**Development of a data fusion model for detection of electronic components and generating of a life-cycle inventory PCB model**

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# Introduction

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## Object recognition from 2D Images

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## Recycling potential of electronic waste

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# Recognition of electronic components

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## Data fusion model

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## Image preprocessing

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### Image rotation correction

To bypass the restriction of rotation invariant features for object recognition, the rotation of the printed circuit board images were determined.

### Scaling determination based on scaling symbol

To bypass the restriction of scale invariant features for object recognition, the scaling of the printed circuit board images were determined using a scaling symbol.

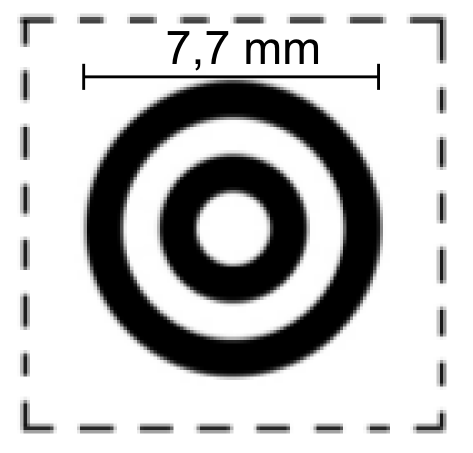


Figure 1: Scale symbol

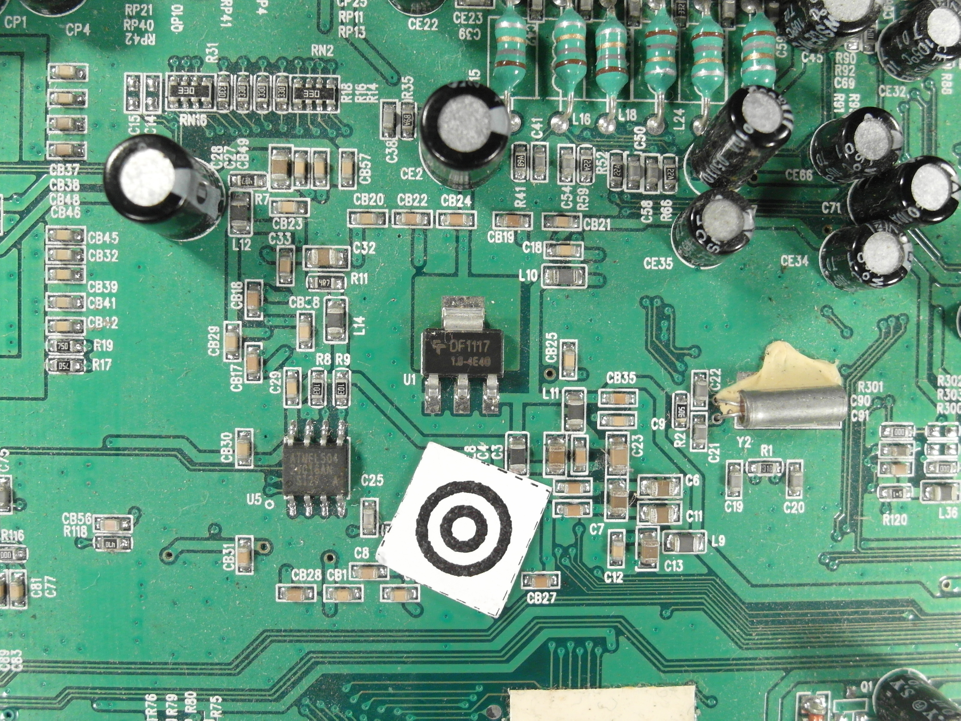


Figure 2: Scale symbol placed on the board

The scaling symbol is shown in Figure 1. The whole scaling determination process is shown in Figure 3.

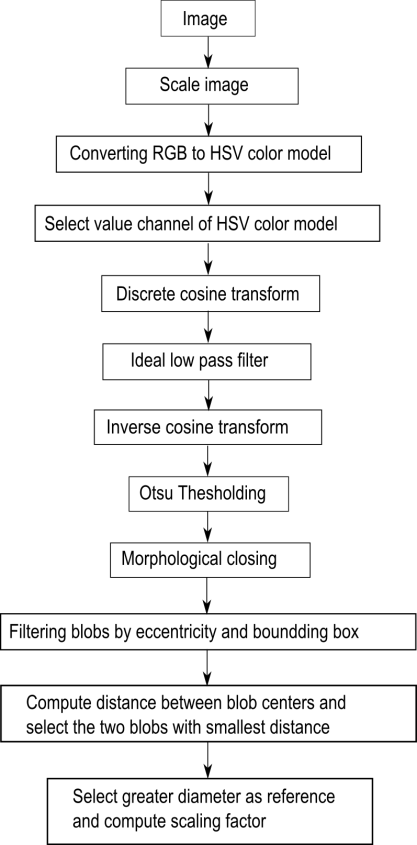


Figure : Scaling determination process

At first the image is converted from the RGB color model to the HSV color model and the brightness channel (value channel) is used to make a discrete cosine transform. The discrete cosine transform is frequently used in image compression such as the JPEG format. The discrete cosine transform is similar to the discrete Fourier transform but uses only cosine functions as kernels. The discrete cosine transform is shown in Equation (1) and (2) (Rafael C.Gonzalez, 2008).

|  |  |
| --- | --- |
|  | (1) |
|  | (2) |

|  |  |
| --- | --- |
|  | (3) |

To suppress illumination changes, an ideal low pass filter is applied in the frequency domain in which the first 10 x 10 cosine coefficients were discarded. Afterwards the inverse cosine transform is applied to get the image in time-domain. To extract the two dark circles of the scaling symbol, Otsu’s method is used to automatically perform thresholding. To avoid salt and pepper noise, a morphological closing operator (5x5) is applied. The image is inverted and the eccentricity and bounding boxes are determined of the blobs. All blobs inside the eccentricity interval and inside the diameter interval are maintained, all others are discarded.

|  |  |
| --- | --- |
| } | (4) |

To find the center of the scaling symbol, the distances between the centers of all blobs are calculated and the two blobs with the smallest distance are the inner and outer dark rings of the scaling symbol. The outer diameter of the larger blob is used as reference to calculate the image scale.

|  |  |
| --- | --- |
|  | (5) |

|  |  |
| --- | --- |
| C:\Users\WIN\Masterthesis\Masterthesis\Masterarbeit_daten\2.2.2\scale5.png  Figure 4: Value channel (brightness) of HSV color image | Figure 5: Cosine transform filtered image |
| Figure 6: Otsu thresholding | C:\Users\WIN\Masterthesis\Masterthesis\Masterarbeit_daten\2.2.2\scale6.png  Figure 7: Blobs of the scaling symbol |

## Electronic component detection

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### Electronic component detection based on color based background detection

Sdf

### Electronic component detection based on 3D range image

Sd

### Electronic component detection based on normalized correlation

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## Feature extraction algorithms for electronic components

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### Fourier analyses for feature extraction

Asd

### Histogram based feature extraction

Sad

### Segment based feature extraction

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### PCA based feature extraction in Laplacian of Gaussian filtered gray scaled image

Asfd

## Feature selection and feature fusion techniques for classification

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# Classification

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## Random forest classifier

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## Support vector machine classifier

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# Decision fusion for component recognition

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# Optical character recognition of electronic component marking

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## Introduction

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## Character segmentation

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## Optical character recognition with Tesseract and Cognex Vision Pro software

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## Electronic part label verification based on Octopart database

Dsf

# Experimental results

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## Dataset creation

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### Image acquisition

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## Classification results

Ef

## Optical character recognition results

Asd

# Life-cycle inventory analyses of printed circuit boards

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## Introduction

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## Printed circuit board region classification based on electronic part recognition results

Sad

## GaBi-Software and LCI data availability of electronic components

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## ILCD format for LCA-data exchange

# Conclusion and prospects

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