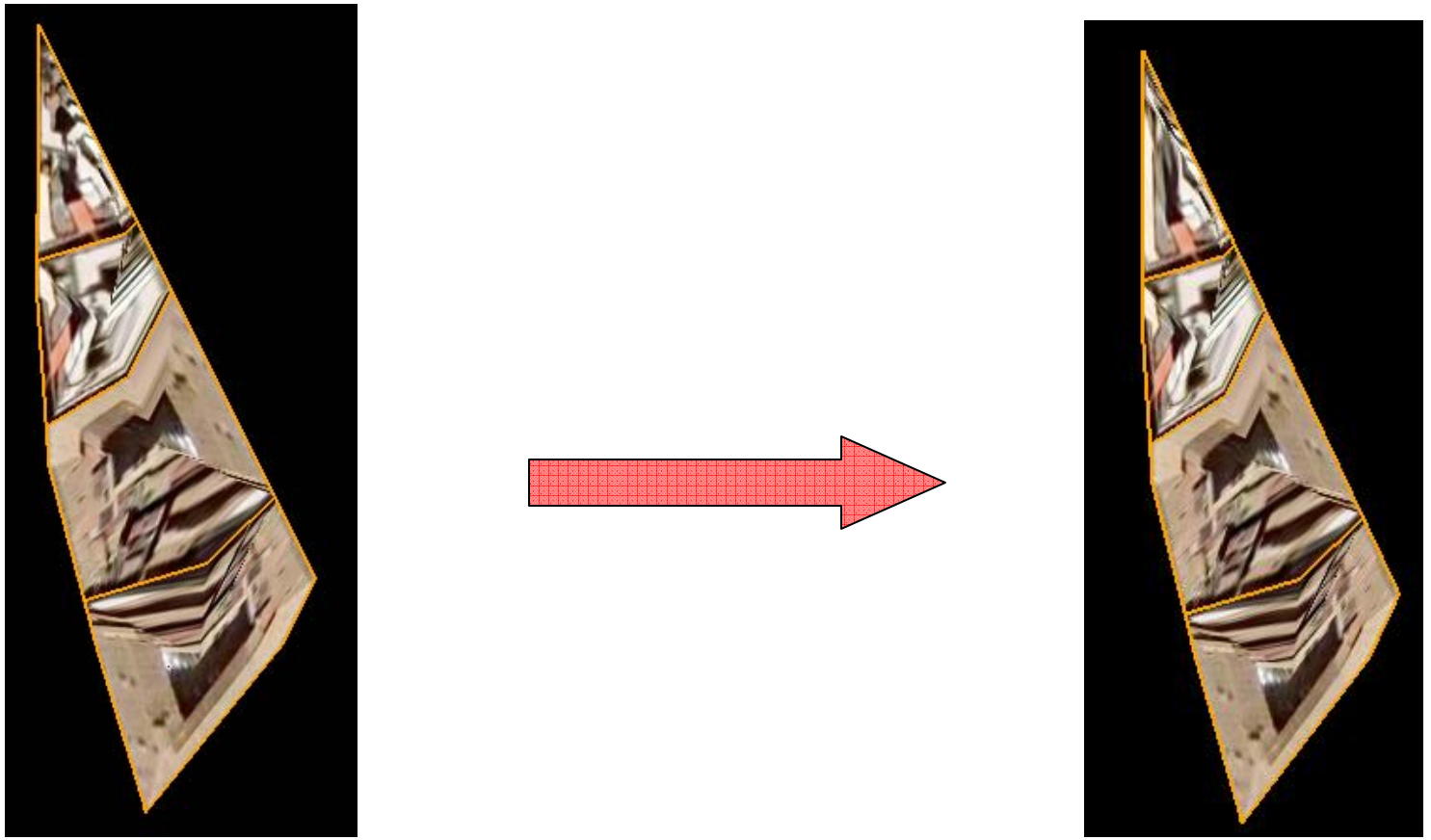




Stretch more



More Stretching



Problems

- For more complex scenes, the mapping looks even worse.
- Can still get seams in the texture.

Future Work

- Can you combine the layouts of two cities?
  - What would it look like if Lafayette wanted to incorporate the layout of Paris.
- Apply the framework to other images.
  - What might a famous painting look like if the artist had used a bigger canvas?
- Integrate with Build-by-Numbers to procedurally create full 3D cities.

Questions?