

Smartphone App Concept for Medical Applications.

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Abstract

The market for smartphone based medical applications is a relatively new and growing quickly. The majority of medical apps are relatively simple health management and tracking applications that might remind a user to take his or her medicine or monitor blood pressure and heart rate data provided by accompanying devices. However, more sophisticated apps can directly provide diagnostic information by capturing and analysing data directly. Several apps exist that can assess the risk of skin cancer by tracking changes in the growth of skin lesions over time.

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Chapter 1

Introduction

TODO: Medical Apps / future promise and benefits / communication with experts / fast diagnosis

TODO: Fields that can benefit from Medical Apps on smart phones

TODO: What is cancerous melanoma? danger? importance of early detection.

1.1 Project Description

This bachelor project will investigate the following questions:

- What smartphone based medical apps are available that can track and assess the risk of skin lesions?
- What methods and algorithms can be employed by mobile phones to calculate the risk?
- What is necessary to build a mobile app that can provide a risk assessment of skin cancer melanoma from captured images?

1.2 Goals

1. Research the medical app market to gain an overview of areas of development, what apps are available, what trends are discernible. Of special interest are apps that use internal sensors (e.g., camera) and mathematical algorithms to detect skin cancer melanoma.
2. Gain familiarity with machine learning and image recognition algorithms. Describe the basic principles of these algorithms.
3. Research and compare available data and algorithms (e.g. in computer vision / machine learning). Define the relevant attributes that can be used to train the algorithm. This can also include changes in size over time.

4. Based on the research and comparison choose a specific algorithm and data with which to proceed. The algorithm must be able to
 - (a) identify the skin lesion correctly,
 - (b) compute the relevant attributes,
 - (c) use these attributes to classify the skin lesions whether it is possibly cancerous or not
5. Implement the algorithm as a prototype (using Python for example). Using images of a skin lesion as input, the algorithm will provide a risk assessment as output. Implement tests that can calculate the accuracy of the algorithm. Compare the implemented algorithm with at least one other algorithm.
6. Create a concept for a medical mobile app that can utilise the features of modern smartphones to provide a risk assessment of skin cancer melanoma based on captured images. This includes a full requirements analysis, i.e. use cases, functional / non-functional requirements, architecture.
7. Implement as proof of concept specific aspects of the medical mobile app.

1.3 Expected Results

1. Results of the medical app market research including graphical presentation of trends and statistics.
2. Documentation of the available data and algorithms including high level excursion into the theory behind machine learning and image recognition algorithms.
3. Comparison of available data and algorithms. Definition of relevant attributes.
4. Decision, which algorithm to use.
5. Documentation of the implementation of the algorithm, including tests, evaluation and comparison with at least one other algorithm.
6. Documentation of a concept for a medial app, including defined use cases, requirements, architecture and implemented design patterns.
7. Proof of Concept: implementation of specific aspects of the medical mobile app.

Chapter 2

Market Research

2.1 Data Gathering

2.1.1 Gathering Data from the Apple iTunes Store

Searching the Apple iTunes store is typically done manually via the iTunes Application from which text and data cannot be automatically extracted. Therefore, searching for and gathering data about IOS Applications is not easy. However, Apple does provide an rss feed that can be used to list Apps in specific categories and ordered according to how new, or how popular they are and if they are free or not. The rss feed is limited to 100 items per category. The data provided by the rss feed is minimal, not much more than title and a text description of the app. There are no sub-genres or tags than can be used to further differentiate the apps.

Using a python script data was gathered from the following rss feeds:

Top 100 Free Medical Apps Top 100 Grossing Medical Apps Top 100 Paid Medical Apps This combined results included data about 255 IOS apps. The title and description fields were imported into a database. Other information from the data such as price, right, or image link were ignored.

2.1.2 Gathering App Data from the Google Play Store

In order to gather data from the Goole app store a script was programmed that could extract lists of apps from a specific url. The following urls were scanned:

- Top Paid Medical Apps : https://play.google.com/store/apps/category/MEDICAL/collection/topselling_paid
- Top Free Medical Apps : https://play.google.com/store/apps/category/MEDICAL/collection/topselling_free

For each app listed the script would extract the url of the app's detail page. From the detail page more information would be gathered and stored in a database. The data set is similar to that of the itunes rss feed. The title and description text were imported, other fields such as pricing and copyright were ignored.

Data on 480 Medical Apps for Android was imported. However a significant percentage of the apps could not be classified because the description text was in a language other than English, German, or French.

2.2 Categorization

The term "Medical App" is broad and neither the iTunes nor Google app stores offer any kind of sub categorization. In order to get a better overview of what sort of Medical Apps are available it was necessary to manually browse the gathered data and assign categories to the apps.

A database management tool was created using the python based Django Web Framework. Django provides many tools that makes constructing and interacting with databases very easy. The built-in backend administration tool can be configured to browse, edit, and filter data.

In order to quickly browse through and categorize over 700 apps. The Django backend admin was configured so apps could be categorized one after the other with a minimum of clicks or scrolling. The user was presented a list of uncategorized apps. The first one is clicked. The user is then presented with a page displaying the title and summary text of the app and a field from which a category can be selected. Once saved, the app is no longer presented on the list, the user can select the next app at the top of the list.

2.2.1 Description of Categories

- **Community** - provides some sort of social networking service through which the user can share data with her family or with a network of people suffering from similar disorders.
- **Fun / Entertainment** - These apps have no real medical purpose. They are for enjoyment only.
- **Alert / First Response** - Apps that assist first responders or that help users alert first responders that help is needed.
- **Health / Lifestyle** - Relaxation and meditation apps, or ovulation and fertility reminders
- **Resource Finder** - Apps that locate resources in the vicinity, nearby pharmacies or care providers.
- **Reminder** - Apps with timer or calendar functionality that might remind a user of an appointment or manage medicine consumption.
- **Algorithmic / Diagnostic** - These are apps that provide some sort of diagnostic information based on data that has been gathered by sensors or entered by the user. Examples are seizure detection apps, or stroke severity evaluation apps.

- **Learning / Educational / Reference** - By far the largest category, this includes apps that provide reference information about diseases or education material like anatomy apps for example.
- **Organisational** - Apps in this category might help a user or practitioner organise, share or track data and documents. Examples are apps that help users track the status of their blood pressure or blood sugar levels, create health diaries, or manage clinical data and images.

2.3 Results

2.3.1 IOS Medical Apps

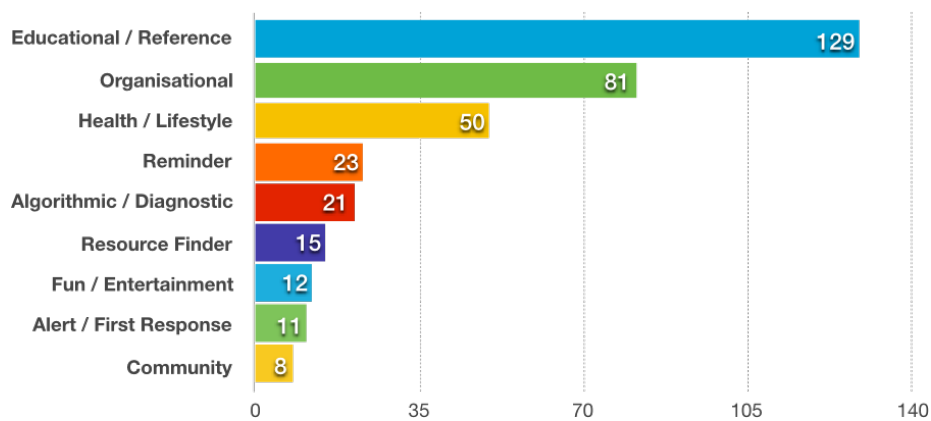


Figure 2.1: Medical Apps on the iTunes Apple Store, Search conducted on 17.05.2016

2.3.2 Android Medical Apps

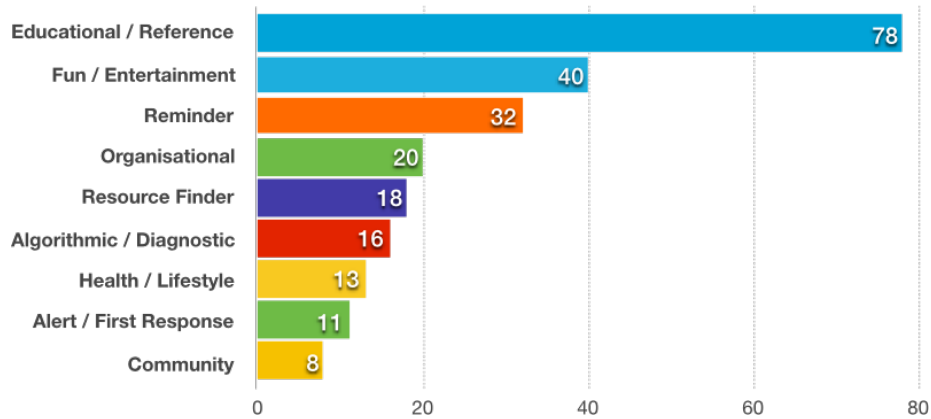


Figure 2.2: Medical Apps on the Google Play Store, Search conducted on 17.05.2016

2.3.3 Dermatology Apps 2013 vs 2016

Mobile apps are an especially good fit for dermatology-related care. Most dermatological conditions are by nature visible. The initial diagnosis and follow up monitoring is mostly done visually. A mobile device with a camera can aid patients and practitioners in the diagnosis of a dermatological condition and tracking its development. The article Mobile Applications in Dermatology [2] in 2013 identified 229 dermatology-related apps across 5 app platforms (Android, Apple, Blackberry, Nokia, and Windows). These were grouped into categories based on their primary functionality. The "Self-surveillance/diagnosis" category was the second largest on the Android and Apple platforms, with 13 and 24 apps respectively.

| Category | Android | Apple | Blackberry | Nokia | Windows | Total, No. (%) |
|-----------------------------|-----------|------------|------------|---------|---------|----------------|
| Reference | 22 | 35 | 3 | 0 | 1 | 61 (26.6) |
| Self-surveillance/diagnosis | 13 | 24 | 1 | 0 | 3 | 41 (17.9) |
| Disease guide | 20 | 10 | 7 | 0 | 2 | 39 (17.0) |
| Educational aid | 7 | 11 | 2 | 0 | 0 | 20 (8.7) |
| Sunscreen/UV recommendation | 7 | 12 | 0 | 0 | 0 | 19 (8.3) |
| Calculator | 2 | 9 | 1 | 0 | 0 | 12 (5.2) |
| Teledermatology | 1 | 7* | 0 | 0 | 0 | 8 (3.5) |
| Conference | 2 | 3 | 0 | 1 | 0 | 6 (2.6) |
| Journal | 2 | 4 | 0 | 0 | 0 | 6 (2.6) |
| Photograph storage/sharing | 1 | 4 | 0 | 0 | 0 | 5 (2.2) |
| Dermoscopy | 0 | 2 | 0 | 0 | 0 | 2 (0.9) |
| Pathology | 0 | 2 | 0 | 0 | 0 | 2 (0.9) |
| Other | 1 | 6 | 0 | 1 | 0 | 8 (3.5) |
| Total applications, No. (%) | 78 (34.1) | 129 (56.3) | 14 (6.1) | 2 (0.1) | 6 (2.6) | 229 (100.0) |

* Two additional Apple iOS teledermatology applications were identified in a query of the term teledermatology during March 2013: HIV-Derm Algo Study (launched October 20, 2012) and SFGH Teledermatology pilot (launched November 12, 2012).

Figure 2.3: Total Applications, Brewer 2013

Using the same search criteria and categories from the article above indicates that the availability of dermatological apps is growing. Today there are 33 dermatological apps on the Apple platform that can be identified as having "Self-surveillance/diagnostic" features. With the exception of the "Reference" category, all other categories show significantly higher numbers of available apps.

| Category | Apple 2013 | Apple 2016 | Android 2013 | Android 2016 |
|-----------------------------|------------|------------|--------------|--------------|
| Reference | 35 | 29 | 22 | 31 |
| Self-surveillance/diagnosis | 24 | 33 | 13 | 23 |
| Disease guide | 10 | 24 | 20 | 46 |
| Educational aid | 11 | 23 | 7 | 24 |
| Sunscreen/UV recommendation | 12 | 20 | 7 | 19 |
| Calculator | 9 | 4 | 2 | 10 |
| Teledermatology | 7 | 19 | 1 | 12 |
| Conference | 3 | 11 | 2 | 17 |
| Journal | 4 | 19 | 2 | 10 |
| Photograph storage/sharing | 4 | 3 | 1 | 1 |
| Dermoscopy | 2 | 7 | 0 | 3 |
| Pathology | 2 | 0 | 0 | 0 |
| Other | 6 | 8 | 1 | 4 |
| Total | 129 | 200 | 78 | 200 |

Figure 2.4: Demotological Apps by Category, July 2013(Brewer 2013) vs May 2016

It is important to note that the categories listed above are not defined in the stores. The apps must be manually assigned to a category based on an interpretation of the description text in the store and information obtainable on related websites. It is possible therefore that apps that were originally designated to the "Reference" category

might have been interpreted in this paper as a “Educational aid” app for example. The interpretation of the functionality of an app is fuzzy in many cases, and many apps have some crossover functionality. An app developed for self-surveillance will often contain information pertaining to symptoms and treatment (reference).

2.3.4 Dermatological Apps with Automatic Risk Assessment

Of the 55 apps identified belonging to the ”Self-surveillance/diagnosis” category, only 2 provided risk assesment features based on automatic analysis of captured images.

- SkinVision : <https://skinvision.com>
- mSkin Doctor <https://play.google.com/store/apps/details?id=com.maleemtaufiq.mSkinDoctor>

Chapter 3

Image Data Sources

3.1 Dermofit

High quality clinical images with corresponding masks. Great for training and testing.

| Image Type | Description | Amount | Comment |
|---------------------------|--|--------|---|
| Actinic Keratosis | Pre-cancerous patches of flakey or crusty skin, can develop into Squamous Cell Carcinoma | 45 | Not useful as comparison against melanoma |
| Basal Cell Carcinoma | Abnormal, uncontrolled growths of the skin's basal cells. | 239 | Not useful as comparison against melanoma |
| Dermatofibroma | Common and benign skin tumour. | 65 | Useful as comparison, some extreme cases might have to be left out of the training set. |
| Haemangioma | A collection of small blood vessels that form a lump under the skin. | 97 | Useful as comparison, some extreme cases might have to be left out of the training set |
| Intraepithelial Carcinoma | A type of squamous cell skin cancer limited to the upper layer of the skin. | 97 | Not useful |
| Malignant Melanoma | A type of cancer that develops from the pigment-containing cells known as melanocytes. | 76 | This is our baseline set, half will be used for training, the other half for testing |
| Melanocytic Nevus | Typical mole, benign. | 331 | Very usefull as comparison to Melanoma |
| Pyogenic Granuloma | Common skin growth, small, round and red in color due to large number of blood vessels. | 24 | Not usefull |
| Seborrhoeic Keratosis | Common non-cancerous skin growth. | 257 | Maybe usefull |
| Squamous Cell Carcinoma | Abnormal and uncontrolled growth of squamous cells in the epidermis. | 88 | Not usefull |

Table 3.1: Dermofit Image Categories

3.2 DermQuest

Online teaching and learning resource with large image database.

Image were selected based on their usefullness for this project. Usefullness is based on quality and type of image. Dermoscopic images were not selected. Instead images were taken that appeared to be taken with a standard camera. The images only contained the mole to be examined and the surrounding skin area. No other details like eyelids, ears, or dark shadows.

Subgroups of Melanocytic Nevus were chosen. Dysplastic and Intradermal Nevus for the non-cancerous cases, and Malignant Melanoma as the cancerous cases.

| Image Type | Description | Amount | Comment |
|--------------------|--|--------|--|
| Benign Keratosis | | 5 | |
| Malignant Melanoma | A type of cancer that develops from the pigment-containing cells known as melanocytes. | 39 | This is our baseline set, half will be used for training, the other half for testing |
| Melanocytic Nevus | Typical mole, benign. | 51 | Very usefull as comparison to Melanoma |

Table 3.2: DermQuest Image Categories

3.3 PH2Dataset

Demascopic Images

Many of the mole images extend almost to or even beyond the image border. This makes some of the processing difficult. However the images include an excel spreadsheet which clearly designates what type of mole, including some scoring info such as Asymmetry and Color information. Includes border mask images.

| Image Type | Description | Amount | Comment |
|----------------|-------------|--------|---------------------------|
| Common Nevus | | 79 | |
| Atypical Nevus | | 79 | |
| Melanoma | | 39 | Baseline set for training |

Table 3.3: PH2 Image Categories

Chapter 4

Image Feature Extraction

A digital image is a matrix of pixels that contain color information, typically comprised of the 3 color channels red, green, and blue. A person can look at an image and quickly make statements about its content. For instance, someone might look at an image of a street scene and be able to easily say "This is an image of a street in a town, there is one automobile, three people and a building in this scene". A person would easily be able to draw outlines around the objects and be able to differentiate between areas in each object.

For a computer to be able to "make statements" about the contents of an image it must use algorithms to group together and differentiate between objects in an image. The grouping together and differentiating of areas in an image is known as *segmentation*. The statements that a computer can make about the content of an image are usually of statistical nature and are referred to as *feature extraction*. Before segmentation an image goes through a *preprocessing* stage in order to remove or reduce irrelevant information or noise.

There are no universal algorithms for preprocessing, segmentation, or feature extraction. The algorithms employed depend on the context of the images to be analyzed and the type of information that one is looking for.

4.1 Preprocessing

4.1.1 Equalization

4.1.2 Median Blur

4.1.3 Gaussian Blur

4.2 Segmentation

4.2.1 Iterative Thresholding

4.2.2 Region Selection

4.3 Image Feature Extraction

Chapter 5

TDS Algorithm

5.1 Description of the Algorithm

Early detection of melanoma greatly increases the chances of successful treatment. A biopsy can be performed in order to gain a definitive diagnosis. However, biopsies are invasive, painful and take time. There are also visual markers Dermatologists look for in order to make a risk assessment. The ABCD Rule, also known as Stokes or TDS Calculation, looks for 4 sets of features. Based on the features the Total Dermoscopy Score (TDS) is calculated.

The 4 sets of features are Asymmetry (A), Border Irregularity (B), Color (C) and Differential Structure or Diameter (D).

Asymmetry can have a value of 0, 1 or 2 depending on the symmetry of the lesion. Where 0 is symmetric and 2 is asymmetric. A value of 1 indicates at least one axis was found across which symmetry exists. The Border score is an integer value from 0 to 8 indicating the presence of border irregularities in 8 regions. Color is an integer value from 1 to 6 indicating the presence of one to six specific colors. Similarly, the value for D indicates the presence of one to five distinct structures or textures. Alternatively, in some literature [4] D is defined as Diameter, where a diameter greater than 6mm results in a value of 5, otherwise 1.

The final TDS Score is the weighted sum of the ABCD Values and is in the range 1.0 to 8.9.

$$TDS = A * 1.3 + B * 0.1 + C * 0.5 + D * 0.5 \quad (5.1)$$

A diagnosis can be made based on the TDS Score according to the following table:

| Evaluation | TDS Score |
|------------|--------------|
| Benign | <4.75 |
| Suspicious | 4.75 to 5.45 |
| Malignant | >5.45 |

Table 5.1: TDS Evaluation [5]

5.1.1 Adaptation for use in a smart phone application

The ABCD Rule, also known as the Total *Dermoscopy* Score, is really only applicable to images captured using a dermatoscope. Especially the differential structures are only visible on dermoscopic images where the subsurface structures are made visible [1].

Since the D component is not applicable to images captured with a smart phone this project will use a modified TDS without the D component. The original TDS formula 5.1 can have values ranging from 1 to 8.9 and D can be 0.5 to 2.5. Without D the TDS can have values between 0.5 and 6.4.

$$TDS_{mod} = A * 1.3 + B * 0.1 + C * 0.5 \quad (5.2)$$

This results in a benign cutoff score of 3.2 and malignant cutoff of 3.7.

| Evaluation | Score |
|------------|-------------|
| Benign | <3.20 |
| Suspicious | 3.20 to 3.7 |
| Malignant | >3.7 |

Table 5.2: Adapted TDS Evaluation

5.2 Automatic Calculation of ABCD Values

The ABCD Rule is used by Dermatologists to differentiate benign from malignant melanocytic tumors. Because it is a clearly defined rule based on easily recognizable visual features it is easy to apply. Clinicians with limited dermoscopy experience achieve better results using the ABCD rule than other methods [5]. The following sections detail methods to automate the calculation of the ABCD scores.

5.2.1 Asymmetry

The "Center of mass" method of measuring asymmetry is relatively easy to calculate and is more accurate compared to other complex algorithms [3].

This algorithm begins by calculating an array of radii from the lesion's center of mass to border for each of 360 degrees. The coordinates for the center of mass are calculated from the sum of all x and y coordinates of pixels within the lesion's border each divided by the sum of pixels.

For each of the 360 radii r_i a score is calculated by comparing the lengths of pairs of radii that are symmetric across r_i . If the lengths of the pair of symmetric radii have a difference of less than 10% then a point is given. The sum of points is the SFA_i (Score For Axis) for r_i .

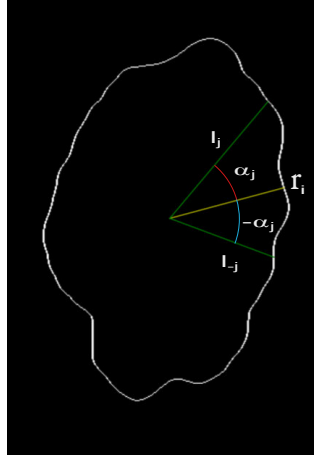


Figure 5.1: Calculate SFA for r_i

The radius with the maximum SFA score is defined as the major axis of symmetry. The SFA of the major axis as well as the perpendicular are stored. The Asymmetry score is evaluated as follows:

| SFA Results | Description | Asymmetry Score |
|--|----------------------------|-----------------|
| major axis ≥ 140 minor axis ≥ 140 | Symmetric across both axis | 0 |
| major axis ≥ 140 minor axis < 140 | Symmetric across one axis | 1 |
| major axis < 140 minor axis < 140 | Asymmetric | 2 |

Table 5.3: TDS Evaluation [5]

5.2.2 Border

An image is generated where only the pixels at the border or the lesion are visible, the rest of the image is black. The pixels are gathered sequentially into an array starting at any arbitrary border pixel and traversing the border continually. It's important that the sequential order of the pixels be maintained since the change in angle and distance to the lesions center will be measured.

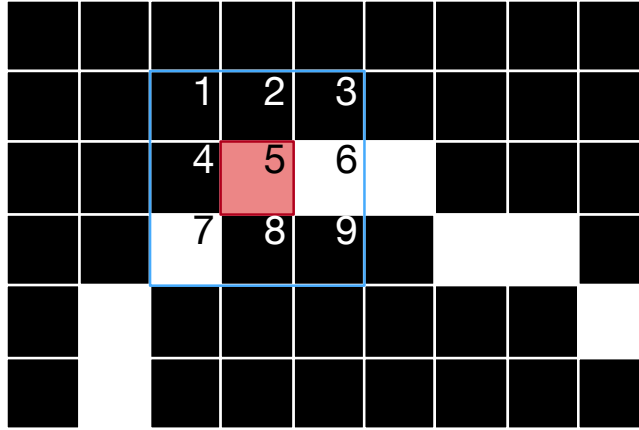


Figure 5.2: Traverse the border sequentially

An algorithm was developed that finds an arbitrary border pixel in an image that is otherwise black by iterating through pixels starting at the top left corner. When it has found a pixel that is not black it tests neighboring pixels, starting with the upper left neighbor and traversing the pixels row by row starting from the left most pixel in a row, as illustrated by the numbered pixels in figure 5.2. The center pixel, pixel number 5, is skipped.

When a non black pixel is detected it is compared to a list of previously detected pixels. If it has not been previously detected, it is added to the list and becomes the new center. The algorithm is repeated.

If no new non-black pixel is detected the outer range is expanded by one pixel at each edge and the pixels at the edge of a 5 x 5 area are tested. This is repeated until a new pixel is found. This prevents the algorithm from halting if there are discontinuities in the border.

When the algorithm reaches the starting pixels it ends. The list of pixels now contains a sequential list of pixels that are in sequential order.

For each pixel the distance and angle from the lesion's center of mass is calculated. If a lesion's border is irregular the measure of distance and angle from the center will be erratic, whereas if the border is relatively circular and smooth the measure of distance and the difference in angle will not change abruptly between neighboring pixels.

The distance function is averaged around the distance of the start pixel (set to zero) in order to reduce discontinuities. A gaussian lowpass filter is used to reduce noise and aliasing artifacts due to pixelization.

From the smoothed distance function the first derivative is calculated. From the angle function the difference from neighboring pixels is calculated. The resulting two functions are split into 8 equal segments. Each segment is analysed for strong variations in distance and sign changes in the difference of the angles. A sign change would indicate a very strong change in direction of the border function. For each segment in which strong variations are detected a point in the B score is added.

A lesion with strong variations in one segment, but otherwise smooth border function would have a B score of 1, whereas a lesion with variation is each of the 8 segments would have a B score of 8.

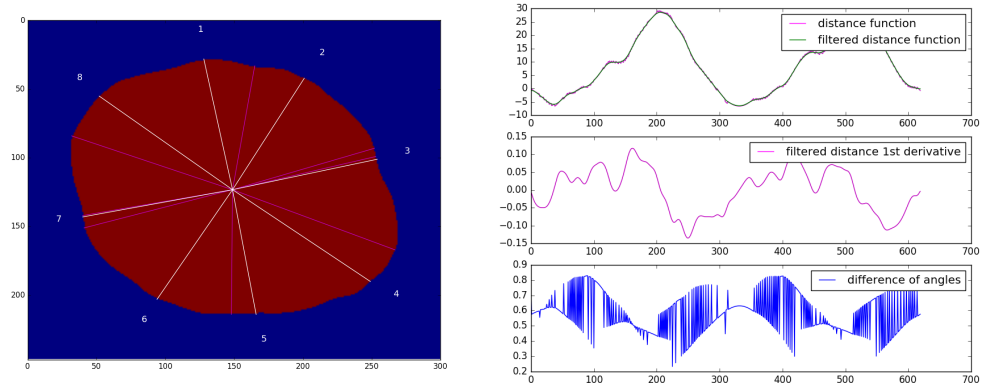


Figure 5.3: Example of border score 0

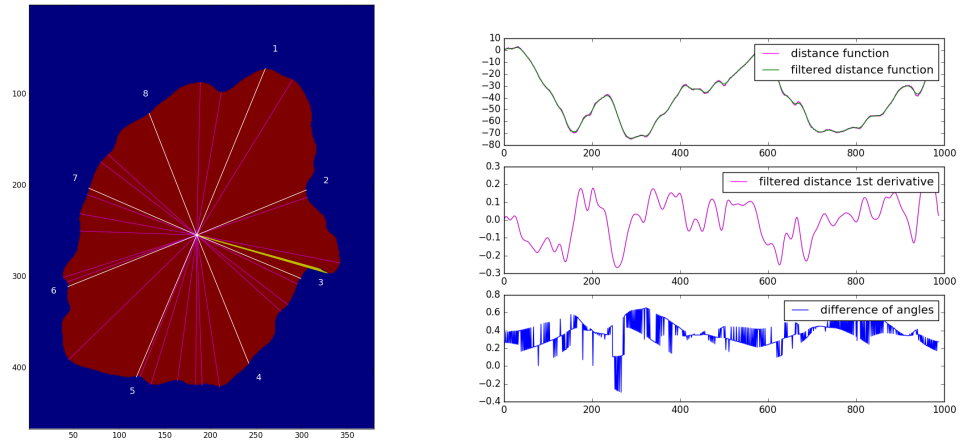


Figure 5.4: Example of border score 4

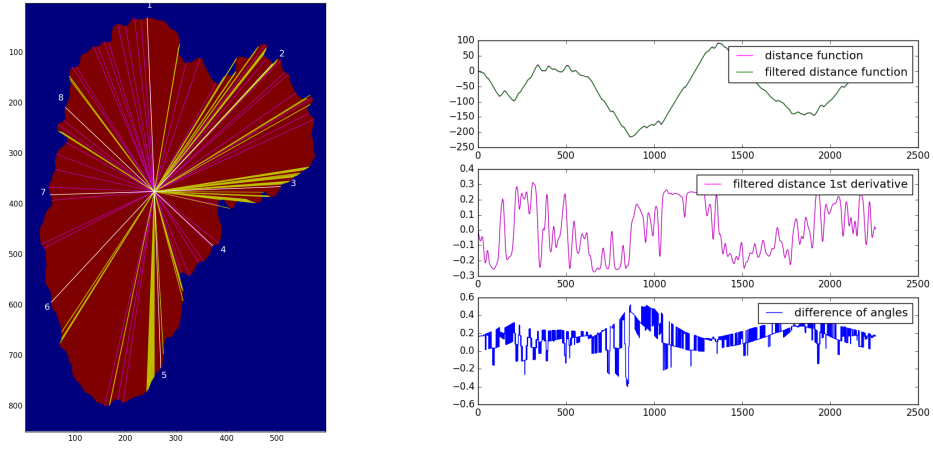


Figure 5.5: Example of border score 8

5.2.3 Color

In order to calculate the color score the *Quantification of Color* [1] algorithm was implemented in which the distance of each pixel to a defined set of colors is evaluated.

The original image is first filtered using a low pass Gaussian filter in order to reduce noise. Then for each pixel with the lesion area the euclidean distance from 6 RGB values is calculated. The 6 RGB values, as shown in table 5.4, represent the colors that are relevant to the TDS calculation.

| Color | R | G | B |
|-------------|-----|-----|-----|
| White | 255 | 255 | 255 |
| Red | 204 | 51 | 51 |
| Light Brown | 153 | 102 | 0 |
| Dark Brown | 51 | 0 | 0 |
| Blue Gray | 51 | 153 | 255 |
| Black | 0 | 0 | 0 |

Table 5.4: RGB values of the six possible TDS-relevant colors [1]

For each color a counter is incremented when a pixel is found that is closest to it. The end results are divided by the total number of pixels within the lesion's boundaries. For each color with a value greater than 0.01 a point is given to the TDS C score.

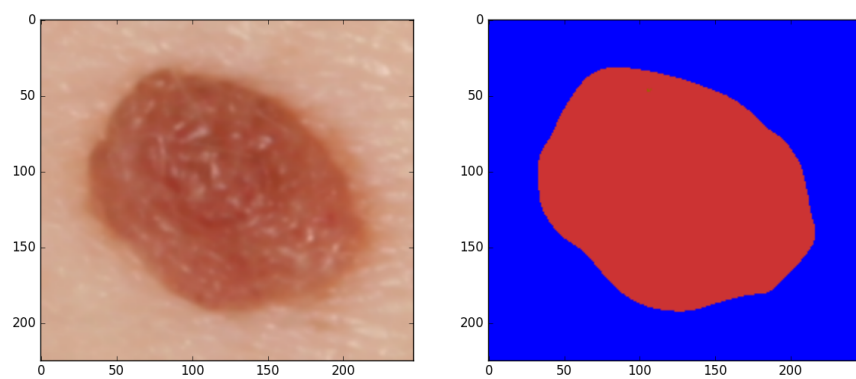


Figure 5.6: Example of color score 1

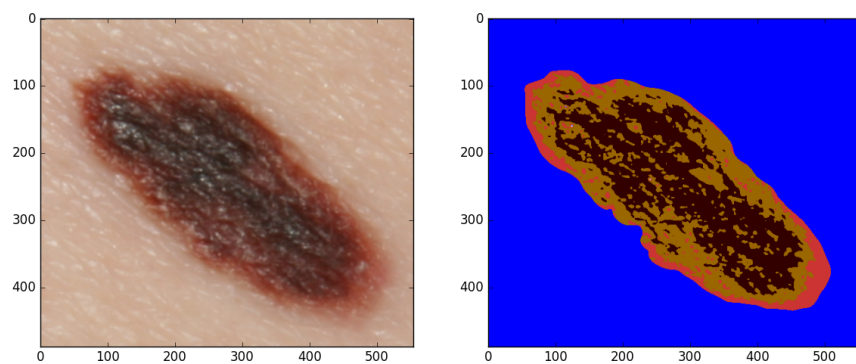


Figure 5.7: Example of color score 3

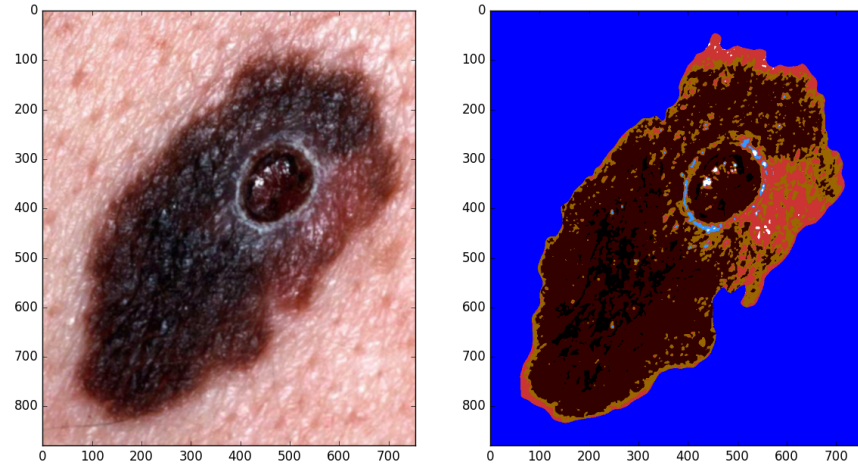


Figure 5.8: Example of color score 4

5.2.4 Differential

5.3 Two Examples

5.3.1 Postitiv Example

5.3.2 False Example

TDS Values were calculated but classification result was false.

5.4 Results of Algorithm

| Name | Source | Category | Asymmetry | Border | Color | TDS |
|-----------|----------|--------------------|-----------|--------|-------|------|
| B1052.png | Dermofit | Malignant Melanoma | 2 | 4 | 3.0 | 4.50 |
| B287.png | Dermofit | Malignant Melanoma | 2 | 5 | 2.0 | 4.10 |
| B302.png | Dermofit | Malignant Melanoma | 0 | 3 | 2.0 | 1.30 |
| B314.png | Dermofit | Malignant Melanoma | 2 | 6 | 2.0 | 4.20 |
| B65.png | Dermofit | Malignant Melanoma | 2 | 4 | 3.0 | 4.50 |
| C158.png | Dermofit | Malignant Melanoma | 0 | 2 | 3.0 | 1.70 |
| C201.png | Dermofit | Malignant Melanoma | 2 | 4 | 3.0 | 4.50 |
| C263a.png | Dermofit | Malignant Melanoma | 2 | 4 | 3.0 | 4.50 |

| | | | | | | |
|-----------|----------|--------------------|---|---|-----|------|
| C311b.png | Dermofit | Malignant Melanoma | 2 | 8 | 3.0 | 4.90 |
| C359.png | Dermofit | Malignant Melanoma | 1 | 3 | 3.0 | 3.10 |
| D143.png | Dermofit | Malignant Melanoma | 0 | 1 | 3.0 | 1.60 |
| D39.png | Dermofit | Malignant Melanoma | 2 | 3 | 3.0 | 4.40 |
| D630.png | Dermofit | Malignant Melanoma | 0 | 2 | 1.0 | 0.70 |
| D678.png | Dermofit | Malignant Melanoma | 0 | 0 | 3.0 | 1.50 |
| T233a.png | Dermofit | Malignant Melanoma | 1 | 8 | 2.0 | 3.10 |
| T86b.png | Dermofit | Malignant Melanoma | 1 | 3 | 3.0 | 3.10 |
| A121a.png | Dermofit | Melanocytic Nevus | 0 | 3 | 3.0 | 1.80 |
| A21b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 2.0 | 1.20 |
| A2b.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| A8c.png | Dermofit | Melanocytic Nevus | 2 | 4 | 2.0 | 4.00 |
| A8d.png | Dermofit | Melanocytic Nevus | 1 | 2 | 1.0 | 2.00 |
| A8e.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| B125c.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| B157.png | Dermofit | Melanocytic Nevus | 1 | 2 | 3.0 | 3.00 |
| B17a.png | Dermofit | Melanocytic Nevus | 1 | 2 | 3.0 | 3.00 |
| B17b.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| B17c.png | Dermofit | Melanocytic Nevus | 1 | 2 | 1.0 | 2.00 |
| B17f.png | Dermofit | Melanocytic Nevus | 1 | 3 | 2.0 | 2.60 |
| B197d.png | Dermofit | Melanocytic Nevus | 1 | 0 | 1.0 | 1.80 |
| B202b.png | Dermofit | Melanocytic Nevus | 1 | 0 | 3.0 | 2.80 |
| B293b.png | Dermofit | Melanocytic Nevus | 0 | 1 | 1.0 | 0.60 |
| B293d.png | Dermofit | Melanocytic Nevus | 0 | 1 | 1.0 | 0.60 |
| B293e.png | Dermofit | Melanocytic Nevus | 0 | 2 | 2.0 | 1.20 |
| B311c.png | Dermofit | Melanocytic Nevus | 1 | 4 | 1.0 | 2.20 |
| B350a.png | Dermofit | Melanocytic Nevus | 0 | 0 | 1.0 | 0.50 |
| B355b.png | Dermofit | Melanocytic Nevus | 2 | 0 | 1.0 | 3.10 |
| B356.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| B361a.png | Dermofit | Melanocytic Nevus | 0 | 1 | 1.0 | 0.60 |
| B379a.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| B379b.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| B447a.png | Dermofit | Melanocytic Nevus | 2 | 8 | 2.0 | 4.40 |
| B447b.png | Dermofit | Melanocytic Nevus | 1 | 3 | 2.0 | 2.60 |
| B472b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 1.0 | 0.70 |
| B508.png | Dermofit | Melanocytic Nevus | 2 | 5 | 2.0 | 4.10 |
| B522b.png | Dermofit | Melanocytic Nevus | 0 | 0 | 1.0 | 0.50 |
| B52a.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| B52c.png | Dermofit | Melanocytic Nevus | 0 | 4 | 2.0 | 1.40 |
| B543.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| B549c.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| B574.png | Dermofit | Melanocytic Nevus | 1 | 0 | 2.0 | 2.30 |
| B598a.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| B612b.png | Dermofit | Melanocytic Nevus | 1 | 2 | 1.0 | 2.00 |
| B654c.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| B66c.png | Dermofit | Melanocytic Nevus | 0 | 3 | 2.0 | 1.30 |

| | | | | | | |
|-----------|----------|-------------------|---|---|-----|------|
| B676a.png | Dermofit | Melanocytic Nevus | 0 | 3 | 2.0 | 1.30 |
| B676b.png | Dermofit | Melanocytic Nevus | 1 | 4 | 3.0 | 3.20 |
| B69a.png | Dermofit | Melanocytic Nevus | 1 | 2 | 3.0 | 3.00 |
| B69b.png | Dermofit | Melanocytic Nevus | 2 | 2 | 2.0 | 3.80 |
| B89e.png | Dermofit | Melanocytic Nevus | 2 | 1 | 1.0 | 3.20 |
| B91a.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| B91b.png | Dermofit | Melanocytic Nevus | 1 | 6 | 3.0 | 3.40 |
| B91c.png | Dermofit | Melanocytic Nevus | 2 | 0 | 2.0 | 3.60 |
| D144.png | Dermofit | Melanocytic Nevus | 2 | 3 | 3.0 | 4.40 |
| D176b.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| D239a.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| D239b.png | Dermofit | Melanocytic Nevus | 0 | 0 | 1.0 | 0.50 |
| D271a.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| D291b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 2.0 | 1.20 |
| D339.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| D374.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| D384.png | Dermofit | Melanocytic Nevus | 0 | 7 | 2.0 | 1.70 |
| D395.png | Dermofit | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| D404.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| D426.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| D427b.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| D492.png | Dermofit | Melanocytic Nevus | 2 | 1 | 2.0 | 3.70 |
| D526b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 2.0 | 1.20 |
| D567b.png | Dermofit | Melanocytic Nevus | 2 | 2 | 1.0 | 3.30 |
| D626.png | Dermofit | Melanocytic Nevus | 0 | 2 | 3.0 | 1.70 |
| D715.png | Dermofit | Melanocytic Nevus | 0 | 0 | 1.0 | 0.50 |
| D722.png | Dermofit | Melanocytic Nevus | 2 | 6 | 2.0 | 4.20 |
| D723a.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| D726d.png | Dermofit | Melanocytic Nevus | 0 | 7 | 2.0 | 1.70 |
| D726e.png | Dermofit | Melanocytic Nevus | 1 | 3 | 2.0 | 2.60 |
| P103a.png | Dermofit | Melanocytic Nevus | 0 | 3 | 2.0 | 1.30 |
| P126b.png | Dermofit | Melanocytic Nevus | 2 | 1 | 1.0 | 3.20 |
| P144.png | Dermofit | Melanocytic Nevus | 0 | 1 | 1.0 | 0.60 |
| P18.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P196.png | Dermofit | Melanocytic Nevus | 2 | 3 | 2.0 | 3.90 |
| P199.png | Dermofit | Melanocytic Nevus | 1 | 2 | 1.0 | 2.00 |
| P2.png | Dermofit | Melanocytic Nevus | 0 | 3 | 1.0 | 0.80 |
| P237b.png | Dermofit | Melanocytic Nevus | 1 | 6 | 2.0 | 2.90 |
| P256a.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| P271f.png | Dermofit | Melanocytic Nevus | 2 | 2 | 2.0 | 3.80 |
| P277b.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P291.png | Dermofit | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| P304a.png | Dermofit | Melanocytic Nevus | 1 | 0 | 2.0 | 2.30 |
| P306a.png | Dermofit | Melanocytic Nevus | 1 | 0 | 3.0 | 2.80 |
| P306c.png | Dermofit | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| P337a.png | Dermofit | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |

| | | | | | | |
|-----------|----------|-------------------|---|---|-----|------|
| P337b.png | Dermofit | Melanocytic Nevus | 0 | 1 | 3.0 | 1.60 |
| P337d.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| P337e.png | Dermofit | Melanocytic Nevus | 1 | 1 | 1.0 | 1.90 |
| P354a.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| P359b.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| P365d.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| P365e.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P376b.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P376d.png | Dermofit | Melanocytic Nevus | 2 | 5 | 1.0 | 3.60 |
| P382a.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| P384b.png | Dermofit | Melanocytic Nevus | 1 | 2 | 2.0 | 2.50 |
| P384c.png | Dermofit | Melanocytic Nevus | 1 | 7 | 2.0 | 3.00 |
| P392.png | Dermofit | Melanocytic Nevus | 0 | 1 | 3.0 | 1.60 |
| P399.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P404a.png | Dermofit | Melanocytic Nevus | 1 | 0 | 2.0 | 2.30 |
| P404c.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |
| P407b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 2.0 | 1.20 |
| P407c.png | Dermofit | Melanocytic Nevus | 0 | 1 | 2.0 | 1.10 |
| P432.png | Dermofit | Melanocytic Nevus | 2 | 4 | 2.0 | 4.00 |
| P435b.png | Dermofit | Melanocytic Nevus | 0 | 3 | 3.0 | 1.80 |
| P454a.png | Dermofit | Melanocytic Nevus | 1 | 1 | 3.0 | 2.90 |
| P454b.png | Dermofit | Melanocytic Nevus | 0 | 0 | 1.0 | 0.50 |
| P45a.png | Dermofit | Melanocytic Nevus | 2 | 1 | 3.0 | 4.20 |
| P45b.png | Dermofit | Melanocytic Nevus | 1 | 5 | 2.0 | 2.80 |
| P49.png | Dermofit | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| P505c.png | Dermofit | Melanocytic Nevus | 2 | 1 | 2.0 | 3.70 |
| P505e.png | Dermofit | Melanocytic Nevus | 1 | 7 | 2.0 | 3.00 |
| P509c.png | Dermofit | Melanocytic Nevus | 1 | 1 | 2.0 | 2.40 |
| P53b.png | Dermofit | Melanocytic Nevus | 0 | 6 | 1.0 | 1.10 |
| P56b.png | Dermofit | Melanocytic Nevus | 0 | 2 | 3.0 | 1.70 |
| P58.png | Dermofit | Melanocytic Nevus | 0 | 3 | 2.0 | 1.30 |
| P63.png | Dermofit | Melanocytic Nevus | 1 | 6 | 1.0 | 2.40 |
| P88b.png | Dermofit | Melanocytic Nevus | 0 | 0 | 2.0 | 1.00 |

Table 5.5: Results of TDS calculation for Dermfit

| Name | Source | Category | Asymmetry | Border | Color | TDS |
|---------------|-----------|--------------------|-----------|--------|-------|------|
| 012383HB.jpeg | DermQuest | Benign Keratosis | 2 | 5 | 3.0 | 4.60 |
| 012824HB.JPG | DermQuest | Benign Keratosis | 0 | 2 | 3.0 | 1.70 |
| 019462HB.JPG | DermQuest | Malignant Melanoma | 2 | 4 | 3.0 | 4.50 |
| 019475HB.JPG | DermQuest | Malignant Melanoma | 1 | 2 | 3.0 | 3.00 |
| 019523HB.JPG | DermQuest | Malignant Melanoma | 2 | 2 | 6.0 | 5.80 |
| 019563HB.JPG | DermQuest | Malignant Melanoma | 2 | 1 | 4.0 | 4.70 |
| 019578HB.JPG | DermQuest | Malignant Melanoma | 2 | 2 | 2.0 | 3.80 |
| 019681HB.JPG | DermQuest | Malignant Melanoma | 1 | 4 | 3.0 | 3.20 |

| | | | | | | |
|---------------|-----------|--------------------|---|---|-----|------|
| 019682HB.JPG | DermQuest | Malignant Melanoma | 1 | 5 | 3.0 | 3.30 |
| 019725HB.JPG | DermQuest | Malignant Melanoma | 0 | 2 | 4.0 | 2.20 |
| 019736HB.JPG | DermQuest | Malignant Melanoma | 1 | 1 | 3.0 | 2.90 |
| 020192HB.JPG | DermQuest | Malignant Melanoma | 1 | 5 | 4.0 | 3.80 |
| 020250HB.JPG | DermQuest | Malignant Melanoma | 2 | 3 | 3.0 | 4.40 |
| 020266HB.JPG | DermQuest | Malignant Melanoma | 1 | 0 | 3.0 | 2.80 |
| 020268HB.JPG | DermQuest | Malignant Melanoma | 1 | 1 | 4.0 | 3.40 |
| 020302HB.JPG | DermQuest | Malignant Melanoma | 2 | 8 | 4.0 | 5.40 |
| 020319HB.JPG | DermQuest | Malignant Melanoma | 1 | 2 | 5.0 | 4.00 |
| 044936HB.JPG | DermQuest | Malignant Melanoma | 2 | 3 | 4.0 | 4.90 |
| 005613HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 3 | 3.0 | 1.80 |
| 005728HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 3 | 4.0 | 4.90 |
| 005859HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| 005900HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 3 | 5.0 | 2.80 |
| 006027HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 8 | 3.0 | 4.90 |
| 006074HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 6 | 3.0 | 3.40 |
| 006095HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 1 | 4.0 | 2.10 |
| 010769HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 6 | 3.0 | 4.70 |
| 010992VB.jpeg | DermQuest | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| 011031HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 0 | 4.0 | 2.00 |
| 011040VB.jpeg | DermQuest | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| 011201HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 0 | 3.0 | 2.80 |
| 011548HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 1 | 3.0 | 4.20 |
| 011697HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 4 | 4.0 | 3.70 |
| 011697HB.JPG | DermQuest | Melanocytic Nevus | 1 | 4 | 4.0 | 3.70 |
| 011936HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 6 | 3.0 | 3.40 |
| 011936HB.JPG | DermQuest | Melanocytic Nevus | 1 | 6 | 3.0 | 3.40 |
| 021733HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 3 | 1.0 | 2.10 |
| 021835HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 2 | 4.0 | 4.80 |
| 021837HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 0 | 4.0 | 3.30 |
| 021848HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 7 | 3.0 | 4.80 |
| 021852HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 0 | 3.0 | 1.50 |
| 021869HB.jpeg | DermQuest | Melanocytic Nevus | 1 | 0 | 4.0 | 3.30 |
| 021878HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 1 | 3.0 | 4.20 |
| 021902HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 4 | 3.0 | 1.90 |
| 045720HB.jpeg | DermQuest | Melanocytic Nevus | 0 | 1 | 3.0 | 1.60 |
| 046342HB.jpeg | DermQuest | Melanocytic Nevus | 2 | 1 | 3.0 | 4.20 |
| 046343HB.JPG | DermQuest | Melanocytic Nevus | 1 | 6 | 4.0 | 3.90 |

Table 5.6: Results of TDS calculation for DermQuest

| Name | Source | Category | Asymmetry | Border | Color | TDS |
|------------|------------|-------------------|-----------|--------|-------|-----|
| IMD015.bmp | PH2Dataset | Melanocytic Nevus | | 5 | 2.0 | |
| IMD016.bmp | PH2Dataset | Melanocytic Nevus | | 2 | 2.0 | |
| IMD018.bmp | PH2Dataset | Melanocytic Nevus | | 1 | 2.0 | |

| | | | | | |
|------------|------------|-------------------|---|-----|--|
| IMD020.bmp | PH2Dataset | Melanocytic Nevus | 1 | 2.0 | |
| IMD027.bmp | PH2Dataset | Melanocytic Nevus | 7 | 2.0 | |
| IMD038.bmp | PH2Dataset | Melanocytic Nevus | 2 | 3.0 | |
| IMD039.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD043.bmp | PH2Dataset | Melanocytic Nevus | 7 | 3.0 | |
| IMD045.bmp | PH2Dataset | Melanocytic Nevus | 1 | 2.0 | |
| IMD050.bmp | PH2Dataset | Melanocytic Nevus | 6 | 2.0 | |
| IMD078.bmp | PH2Dataset | Melanocytic Nevus | 8 | 3.0 | |
| IMD103.bmp | PH2Dataset | Melanocytic Nevus | 5 | 2.0 | |
| IMD105.bmp | PH2Dataset | Melanocytic Nevus | 4 | 2.0 | |
| IMD107.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD132.bmp | PH2Dataset | Melanocytic Nevus | 5 | 3.0 | |
| IMD133.bmp | PH2Dataset | Melanocytic Nevus | 2 | 2.0 | |
| IMD134.bmp | PH2Dataset | Melanocytic Nevus | 4 | 2.0 | |
| IMD137.bmp | PH2Dataset | Melanocytic Nevus | 5 | 2.0 | |
| IMD139.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD140.bmp | PH2Dataset | Melanocytic Nevus | 5 | 3.0 | |
| IMD142.bmp | PH2Dataset | Melanocytic Nevus | 5 | 3.0 | |
| IMD143.bmp | PH2Dataset | Melanocytic Nevus | 2 | 3.0 | |
| IMD144.bmp | PH2Dataset | Melanocytic Nevus | 2 | 3.0 | |
| IMD156.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD171.bmp | PH2Dataset | Melanocytic Nevus | 4 | 2.0 | |
| IMD173.bmp | PH2Dataset | Melanocytic Nevus | 7 | 2.0 | |
| IMD204.bmp | PH2Dataset | Melanocytic Nevus | 1 | 2.0 | |
| IMD243.bmp | PH2Dataset | Melanocytic Nevus | 8 | 3.0 | |
| IMD256.bmp | PH2Dataset | Melanocytic Nevus | 7 | 2.0 | |
| IMD280.bmp | PH2Dataset | Melanocytic Nevus | 2 | 2.0 | |
| IMD328.bmp | PH2Dataset | Melanocytic Nevus | 1 | 3.0 | |
| IMD331.bmp | PH2Dataset | Melanocytic Nevus | 5 | 3.0 | |
| IMD356.bmp | PH2Dataset | Melanocytic Nevus | 2 | 3.0 | |
| IMD360.bmp | PH2Dataset | Melanocytic Nevus | 1 | 3.0 | |
| IMD369.bmp | PH2Dataset | Melanocytic Nevus | 5 | 3.0 | |
| IMD380.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD382.bmp | PH2Dataset | Melanocytic Nevus | 4 | 4.0 | |
| IMD383.bmp | PH2Dataset | Melanocytic Nevus | 3 | 2.0 | |
| IMD384.bmp | PH2Dataset | Melanocytic Nevus | 5 | 2.0 | |
| IMD392.bmp | PH2Dataset | Melanocytic Nevus | 6 | 2.0 | |
| IMD430.bmp | PH2Dataset | Melanocytic Nevus | 2 | 3.0 | |
| IMD433.bmp | PH2Dataset | Melanocytic Nevus | 4 | 3.0 | |

Table 5.7: Results of TDS calculation for PH2Dataset

Performance Evaluation

Chapters 11.1, 11.2, maybe 11.3

Chapter 6

Machine Learning

6.1 Section Title

6.2 Results of Algorithm

Performance Evaluation

Chapters from book 11.1, 11.2, 11.3, 11.5, 11.6

Chapter 7

Implementaion of the Algorithm

7.1 Section Title

Chapter 8

Concept of the Application

In section 2.2.1 categories of medical smart phone apps were defined. Apps in the same categories might have a similar feature set and capabilities. An app in the Alert / First Response category might have a database that stores important contacts in the user's area and a user interface that allows the user to quickly alert a contact in an emergency situation. An app in the Learning / Educational / Reference category might be modelled as a quiz app which presents the user with a question and several possible answers to choose from. Answers from several questions will can be evaluated and a score is presented to the user at the end of a session. The app would be implemented with a database of questions and weighted answers, as well as an interface that presents the questions to the user sequentially.

One of the goals of this project is to define requirements for an app that provides a risk assessment of a lesion being benign or malignant. A high level description of the primary functionality of the app is the following:

- The smart phone app allows the user to capture and analyse an image of a skin lesion and provide a risk assessment to the user of the lesion being a malignant melanoma.

The user might also like to save the image and results in order to be able to compare it with other assessments in the future, or to review the assessment with a dermatologist. For comparison it might be useful to save associated metadata, such as the date and location on the body of the lesion. For convenience it might be nice to send the assessment and image via email to a specialist for review. Secondary functionality can be described as follows:

- The app allows the user to save or archive the image and corresponding assessment for future comparison and review.
- The user can add, edit, and save metadata associated with the image of the lesion.
- The user can browse archived images, assessments, and associated metadata.
- The user can send a set of images with associated assessment and metadata via email.

8.1 Use Cases

| | |
|-----------------------|---|
| ID | Short Identifier |
| Name | Descriptive Title |
| Description | Use case in user story form |
| Dependencies | dependencies |
| Trigger | The event that starts the Use Case |
| Preconditions | The system state which must be active before the Use Case can occur |
| Normal Flow | Sequence of events that occur during the use case. |
| Alternate Flow | Alternative sequence of events that might occur. |
| Results | triggers |
| Comments | Other infos |

Table 8.1: Use Case Template

| | |
|-----------------------|---|
| ID | UC-1 |
| Name | Capture Image |
| Description | As a user I can capture an image of the skin lesion that I would like to have analysed. |
| Dependencies | None |
| Trigger | The user activated the application and selected the "image capture" navigation item. |
| Preconditions | The system state which must be active before the Use Case can occur |
| Normal Flow | <ol style="list-style-type: none">1. Point the camera at the skin lesion.2. Rotate and move the camera until the skin lesion is centered and optimally sized.3. The user touches the screen to capture the image.4. The user is notified (beep) that the image has been captured5. The user can repeat from the beginning |
| Alternate Flow | None |
| Results | The captured images are placed by the system in a processing queue to calculate the lesion's border. |
| Comments | It is important that a user can capture the image with just one hand. If a lesion is located on a user's hand or arm, it's not possible to use two hands. |

Table 8.2: Use Case 1

| | |
|-----------------------|---|
| ID | UC-2 |
| Name | Confirm correct calculation of skin lesion's border |
| Description | As a user I want to confirm that the skin lesion's borders have been properly calculated. |
| Dependencies | UC-1 |
| Trigger | The user selected the "confirm border" navigation item. |
| Preconditions | At least one image has been queued for border calculation. |
| Normal Flow | <ol style="list-style-type: none"> 1. The user is presented with a list of images. 2. The following step is repeated for each image in the list. 3. The user confirms that the border of the lesion has been precisely calculated. |
| Alternate Flow | <p>A1. Border calculation for image has not completed.</p> <p>A1.3 The user can refresh the image preview until the results of the border are visible.</p> <p>A1.4 The user confirms that the border of the lesion has been precisely calculated.</p> <p>A2 Border calculation is not precise or has failed.</p> <p>A2.3 The user confirms that the border of the lesion has not been precisely calculated.</p> <p>A2.4 The image is deleted.</p> |
| Results | After positiv confirmation, images are placed by the system in the risk assessment calculation queue. If no images can be positively confirmed, the user can recapture new images (UC-1) |
| Comments | |

Table 8.3: Use Case 2

| | |
|-----------------------|---|
| ID | UC-3 |
| Name | View risk assessment |
| Description | As a user I want to view the results of the risk assessment calculation. |
| Dependencies | UC-2 |
| Trigger | The user selected the "risk assessment results" navigation item. |
| Preconditions | The system was able to complete the risk assessment calculation |
| Normal Flow | <ol style="list-style-type: none"> 1. The user is presented with a list of images. 2. The following step is repeated for each image in the list. 3. The user can select and view an image and corresponding results in detail. |
| Alternate Flow | <p>A1. Risk assessment calculation for image has not completed.</p> <p>A1.3 The user can refresh the results details until the results of a risk assessment is available.</p> |
| Results | |
| Comments | |

Table 8.4: Use Case 3

| | |
|-----------------------|--|
| ID | UC-4 |
| Name | Save image and results |
| Description | As a user I want to save the image and the results of the risk assessment. |
| Dependencies | UC-3 |
| Trigger | The user selects the "save" navigation item. |
| Preconditions | The system was able to complete the risk assessment calculation. |
| Normal Flow | <ol style="list-style-type: none"> 1. The user is presented with a list of images. 2. The can select one or more images with the corresponding risk assessment results. 3. The user can add a title and comment. 4. The user is presented with a confirmation that the package has been saved. |
| Alternate Flow | |
| Results | A package of images and corresponding risk assessment data is stored in the archive with some metadata (title and comment). |
| Comments | |

Table 8.5: Use Case 4

| | |
|-----------------------|--|
| ID | UC-5 |
| Name | View archived images and data. |
| Description | As a user I want to view previously saved images and the corresponding risk assessment data. |
| Dependencies | UC-4 |
| Trigger | The user selects the "archive" navigation item. |
| Preconditions | The system was able to complete the risk assessment calculation. |
| Normal Flow | <ol style="list-style-type: none"> 1. The user is presented with a list of archived packages. 2. The user can select an item in the list 3. The user is presented with the images, corresponding risk assessment data and metadata for the selected item. |
| Alternate Flow | |
| Results | A package of images and corresponding risk assessment data is stored in the archive with some metadata (title and comment). |
| Comments | |

Table 8.6: Use Case 5

| | |
|-----------------------|---|
| ID | UC-6 |
| Name | Send results to dermatologist. |
| Description | As a user I want to send a previously saved image, feature extraction data and assessment results to a dermatologist. |
| Dependencies | UC-4 |
| Trigger | The user selects the "archive" navigation item. |
| Preconditions | The system was able to complete the risk assessment calculation. |
| Normal Flow | <ol style="list-style-type: none"> 1. The user is presented with a list of archived packages. 2. The user can select an item in the list 3. The user can send the item as an email attachment. |
| Alternate Flow | |
| Results | |
| Comments | |

Table 8.7: Use Case 6

8.2 User Interface



Figure 8.1: Image Capture View

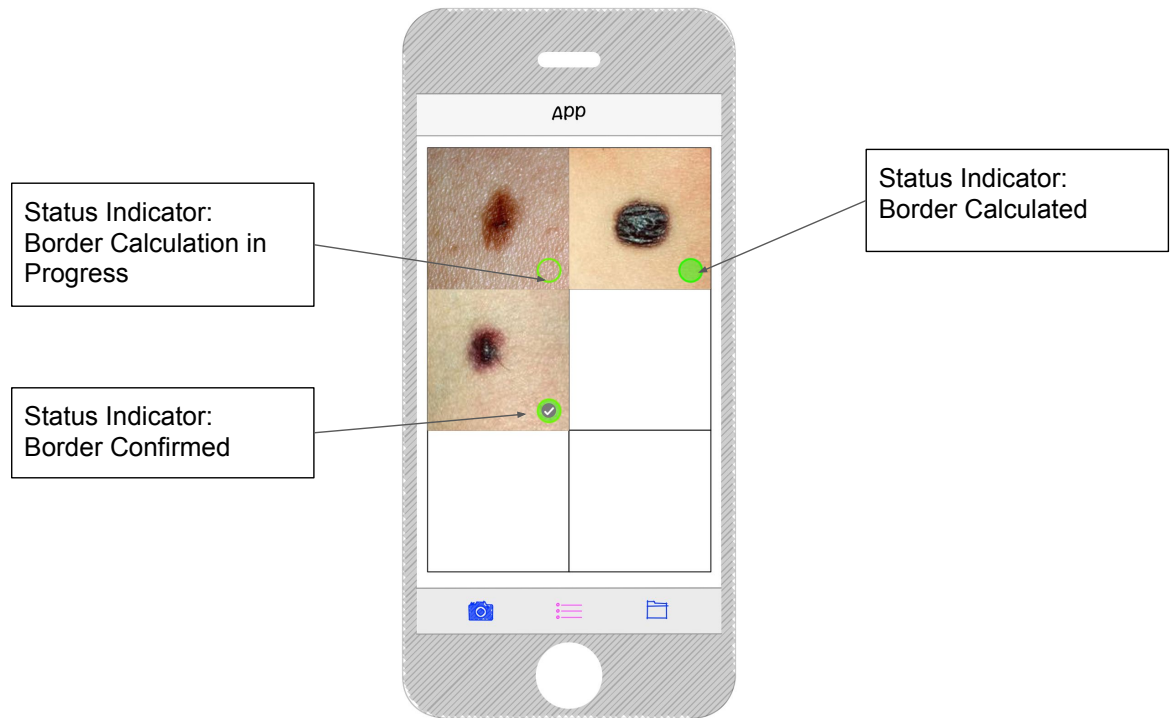


Figure 8.2: Image List View



Figure 8.3: Border Confirm View

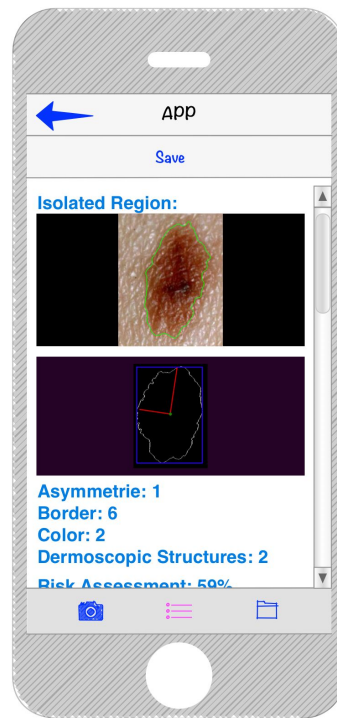


Figure 8.4: Image Detail View

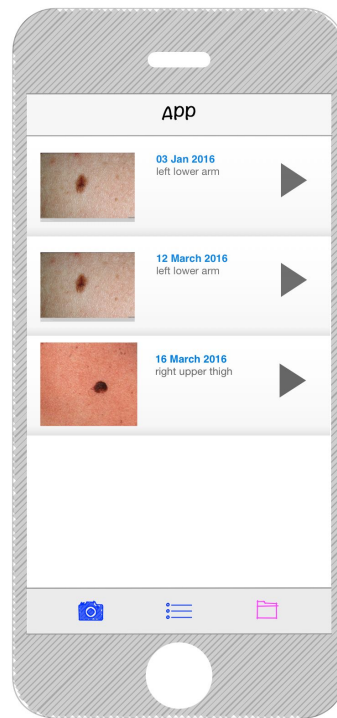


Figure 8.5: Archive View



Figure 8.6: Archive Detail View

8.3 Requirements

8.4 Prioritized Requirements

| ID | Priority | Name | Implemented |
|---------|----------|--------------------------------|-------------|
| REQ-F-1 | - | Preview Camera Input | - |
| REQ-F-2 | - | Capture Camera Input | - |
| REQ-F-3 | - | Border Extraction | - |
| REQ-F-4 | - | Browse Images and Results | - |
| REQ-F-5 | - | Select Image To View in Detail | - |
| REQ-F-6 | - | Border Confirmation | - |
| REQ-F-7 | - | Feature Extraction | - |
| REQ-F-8 | - | Feature Extraction | - |

Table 8.8: Prioritized Requirement List

| | |
|-------------------------|---|
| ID | REQ-F-1 |
| Name | Preview Camera Input |
| Description | The system will let the user view a preview of the camera's input in realtime |
| Preconditions | None |
| Acceptance Tests | |
| Relations | UC-1 |
| Comments | |

Table 8.9: Functional Requirement 1

| | |
|-------------------------|--|
| ID | REQ-F-1 |
| Name | Capture Camera Input |
| Description | The system will let the user capture an image from the camera's input. |
| Preconditions | None |
| Acceptance Tests | |
| Relations | UC-1 |
| Comments | |

Table 8.10: Functional Requirement 1

| | |
|-------------------------|--|
| ID | REQ-F-3 |
| Name | Border Extraction |
| Description | The system must be able to calculate the border of a lesion in a captured image. |
| Preconditions | None |
| Acceptance Tests | |
| Relations | UC-2 |
| Comments | |

Table 8.11: Functional Requirement 3

| | |
|-------------------------|---|
| ID | REQ-F-4 |
| Name | Browse Images and Results |
| Description | The system will let the user browse through a list of images. The list will display the status of the images. |
| Preconditions | None |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.12: Functional Requirement 4

| | |
|-------------------------|--|
| ID | REQ-F-5 |
| Name | Select Image To View in Detail |
| Description | The system will let the user select and view an image as well as the results of completed processes. |
| Preconditions | None |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.13: Functional Requirement 5

| | |
|-------------------------|---|
| ID | REQ-F-6 |
| Name | Border Confirmation |
| Description | The system will let the user confirm that the border of a lesion hat been precisely calculated. |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.14: Functional Requirement 6

| | |
|-------------------------|--|
| ID | REQ-F-7 |
| Name | Feature Extraction |
| Description | The system must be able to extract relavent features from the isolated lesion image. |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.15: Functional Requirement 7

| | |
|-------------------------|--|
| ID | REQ-F-8 |
| Name | Add To Process Queue |
| Description | The system must be able to add an image process job to the process queue |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.16: Functional Requirement 8

| | |
|-------------------------|--|
| ID | REQ-F-9 |
| Name | Assign Image to Process |
| Description | The system must be able to assign an image process to an image process job |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.17: Functional Requirement 9

| | |
|-------------------------|--|
| ID | REQ-F-10 |
| Name | Remove From Queue |
| Description | When an image process job is complete it will be removed from the process queue. |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.18: Functional Requirement 10

| | |
|-------------------------|--|
| ID | REQ-F-11 |
| Name | Process Queue |
| Description | The system will process jobs in the process Queue. |
| Preconditions | |
| Acceptance Tests | |
| Relations | |
| Comments | |

Table 8.19: Functional Requirement 11

8.5 Prioritisation

8.6 Software Architecture

https://en.wikipedia.org/wiki/Architectural_pattern

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Chapter 9

Appendix

9.1 Optimizations

9.1.1 Border Extraction

9.1.2 SFA Threshold