Quantitative Conjunctival Provocation Test

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Overview

- Introduction
  - Materials and methods
    - Image material
    - Image processing chain
    - Evaluation
  - Results
  - Summary and discussion
Introduction

- Conjunctival Provocation Test
  - Apply allergen solution
  - Evaluate response

- Application
  - Allergy diagnosis in clinical trials

- Aim
  - Quantification of change in conjunctiva redness
  - Fully automated image processing
Overview

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Image material

- Camera: Olympus PEN E-P1
- Macro Lens: Olympus M.Zuiko Digital ED 60mm f/2.8
- Light: Hama 12 LED-Macro-Light, DSLR
- Stand: Custom made at IMSIE, University Hospital Cologne
Image processing

*Photo without allergen*

1. Segmentation
2. Registration
3. Redness measurement
4. Relative redness

*Photo with allergen*

1. Segmentation
2. Registration
3. Redness measurement
4. Relative redness
Image processing

**Photo without allergen**

- Segmentation

**Photo with allergen**

- Segmentation

**Registration**

- Redness measurement

**Relative redness**
Segmentation

Steps

- Binarize
  - Threshold in YUV color space
  - Edge-based correction
- Find components
- Select conjunctiva
- Smooth ROI

Example

Original  Binarized (color/gray)  Conjunctiva  Smoothed ROI
Segmentation

- Binarization
- Conjuntiva component selection
- ROI smoothing
- Final mask
- Iris segmentation
- Iris circle
Segmentation

Threshold at average Y in YUV color space
Morphological operations
Subtract edges from mask
Canny edge detection (parametrization 1)
Morphological operations

Iris segmentation

Conjuntiva component selection

ROI smoothing

Final mask

Iris circle
Segmentation (edge-based correction)

- **Goal**
  - Remove artefacts (bridges from thresholding)

- **Steps**
  - Canny edge map & morphological optimization
  - Subtract from the mask before connected components

- **Example**
  - Regions above threshold
  - Canny edges
  - Final mask
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Quantitative Conjunctival Provocation Test

Segmentation

- Threshold at average Y in YUV color space
- Morphological operations
- Subtract edges from mask
- Canny edge detection (parametrization 1)
- Morphological operations
- iris segmentation

Conjunctiva component selection

ROI smoothing

Final mask

iris circle
Segmentation

Threshold at average Y in YUV color space
Morphological operations
Canny edge detection (parametrization 1)
Morphological operations
Subtract edges from mask
Connected component analysis
Select component under iris
ROI smoothing

Iris segmentation
Iris circle
Final mask
Segmentation

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Threshold at average Y in YUV color space
Morphological operations
Subtract edges from mask
Connected component analysis
Select component under iris
Convex hull
Subtract iris
Final mask

Iris segmentation
Iris circle
Segmentation

Threshold at average Y in YUV color space
Morphological operations
Canny edge detection (parametrization 1)
Morphological operations
Canny edge detection (parametrization 2)
Hough Circle Transform

Subtract edges from mask
Connected component analysis
Select component under iris
Convex hull
Subtract iris

Iris circle
Iris segmentation

Steps

- Canny edge detection
- Gradient-based Hough Circle Transform

Example

- Canny edges
- Hough space (sliced at $r$ of global maximum)
- Most voted circle
Image processing

*Photo without allergen*  
- Segmentation  
- Registration  
- Redness measurement  
- Relative redness

*Photo with allergen*  
- Segmentation  
- Registration  
- Redness measurement  
- Relative redness
Registration

- **Goal**
  - measure same region

- **Steps**
  - Register the images (similarity transform with SIFT algorithm)
  - Intersect ROIs

- **Example**
  - Detected features
  - Detected matches
  - Registered images
Image processing

Photo without allergen

Segmentation

Registration

Redness measurement

Relative redness

Photo with allergen

Segmentation

Registration

Redness measurement
Redness measurement

Steps

- Select red pixels (thresholding in HSV space)
- Calculate per pixel redness (projection in HSV)
  \[ redness = saturation \cdot \cos(hue) \]
- Return mean redness of red pixels

Examples

- Gray scale represents the redness
Image processing

**Photo without allergen**

- Segmentation
- Registration
- Redness measurement
- Relative redness

**Photo with allergen**

- Segmentation
- Registration
- Redness measurement
- Relative redness

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Relative redness index

- Goal: measure redness change
- Relative redness
  \[
  \frac{\text{redness after allergen}}{\text{redness before allergen}}
  \]
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Evaluation

- Observational diagnostic study (Wiesbaden)
  - Goal: assess test-retest reliability of CPT
  - Patients: 23 allergic patients
  - Procedure:
    - Test 1: Take photo before and after application of allergen (dose individually predetermined)
    - Test 2: After a couple of weeks, repeat test with the same dose
    - No therapy between tests
  - Expectation: correlation between Test 1 and Test 2 relative redness measure
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Results: Test-retest reliability

\[ y = 0.344x + 0.8424 \]

\[ R^2 = 0.2274 \]
Results: Algorithm robustness

Relative decrease of ROI size

Allergen dose: 100, 1000, 10000
Discussion and summary

- Image processing chain for automatic quantitative CPT evaluation

- Assessed
  - Test-retest reliability
  - Measurement robustness

- Future work: integration into web-based clinical system