

Extraction of tiled top-down irregular pyramids from large images

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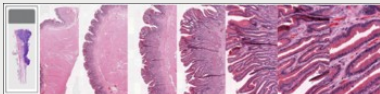
- 1 Introduction and Context
- 2 Definition of a Tiled Topological Model
- 3 Application and Segmentation
- 4 Conclusion and Perspectives

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Context

Application

- ANR Project FoGrImMi: Search Through Large Microscopic Images
- Medical imaging (histology, cytology)
- Whole Slide Imaging for microscopical images
- Large multi-resolution images (30GB)



Requirements: efficient tools for automatic analysis and processing of very large images.

Objectives

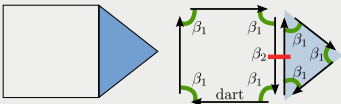
- Define a top-down topological model
- Efficient update after splitting operations
- Hierarchical structure complying with causality principle
- Memory usage

Constraints and proposed solutions

- Topological properties
⇒ combinatorial maps
- Multi-resolution images
⇒ hierarchical model
- Very large images
⇒ top-down construction

Combinatorial and Topological Maps

Combinatorial maps

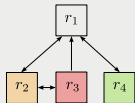


- Dart: \sim half-edge
- β_1 permutation: turns around a face
- β_2 involution: opposite face

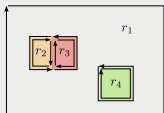
Topological maps



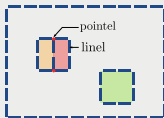
Original image



Tree of regions



Topology



Geometry

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

Framework for Irregular Combinatorial Pyramids

Definition

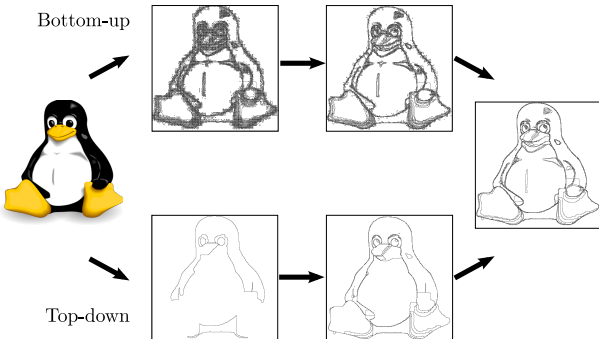
Stack of combinatorial maps successively transformed.

Bottom-up pyramids

- Main operation: merge
- Drawbacks:
 - encode the whole initial partition
⇒ high memory requirements

Top-down pyramids

- Main operation: split
- Advantages:
 - encode upper levels until given segmentation
 - focus of attention



Top-down Pyramidal Model

Definition

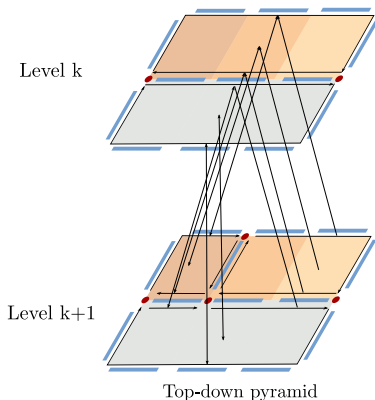
- Stack of topological maps
- Splitting operations from one level to another
- Up/down relations between darts and regions
- Causal structure

Construction

- Copy: level duplication
- Link: hierarchical relations
- Refine: splitting operation
 - use of segmentation criteria
 - splitting: creates one region/pixel
 - merging



Original image



Top-down Pyramidal Model

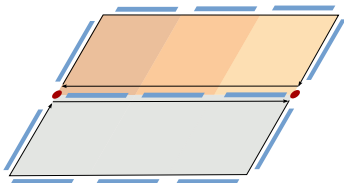
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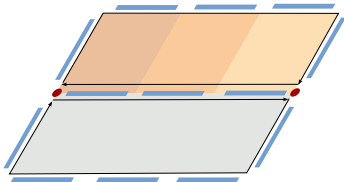
Construction

- **Copy: level duplication**
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Level k



Level $k+1$



Top-down Pyramidal Model

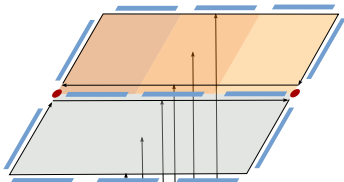
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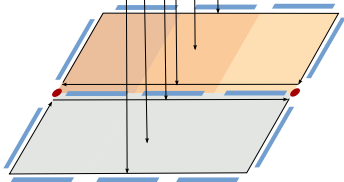
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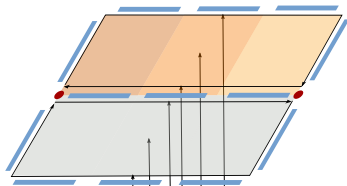
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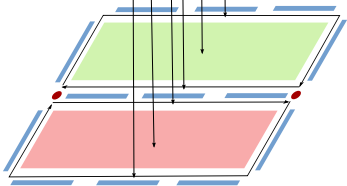
Construction

- Copy: level duplication
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Level k



Level $k+1$



 Split region = true

 Split region = false

Top-down Pyramidal Model

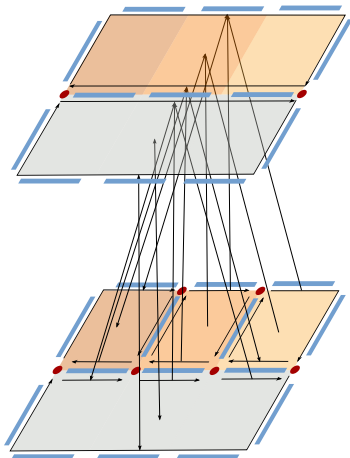
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 - **splitting: creates one region/pixel**
 - merging

Level k



Level k+1

Top-down Pyramidal Model

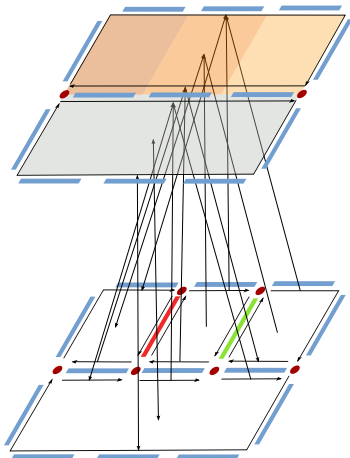
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 - merging

Level k



Level $k+1$

Merge region = true

Merge region = false

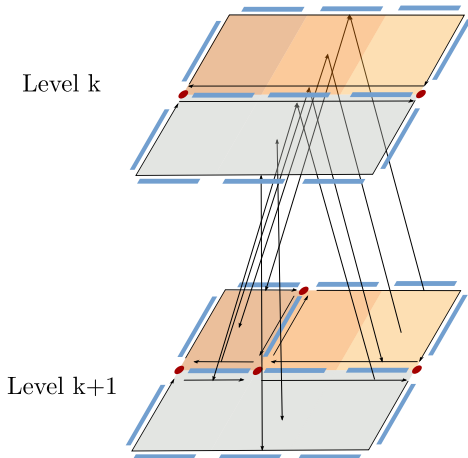
Top-down Pyramidal Model

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- Stack of topological maps
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 - **merging**



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Presentation

Constraint

- Top-down construction *only minimizes* memory
- Application requires a *bound* memory usage

Proposed solution

- Geometrical division of a map in topological tiles
- Insertions of fictive darts on the borders

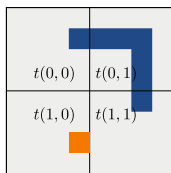
Integration in the pyramidal model

- New operator on darts for adjacent tiles connection
- Swap/load operations
- Incremental construction

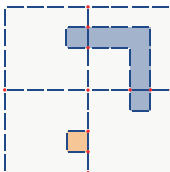
Definitions

Topological tile

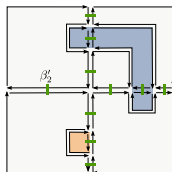
- Topological tile $t(i,j,k)$: partition of a geometrical subdivision (i,j) at level k
- $t(i,j,k+1)$ deduced from $t(i,j,k)$ by splitting operation



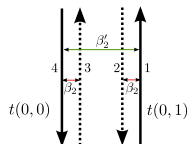
Tiled image



Geometry



Topology

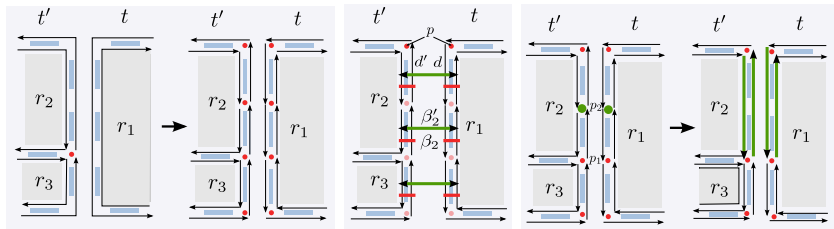


Borders

Tiled top-down pyramid

- Tiled top-down pyramid: set of topological tiles
- Local pyramid: set of tiles loaded in memory

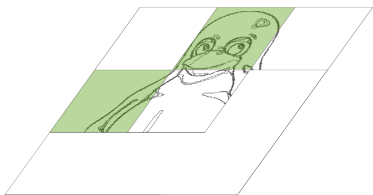
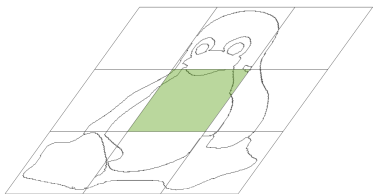
Connection of Adjacent Tiles



Main steps

- Splitting borders
 \Rightarrow ensures two adjacent tiles share the same number of darts on their borders
- Connection of the darts on shared border
 \Rightarrow set β_2' relations
- Simplification step for minimality
 \Rightarrow if the degree of a vertex equals 2 in both tiles

Extraction of a Tiled Pyramid

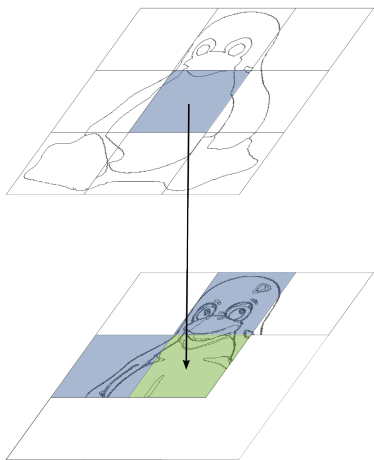


Algorithm

For each tile $t(i, j, k)$ in level k :

- Load $t(i-1, j, k+1)$ and $t(i, j-1, k+1)$
 - Create $t(i, j, k+1)$ from $t(i, j, k)$
 - Connect the neighbors of $t(i, j, k+1)$
 - Save $t(i, j, k+1)$, $t(i-1, j, k+1)$, $t(i, j-1, k+1)$ and $t(i, j, k)$
 - Unload $t(i-1, j, k+1)$, $t(i, j-1, k+1)$ and $t(i, j, k)$
- Scanline extraction
 - **4 tiles at most** in memory

Extraction of a Tiled Pyramid

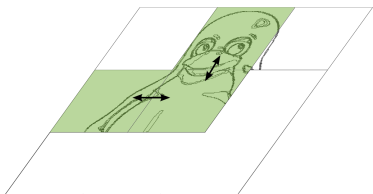
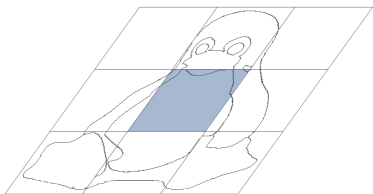


Algorithm

For each tile $t(i, j, k)$ in level k :

- Load $t(i - 1, j, k + 1)$ and $t(i, j - 1, k + 1)$
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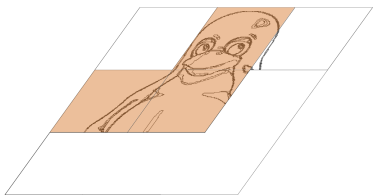
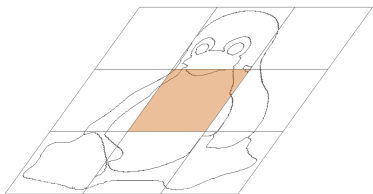


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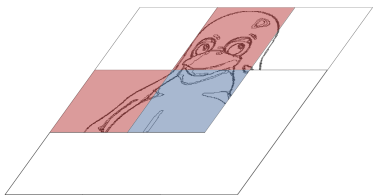
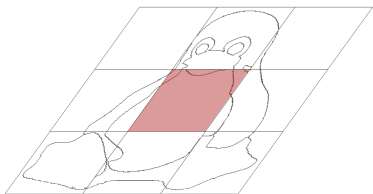


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Extraction of a Tiled Pyramid



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Criteria

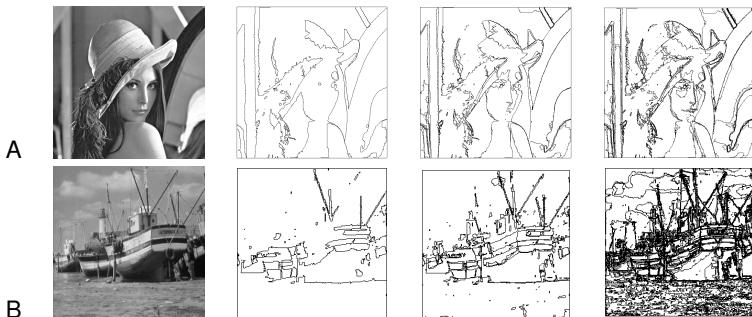


Figure: Basic segmentations for 4 levels pyramids. (A) Hierarchical criterion: standard deviation of up regions; (B) Colorimetric criterion: average gray levels comparison.

Criteria can take into account:

- colorimetric features of regions
- topological features of a level
- hierarchical features of the pyramid

Construction from a Multi-resolution Image

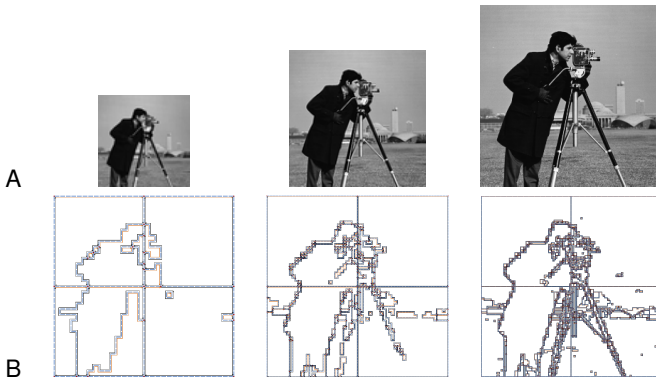


Figure: (A) Image resolutions; (B) Pyramid levels.

- Tiled structure \Rightarrow fictive borders are displayed
- Multi-resolution images
 \Rightarrow pyramid levels and image resolutions are independent notions
- Irregular pyramid \Rightarrow irregular model within the tiles

Results

Table: Memory usage: extraction for different scalings of image *Lena*.

image side (px)	tiles per level	memory (MB)	disc (MB)
512	1	92	7
2048	16	95	20
8192	256	95	272
32768	4096	111	4315

- Extreme configuration: 4 levels 32K*32K
- Natural segmentation: lots of darts and regions
- Controlled memory usage

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Conclusion

- Definition of a data structure
 - topological representation
 - hierarchical causal structure
 - top-down construction

- Implementation
 - based on topological maps
 - tiled subdivision
 - colorimetric, topological and hierarchical segmentation criteria
 - integrated with multi-resolution images

Perspectives

- Segmentation aspect
 - integration of clustering and quantization methods
 - specific application to medical images

- Model improvements
 - compare different strategies for the subdivision in tiles
 - faster processing for very large images
 - different splitting techniques
 - multi-threading support