A top-down construction scheme for irregular pyramids

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2. Recalls
3. A top-down model
4. Operations
5. Results
6. Conclusion and perspectives

Framework

Application

- FoGrImMi project
- Very large medical images (30GB)
- Image processing and segmentation

Requirements

- Image representation
- Segmentation and manipulation of regions
- Focus of attention over interesting areas

Definition of a data structure

- Topological: process regions
- Hierarchical: multi-resolution images
- Top-down: limit memory requirements

Timeline

Model		**Drawbacks**
Quadtrees Regular pyramids	⇒	Segmentation problems
Irregular pyramids	⇒	Only bottom-up constructions

⇒ Definition of a top-down and topological framework for irregular pyramids

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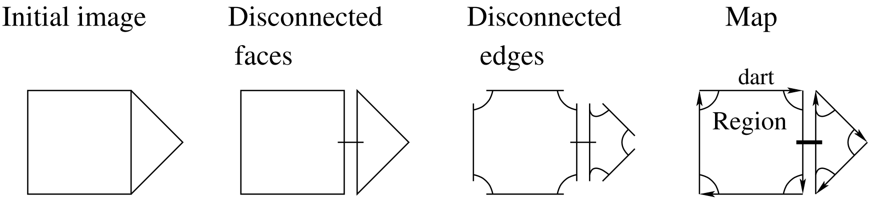
Combinatorial maps



Notions

- Dart: $\sim$ half-edge
- β_1 permutation: turns around a face
- β_2 involution: gives the other orientation of the edge

Topological maps

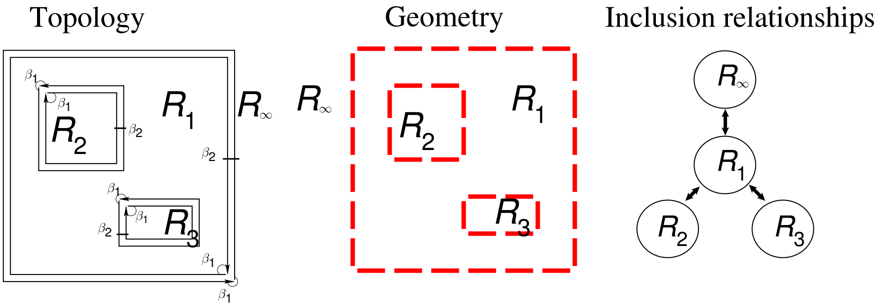
Requirements

- Represent any partition
- Describe adjacency and inclusion relationships
- Efficient processing algorithms

Combination of models

- Minimal combinatorial map (topology representation)
- Interpixel matrix (geometry information)
- Tree of regions (inclusion relationships)

Topological maps



Topology

Geometry

Inclusion relationships

Model features

- Complete (topology and geometry)
- Minimal (number of cells)
- Unique (same partition ⇔ same map)

Pyramids

Simple graph pyramids

- Stack of successively reduced graphs
- Difficult to update after operations

Combinatorial pyramids

- Stack of successively contracted combinatorial maps
- Only bottom-up models
- Whole initial partition encoded

Top-down pyramids

- Only encode upper levels
- Focus of attention: adjust segmentation from first discernable features

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Goals and definitions

Goals

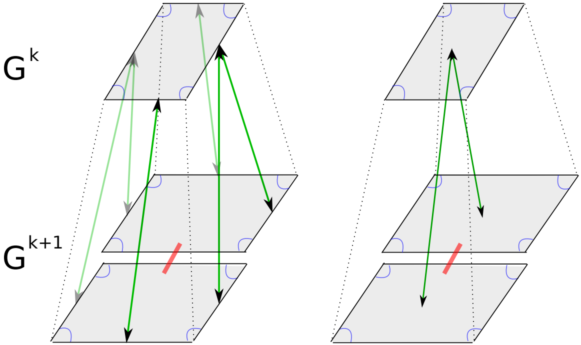
- Top-down topological model
- No explicit encoding
- Causal structure
- Easy update of the model after splitting

Definitions

- Pyramid $\sim$ stack of linked topological maps
- A level k is deduced from $k-1$, applying splitting operations

The hierarchical data structure

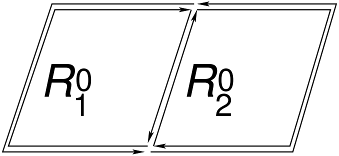
Up/Down relations:



Between darts

Between regions

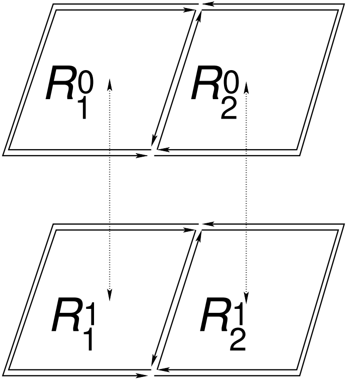
Global construction process



Main steps

- Create first map G^0

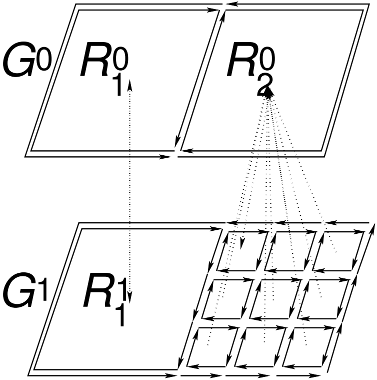
Global construction process



Main steps

- Create first map G^0
- G^1 is a copy linked to G^0

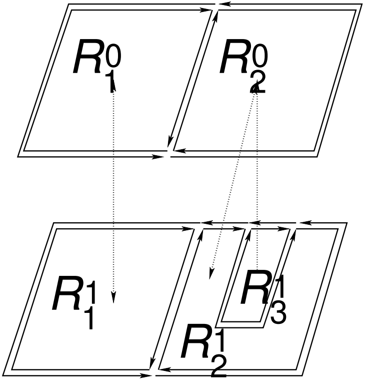
Global construction process



Main steps

- Create first map G^0
- G^1 is a copy linked to G^0
- Split G^1

Global construction process



Main steps

- Create first map G^0
- G^1 is a copy linked to G^0
- Split G^1
- Merge G^1

Duplicating a level

for each dart in G^m

- create a copy in G^{m+1} $\Rightarrow$ geometry
- link it with G^m $\Rightarrow$ up/down relations (darts)
- β_1 and β_2 sewing $\Rightarrow$ topology

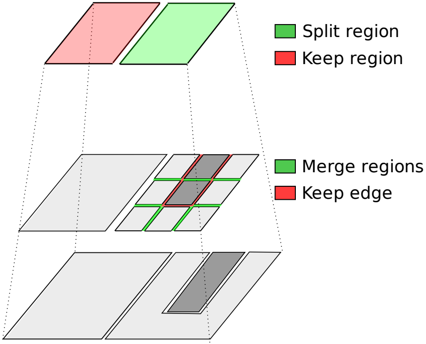
for each region in G^m

- create a copy in G^{m+1} $\Rightarrow$ adjacency relations
- link it with G^m $\Rightarrow$ up/down relations (regions)
- fill in region relations $\Rightarrow$ tree of regions

Refining a level

Algorithm 1: Refining

```
foreach region $R \in G^k$ do
    if splitting criterion(R) is true then
        Split($R$);
Merge($G^k$, merging criterion);
Simplify the map;
```



Splitting criterion: selects one region for burst

Merging criterion: operates on a couple of regions with the same parent

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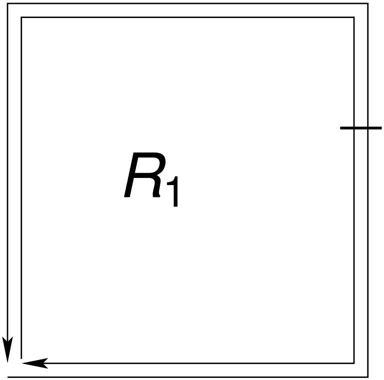
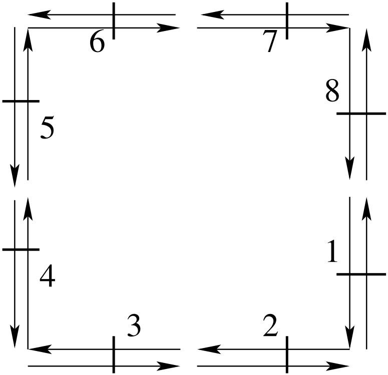
Splitting operation



Key points

- Initial region

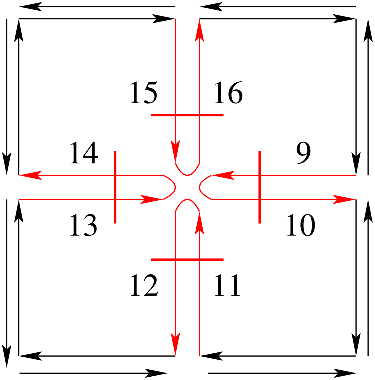
Splitting operation



Key points

- Initial region
- Split edges

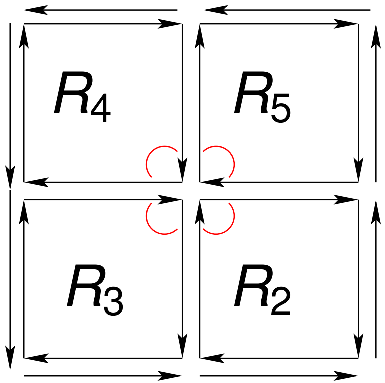
Splitting operation



Key points

- Initial region
- Split edges
- Insert dangling edges

Splitting operation



Key points

- Initial region
- Split edges
- Insert dangling edges
- Sew darts

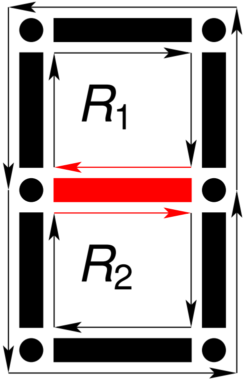
Splitting Operation

Burst method involvements

- create one region/pixel
- costly

⇒ But it is necessary to traverse all pixels to compute colorimetric information on new regions

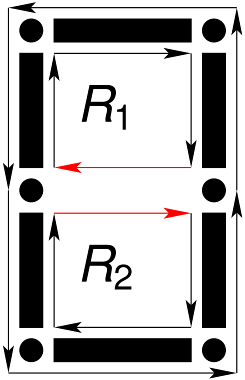
Merging Operation: general case



Key points

- Initial regions

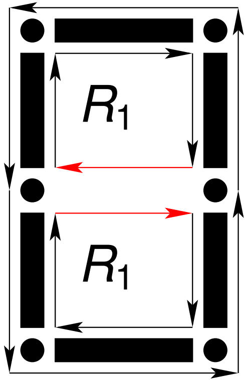
Merging Operation: general case



Key points

- Initial regions
- Turn off geometry

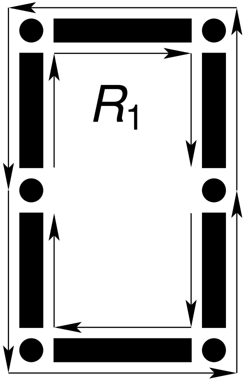
Merging Operation: general case



Key points

- Initial regions
- Turn off geometry
- Relabel darts

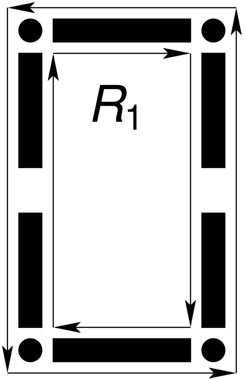
Merging Operation: general case



Key points

- Initial regions
- Turn off geometry
- Relabel darts
- Remove darts

Merging Operation: general case



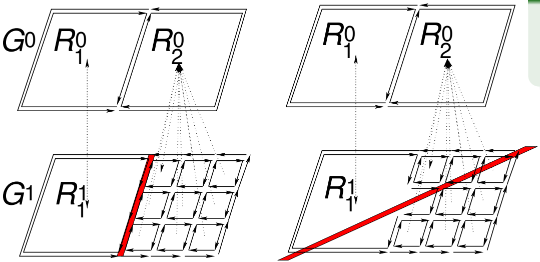
Key points

- Initial regions
- Turn off geometry
- Relabel darts
- Remove darts
- Result (after simplify)

Merging Operation: constraint

Constraint

Only merge regions resulting from the splitting of a same parent



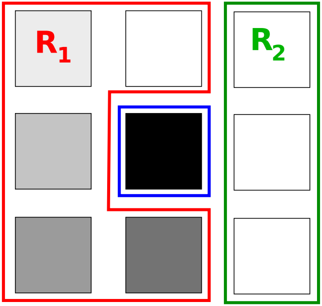
Test

Does the shared edge have a parent ?

Merging Operation: particular case

Multiple adjacency

Merging can be independent of criterion in multi-adjacency situations



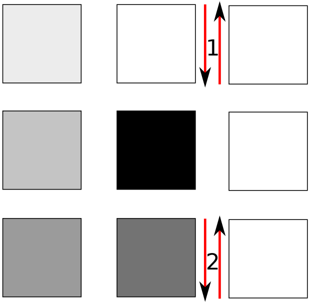
Steps

Multi-adjacency between R_1 and R_2

Merging Operation: particular case

Multiple adjacency

Merging can be independent of criterion in multi-adjacency situations



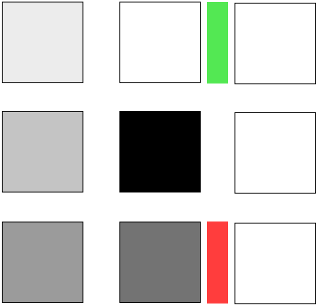
Steps

Shared edges

Merging Operation: particular case

Multiple adjacency

Merging can be independent of criterion in multi-adjacency situations



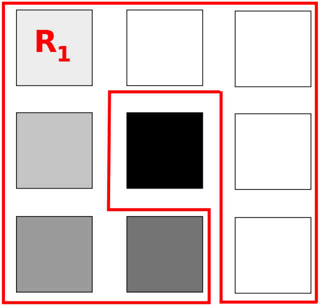
Steps

Merging criterion

Merging Operation: particular case

Multiple adjacency

Merging can be independent of criterion in multi-adjacency situations



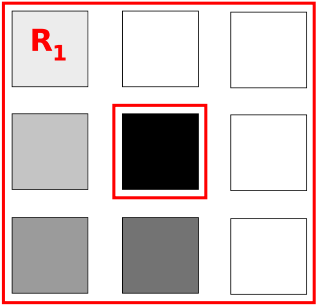
Steps

Remove edge 1

Merging Operation: particular case

Multiple adjacency

Merging can be independent of criterion in multi-adjacency situations



Steps

Remove edge 2

Properties

Preserves causality

- each element of G^k has *at least* one descendant in G^{k+1}
- each element of G^k has *at most* one antecedent in G^{k-1}

Encode any partition

- unrestricted merging within the region burst results
- any connected set of pixels may be group into a region
- splitting does not depend on an initial geometrical pattern

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Experiments

Preliminary results with basic segmentation criteria

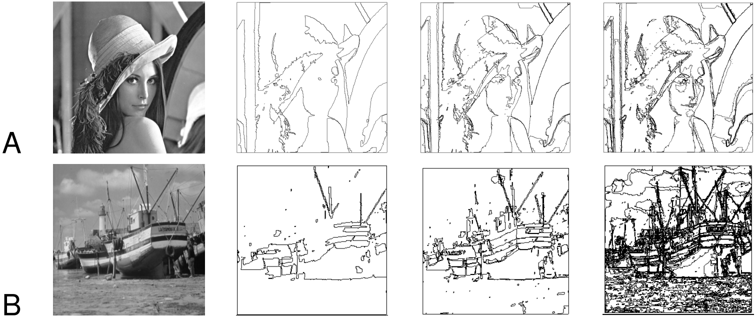

Figure: (A) standard-deviation based segmentation; (B) gray levels comparison;

Statistics

	G^1	G^2	G^3
Number of darts	600	7 728	19 090
Memory occupation (KB)	306	808	1 604
Total level construction time (s)	3.11	2.05	1.94

Table: Top-down construction applied to the Lena image (512*512)

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Conclusion

- Topological maps extended to a top-down hierarchical model
- Applicable implementation with basic criteria
  - compare average gray level
  - refine following the homogeneity of the mother region
- Core operations defined for:
  - level segmentation
  - topology modification

Perspectives

- Improve segmentation aspect
  - develop optimized criteria
- Improve splitting algorithm
  - avoid burst method (one region/pixel)
- Change geometry encoding
  - replace the actual explicit encoding
- Define a tiled structure for each level
  - manage memory by swapping tiles on disk