Segmentation using vector-attribute filters: methodology and application to dermatological imaging

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Outline

Purpose

Vector-attribute filters

Application to dermatological imaging

Results

Conclusion

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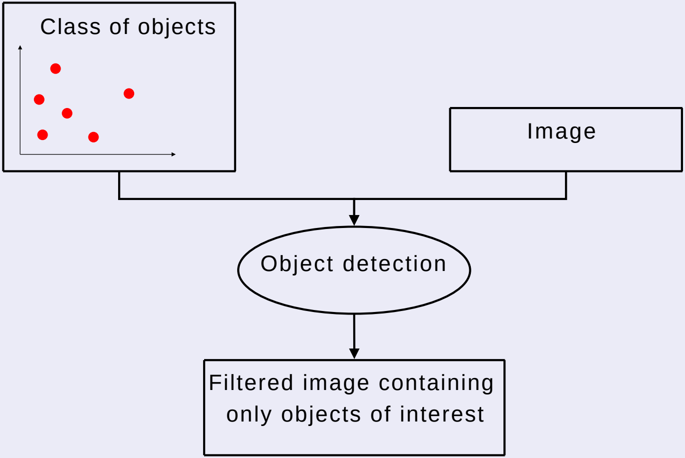
Introduction

Purpose of this work

- To retrieve in a grey-level image all “objects” that belong to a specific class.



Introduction

Vector-attribute filters

- Introduced recently (Urbach et al., ISMM'05).
- Connected operators allowing to remove in a grey-level image all "objects" that are similar enough to a given shape.

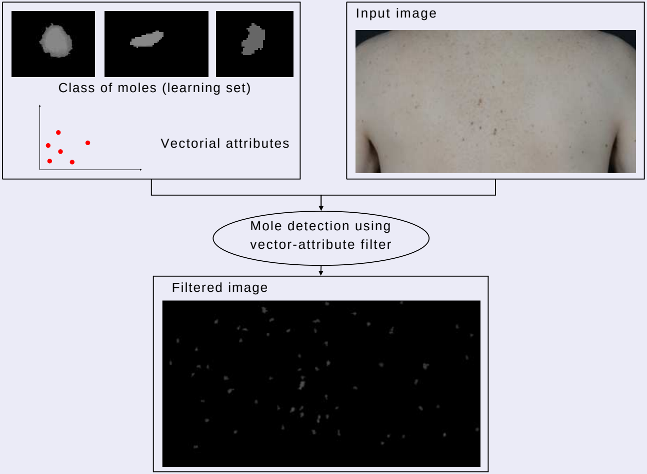
Motivation of this work

- Demonstrate the efficiency and usefulness of vector-attribute filters for object detection purpose.
- Vector-attribute filters have been seldom used in real applications.
- Design an interactive application devoted to dermatological imaging.

Introduction

Application

- Retrieve in dermatological digital photographs all moles similar to a specific set.



Class of moles (learning set)

Vectorial attributes

Input image

Mole detection using vector-attribute filter

Filtered image

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Purpose

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Results

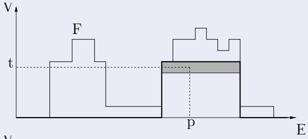
Conclusion

Grey-level vector attribute filters

Principle

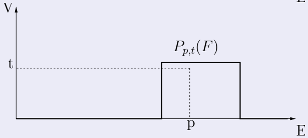
Image *peaks* are the connected components of the threshold sets :

$$X_t(F) = \{p \mid F(p) \geq t\}$$



To each peak, attach a vector containing real-valued attributes :

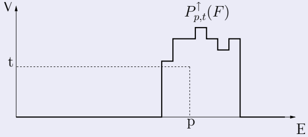
$$\mathbf{v} = (v_1, v_2, \ldots, v_n)$$



Keep only *peaks* which satisfy a given criterion :

$$T(\mathbf{v}) = \text{true}$$

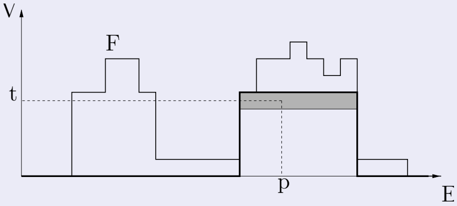
In order to design non-flat attributes, consider the peak and all the superior connected components (the *lobe*).



Grey-level vector attribute filters

Function decomposition

A function can be decomposed into its peak and lobe components.



Function *F*.

Grey-level vector attribute filters

Function decomposition

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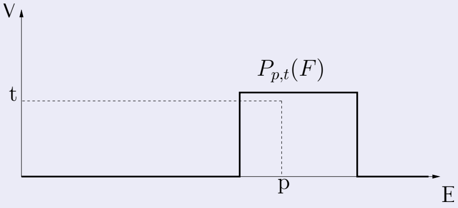


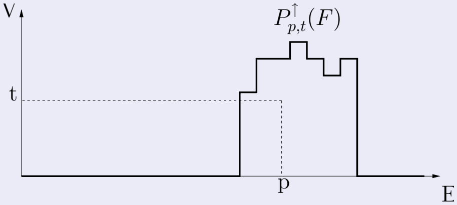
Peak function $P_{p,t}(F)$ containing p at level t.

$$P_{p,t}(F)(x) = \begin{cases} t & \text{if } x \in \gamma_p(X_t(F)), \\ \perp & \text{otherwise.} \end{cases}$$

Grey-level vector attribute filters

Function decomposition

A function can be decomposed into its peak and lobe components.



Lobe function $P^{\uparrow}_{p,t}(F)$ containing p at level t.

$$P^{\uparrow}_{p,t}(F)(x) = \begin{cases} F(x) & \text{if } x \in \gamma_p(X_t(F)), \\ \perp & \text{otherwise.} \end{cases}$$

Grey-level vector attribute filters

Valuation function

- $\tau : V^E \longrightarrow \mathbb{R}^N$
- Attach a vector of values to a lobe function.
- Using lobe functions enables to use non-flat attributes (i.e. height, volume,...).

Grey-level vector attribute filters

Valuation function

- $\tau : V^E \longrightarrow \mathbb{R}^N$
- Attach a vector of values to a lobe function.
- Using lobe functions enables to use non-flat attributes (i.e. height, volume,...).

Criterion

- $T : \mathbb{R}^N \longrightarrow \{true, false\}$
- Accept or reject a vector according to some defined strategy.
- Can be defined with respect to some *learning set*.

Grey-level vector attribute filters

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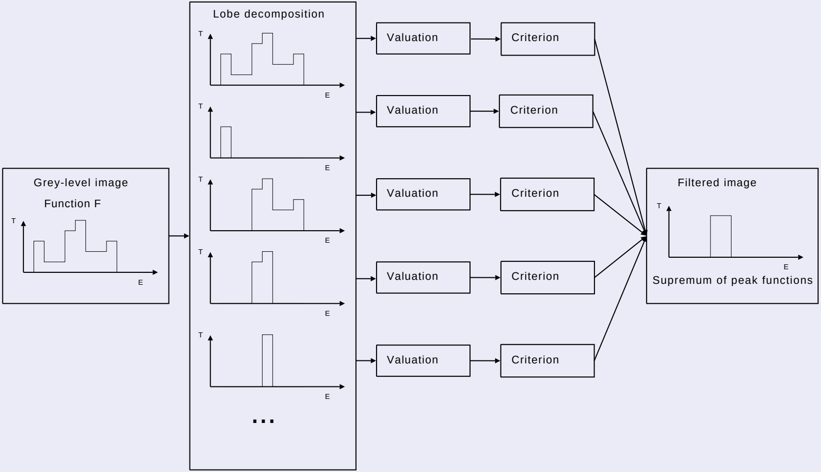
Grey-level vector-attribute filter

- $\phi(F) = \bigvee \{P_{p,t}(F) \mid T(\tau(P^{\uparrow}_{p,t}(F))) = true\}$

Grey-level vector-attribute filters

Vector-attribute filter

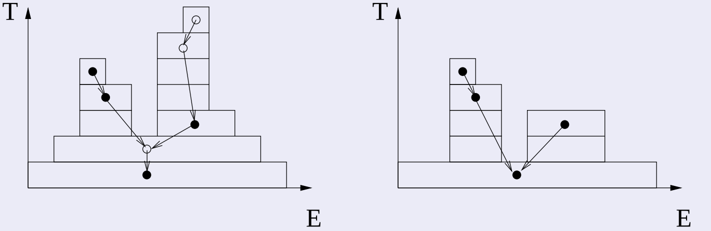


Grey-level vector-attribute filters

Implementation

Efficient implementation using the image component-tree. Efficient algorithms :

- Salembier (recursive flooding)
- Najman (Tarjan's union-find))



Original tree

Filtered tree using *direct* decision

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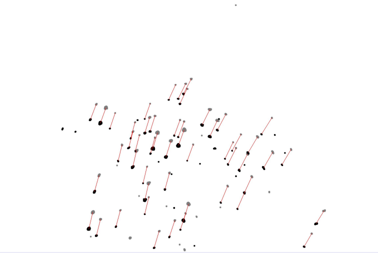
Conclusion

Application to dermatological imaging

Computer-aided diagnosis for dermatologist

- Total Body Photography.

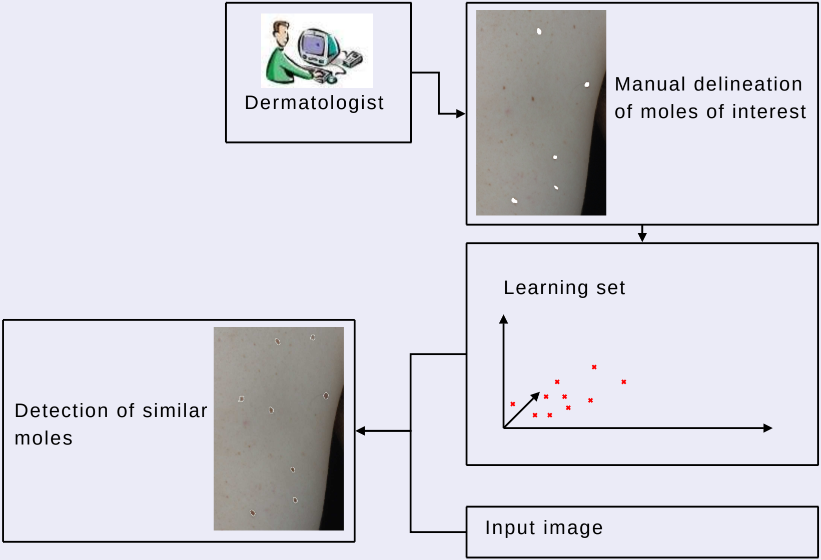
- Images acquired at different times.
- Purpose : early detection of suspicious lesions.
  - Detection and cartography of moles.
  - Moles follow-up in the different images.
  - Alert associated to each mole evolution.



- Mole segmentation : first step of a mole mapping application.

Application to dermatological imaging

Interactive segmentation application



Dermatologist

Manual delineation of moles of interest

Learning set

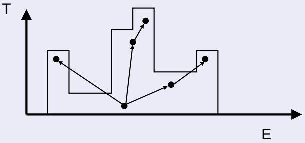
Input image

Detection of similar moles

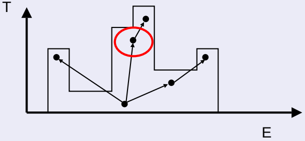
Application to dermatological imaging

Learning set construction

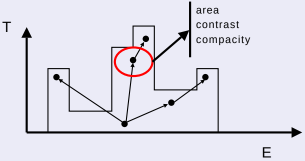
Compute the image component-tree.



For each manually delineated mole : find the corresponding node in the component-tree.

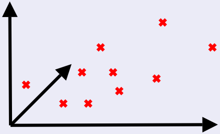


Compute the vector-attribute $\mathbf{v_i}$
(*area*, *contrast*, *compacity*)



Object class defined by :

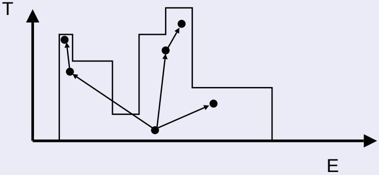
- Mean vector **r**
- Covariance matrix Σ



Application to dermatological imaging

Mole detection

Compute the component-tree of the *saturation* image.



- Filter the component-tree using valuation function :

$$\boxed{\tau = (\textit{area}, \textit{contrast}, \textit{compacity})}$$

- Criterion used :

$$\boxed{T_{\mathbf{r},\varepsilon}(\mathbf{v}) = d_M(\mathbf{r}, \mathbf{v}) < \varepsilon}$$

- d_M is the **Mahalanobis** distance (using the covariance matrix of the learning set).
- ε is a parameter that can be set in real-time thanks to the component-tree implementation.

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Purpose

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Conclusion

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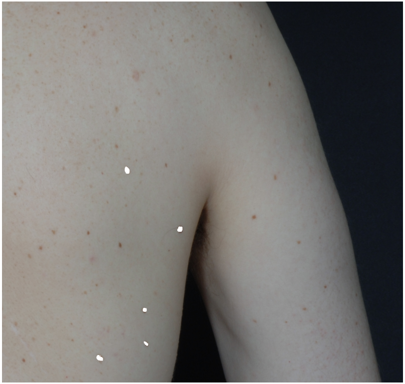
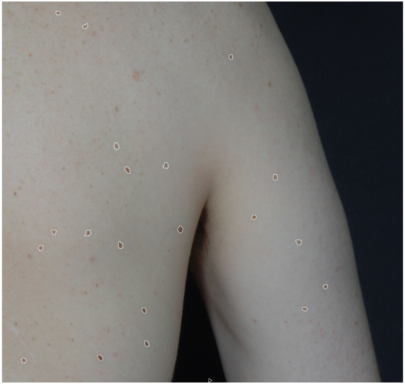
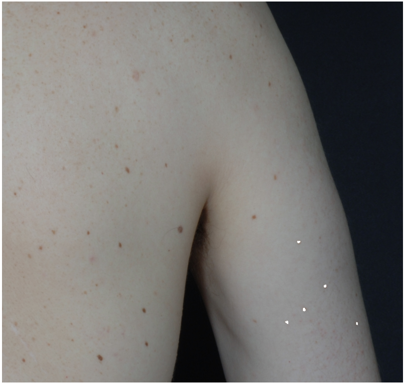


Manually delineated moles

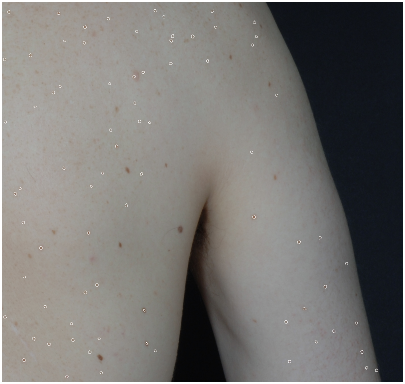


Segmentation result for $\varepsilon = 3$

Results



Manually delineated moles



Segmentation result for $\varepsilon = 3$

Results

Computation time

- Images size : 4288 × 2848 (12 Mp).
- Component-tree computation : 8 s.
- Detection time : 0.1 s.
- Once the tree is computed, ε can be updated in real-time.

Other methods

- For comparison, computation time obtained with template-matching methods (grey-level hit-or-miss transform) : 2 mns.

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Vector-attribute filters

- Enable detection of an object directly in a grey-level image : no binarization is needed.
- Very efficient due to the component-tree implementation.

Dermatological application

- Design of an interactive application for mole detection and segmentation.
- Attribute parameters are retrieved from the learning set.
- Allows real-time interaction with the segmentation parameter ε.
- Using vector-attribute filters imposes some condition on the result (i.e., each flat zone meets a given criterion).

Conclusion

Future works

- Use more descriptive attributes (geometric or shape attributes).
- Use more complex non-flat attributes (texture distribution on a peak/node),...
- Extension to classification tasks involving multiple classes.
- Application to other domains (indexation...).

Properties

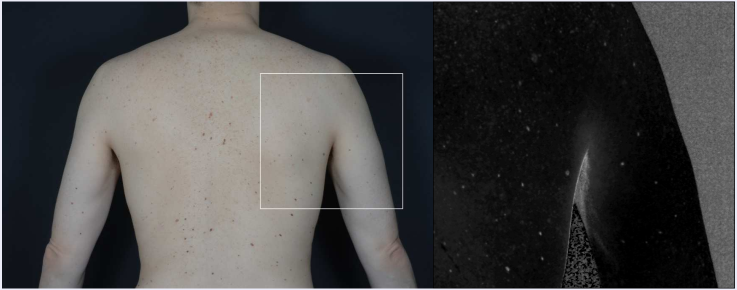
Grey-level vector-attribute filters

- Not increasing.
- Anti-extensive.
- Not idempotent if the *peaks* instead of the *lobes* are used for the reconstruction (as h-reconstruction, volumic filters,...).
- **Not** morphological filters.
- Connected-operators (act only by merging flat-zones).

Dermatological application

Input image

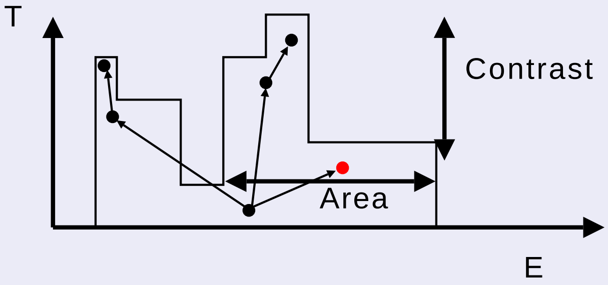
- The filtering is performed on the saturation image.
- Use of the saturation image enables to discriminate moles from skin.



Dermatological application

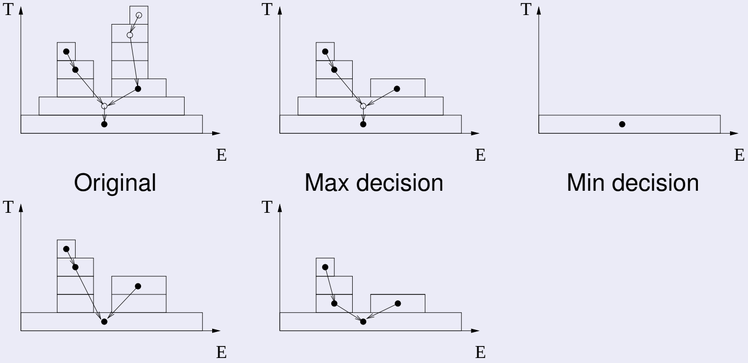
Attributes

- Area : area of the node.
- Contrast (or height) : distance between the node and the leaf.
- Compacity :$(4\pi * \mathit{area})/(\mathit{perimeter}^2)$.



Component-tree

Filtering strategy



Original

Max decision

Min decision

Direct decision

Subtractive decision