Towards Semantic City Models

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The VarCity ERC Advanced Grant

erc
European Research Council
Established by
the European Commission

- VarCity = Variation & the City
- 5-yr project
- Goal: modeling existing cities in 4D, realistically, incl. the static and dynamic parts
- Emphasis is on adding and exploiting semantics

Envisaged pipeline

1. Camera-only mobile mapping -> 3D pt cloud/surfaces
   (+ additional internet-mined images for landmarks)
   this we have developed in the past, is operational

2. Recognition of urban object classes, e.g. people,
   cars, buildings, vegetation, traffic signs, …
   partially solved, we work on better scalability

3. Inverse procedural modeling
   our lab is experienced with forward procedural modeling
   issue: needs a style grammar, we focus on its automated learning

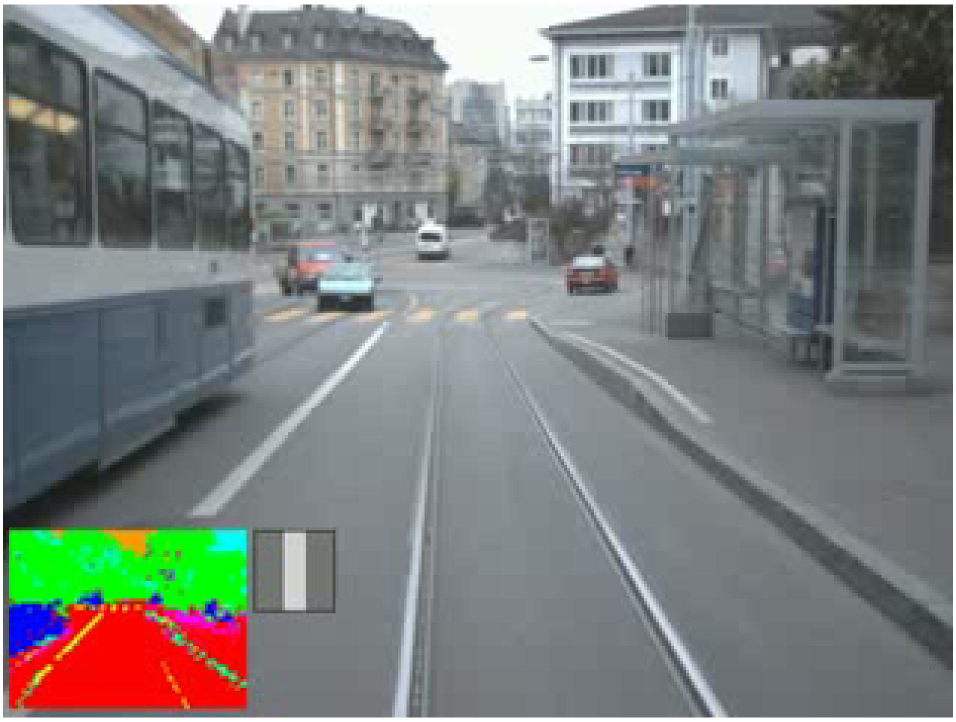
4. Adding dynamics: analyze traffic flows from intermittent data
   again recognition of cars, pedestrians, etc. is a key element

MOBILE MAPPING

Mobile mapping

RECOGNITION

semantic street scene analysis

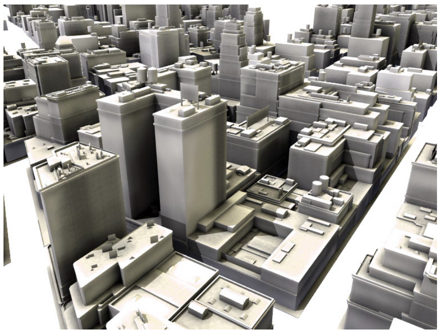


3D & recognition: mutual benefits

- A recent feat in computer vision: object class recognition, very useful *per se*…
- 3D information can strengthen such recognition.
- At least as importantly: recognition can support 3D acquisition.
- Here: 3D pt clouds, style grammars, & object detectors -> inverse procedural modeling

INVERSE PROCEDURAL MODELING

procedural modeling



Procedural modeling using rules

Id : predecessor : cond ⟶ successor : prob

- *id*: rule identifier
- *predecessor*: shape to be replaced (refined)
- *cond*: condition for the replacement to happen
- *successor*: new (refined) shape
- *prob*: probability of this rule to be applied

procedural modeling

```
building ⇢ SplitY{ columns | entablature | I(roof) }
sanctuary

columns ⇢ RepeatX{ column }
column ⇢ SplitY{ base | shaft | capital }
base ⇢ I(corinthian_base)
shaft ⇢ S I(corinthian_shaft)
capital ⇢ I(corinthian_capital)

entablature ⇢ SplitY{ architrave | frieze | cornice }
architrave ⇢ RepeatX{ I(architrave_tile) }
frieze ⇢ I(frieze)
cornice ⇢ RepeatX{ I(cornice_tile) }

sanctuary : orient == front ⇢ SplitXY{ wall | wall | wall ¦
                                       wall | I(door) | wall }
sanctuary ⇢ wall
wall ⇢ I(quad)
```

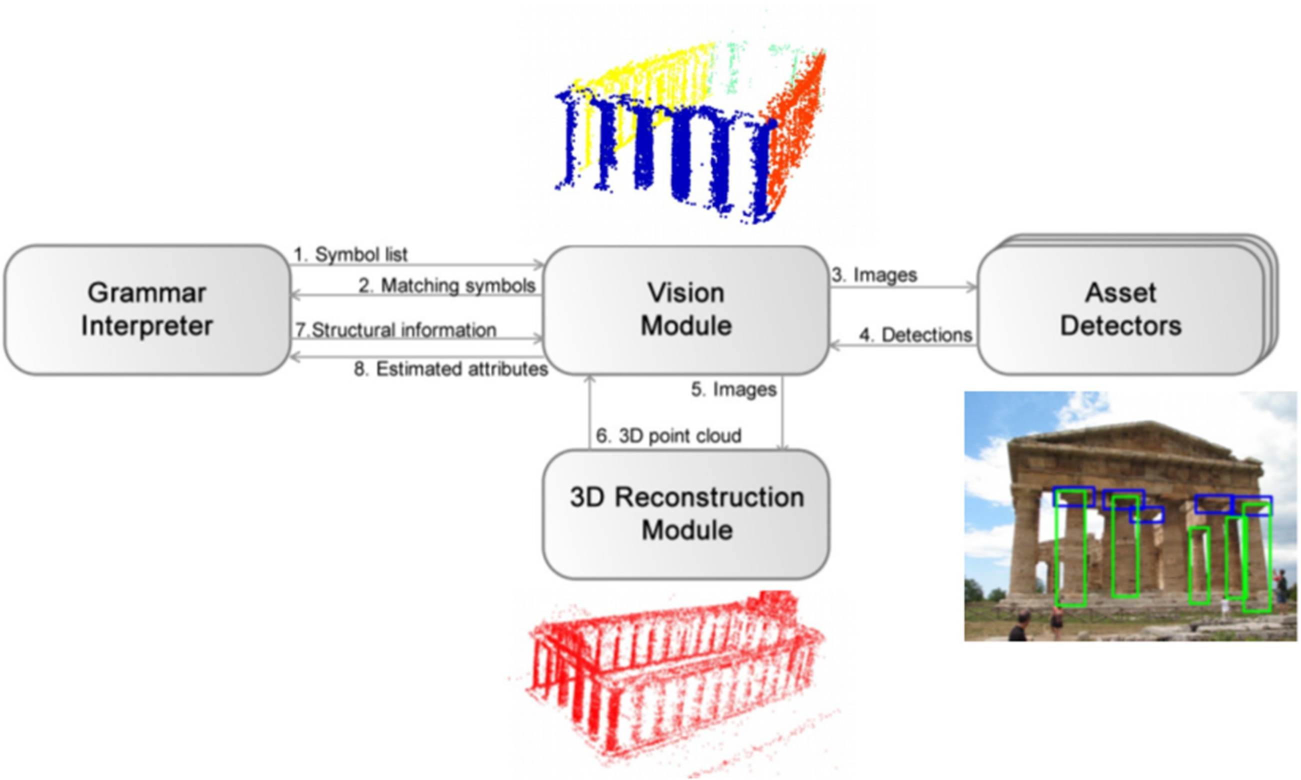
Procedural modeling

Inverse procedural modeling

Our automated pipeline contains:

- Structure-from-motion from images -> 3D pt cloud basically *bottom-up*
- Style-grammar interpreter basically *top-down*
- Building component detectors: this *mid-level* input avoids fragile bottom-up segmentation errors and is a catalyzer between bottom-up and top-down processes

Inverse procedural modeling



Inverse procedural modeling

Inverse procedural modeling

- Style grammars are non-trivial to produce
- and the resulting optimization spans a large space
- … so, is it wise to consider them in the first place?

Inverse procedural modeling

- Procedural models are compact
- and are semantic in nature
- and can produce more realistic visualizations
- and cut down on the pt cloud completeness needed
- and provide robustness to start from generic detectors and learn more dedicated ones on-the-go

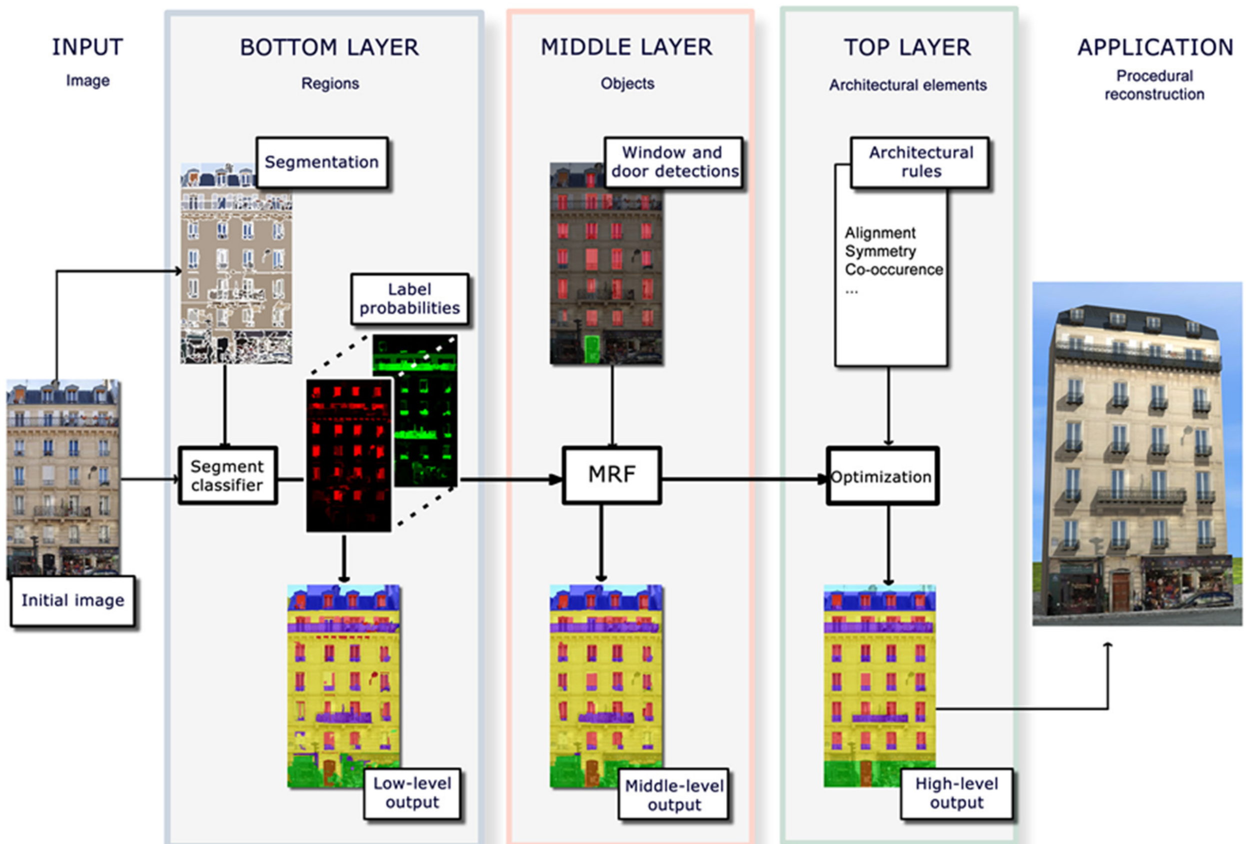
Inverse procedural modeling

- Note that we knew the style – hence appropriate grammar – in advance
- Not scalable if a human needs to tell the style of every single building, as with 3D city modeling
- Therefore we developed style classifiers (a current limitation is their focus on planar, i.e. façade oriented features; but expandable to 3D)

Inverse procedural modeling

- Also when styles are automatically recognized, creating many style grammars remains non-trivial
- And buildings may be of yet another style or a mixture of styles…
- Hence, we need to automatically learn style rules … or to at least start from more generic ones

inverse procedural modeling



inverse procedural modeling

Left: textured plane;
Right: semantic-guided visualisation, looks better and is more compact

Inverse procedural modeling

- User-generated grammar rules may only indirectly describe regularities of the *observed* structures.
- Our generic rules directly target observed structures though
- … and they are used as guidelines and not strict rules
- Our ongoing work extracts style-specific rules from such façade segmentations automatically, which can take the form of lists of rules & probabilities, which need not be human-readable