

Prototype of annotation tools for microscopic digital images on Android devices

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Abstract. Reading a slide under a microscope manually is very complicated. An expert may spend 3-4 hours to read a single slide. Moreover, the intra- and inter-observer variability is known to be high. This prototype was developed to simplify the slide-reading process on Android devices in order to accelerate the reading process and generate more accurate information. The prototype allows users to annotate the boundaries of an object. Moreover, the proposed prototype has successfully reconstructed multiple object boundaries into simple closed curves from a limited amount of user input. The coordinates of the annotated objects are stored in a text file (*.txt) that can be used for further analysis. The prototype's performance with respect to time and memory usage are included.

1. Introduction

Knowledge of object recognition on microscopic images is very useful for future study or to diagnose various kinds of disease. In a clinical setting, such knowledge is important to differentiate between normal and abnormal cells. Thus, it is mandatory to gain the correct knowledge.

An expert in object recognition usually uses a slide that is observed through a microscope. It takes 3-4 hours to read a single slide. The intra- or inter-observer variability is known to be high, so it is possible that errors will occur that could lead to serious consequences.

Microscopic image recognition requires precision and skill. Precision usually takes a long time. So, doing research or diagnosing diseases that require microscopic image recognition takes a long time. A kind of tacit knowledge is obtained by reading objects through a microscope, and it is difficult to pass this knowledge on to young doctors. Hence, a tool that allows this reading process shown in big screen, rather than under microscope only, is needed. To help the experts perform their duty, a tool that can annotate a microscopic image is required. In a previous study, a similar tool was developed [1]. The tool does not have ability to perform object reconstruction with limited object boundary information. Also, the tool was designed as a PC-based application, so it does not support doctor mobility. A portable tool with similar specifications capable of object reconstruction is needed.

The remainder of this paper is outlined as follows: the mathematical model is described in Section II. Section III presents an overview of the proposed system. The data and evaluation scenario are presented in Section IV. The discussions in Section V. The conclusion and further works are highlighted in Section VI.



2. Mathematical Model

2.1. Annotation

An annotation is an explanatory note or comment added to a text or diagram. The purpose of an explanation or comment is to facilitate a better understanding of the representation of a text or a diagram. In other words, annotations are made to improve a text or diagram. According to another definition, annotation is the process of enhancing selected images with information to convey a medical object [2], and includes the use of arrows that point to an object, visualization of an object's boundaries, and so on.

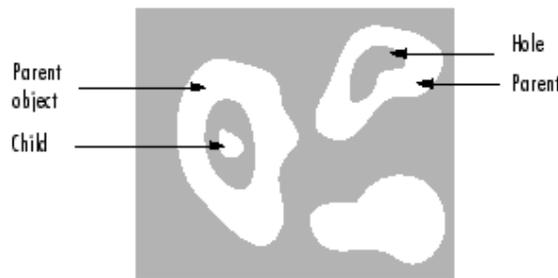


Figure 1. Image annotated with arrows and text

2.2. Digital Images

A digital image is a digital version of a document such as a photograph, literature, art, and so on. The image is represented by a matrix of N rows and M columns, where the elements of the matrix contain gray levels or the colors of each pixel in an image [3].

0	10	0	10	0	10	0
20	0	20	0	20	0	20
0	30	0	30	0	30	0
40	0	40	0	40	0	40
0	50	0	50	0	50	0
60	0	60	0	60	0	60
0	70	0	70	0	70	0
80	0	80	0	80	0	80
0	90	0	90	0	90	0
100	0	100	0	100	0	100

Figure 2. 10 x 10 matrix of an image, the value of each element is in the range of 0 - 2⁸-1

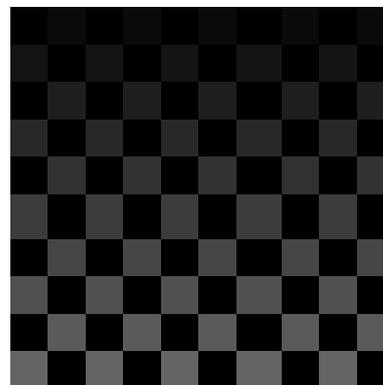


Figure 3. The image generated by the matrix in Figure 1

2.3. Bézier Curve

A Bézier curve is a curve that was introduced by Pierre Bézier in 1962. At that time, Bézier curves were used to design automobile bodies at Renault. These famous curves are now widely used in the field of computer graphics. The curves are made by adjusting certain control points [4], as shown in Figure 4.

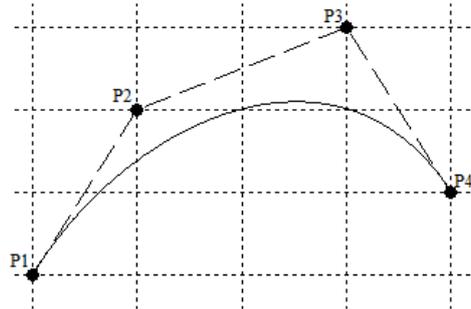


Figure 4. Bézier curve with four points

Given $n + 1$ control points P_0, P_1, \dots, P_n , the Bézier curve of degree n is defined as

$$C(t) = \sum_{i=0}^n P_i B_{i,n}(t) \tag{1}$$

where $B_{i,n}(t)$ is the Bernstein polynomial. The equation is as follows:

$$B_{i,n}(t) = \binom{n}{i} t^i (1-t)^{n-i} \tag{2}$$

$$t \in [0,1] \tag{3}$$

$$\binom{n}{i} = \frac{n!}{i!(n-i)!} \tag{4}$$

The coefficients matrix of Bézier curves is as follows:

$$\begin{bmatrix} 1 & -3 & 3 & -1 \\ 0 & 3 & -6 & 3 \\ 0 & 0 & 3 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

So, to get the curve, the equation is as follows:

$$\begin{bmatrix} x1' & x2' & x3' & x4' \\ y1' & y2' & y3' & y4' \end{bmatrix} = \begin{bmatrix} x1 & x2 & x3 & x4 \\ y1 & y2 & y3 & y4 \end{bmatrix} \begin{bmatrix} 1 & -3 & 3 & -1 \\ 0 & 3 & -6 & 3 \\ 0 & 0 & 3 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} t^0 \\ t^1 \\ t^2 \\ t^3 \end{bmatrix} \tag{6}$$

For the smooth curves, t is as follows:

$$t = \{0, 0.001, 0.002, \dots, 1\} \tag{7}$$

2.4. Interpolation by Relaxed Cubic Splines

Interpolation is a process of estimating intermediate values between precise data points [5]. A cubic spline is a spline constructed of piecewise third-order polynomials with a continuous second derivative [6]. A cubic spline is relaxed if its second derivative is zero at each endpoint. Data points S_0, \dots, S_n are given and the cubic spline curve is $P(t)$ for $0 \leq t \leq n$, such that $P(i) = S_i$; that is, the curve goes through the data points. One approach is to use B-splines as an intermediate step. The appropriate control points B_0, \dots, B_n must be computed prior to the computation of the Bézier control points for the individual pieces.

To compute the B-spline control points, the matrix form for linear equations is as follows (for $n = 5$):

$$\begin{bmatrix} 4 & 1 & 0 & 0 \\ 1 & 4 & 1 & 0 \\ 0 & 1 & 4 & 1 \\ 0 & 0 & 1 & 4 \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} = \begin{bmatrix} 6S_1 - S_0 \\ 6S_2 \\ 6S_3 \\ 6S_4 - S_5 \end{bmatrix} \tag{8}$$

The coefficients matrix of the cubic spline (which is usually called the “1 4 1 matrix”) for this relaxed cubic spline will have an M square matrix, where $M = n - 1$. To compute the Bézier control points, the equation is as follows:

$$\begin{bmatrix} S_i - 1 \\ \frac{2}{3}B_{i-1} + \frac{1}{3}B_i \\ \frac{1}{3}B_{i-1} + \frac{2}{3}B_i \\ S_i \end{bmatrix} \tag{9}$$

A relaxed cubic spline is shown in Figure 5.

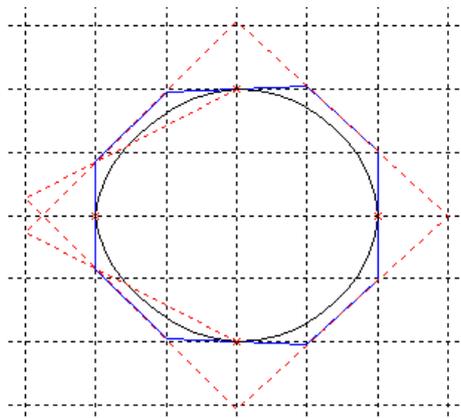


Figure 5. Relaxed cubic spline

3. Proposed System Overview

This prototype will be developed for Android devices. The use of Android devices is intended to support doctor mobility.

This prototype uses a common image format like .jpg, .bmp, and so on. Users can run the prototype in the following order.

- Choose an image that will be annotated
- Mark the boundaries of the object by dragging on the desired location
- Users can use the zooming facilities by pinching the desired location
- The system will automatically reconstruct the object
- After users complete the annotation and save it, the system automatically stores all the object coordinates in a .txt file.



Figure 6. System flow: (1) the initial view of the prototype, (2) displaying the image that will be annotated, (3) user's given object boundaries (with zooming facility), (4) system's generated closed curve, (5) curve that has been saved, (6) final appearance of the object that has been annotated (zooming out)

4. Data and Evaluation

The data used in this research were HER2 microscopic images obtained from the Universitas Islam Indonesia Pathology Laboratory. These data will be used for testing the performance of this prototype. The Android device used in this research is a Samsung Galaxy Tab GT-P3110, and the operating system is Android Jelly Bean version 4.1.2. The IDE used to develop this prototype is Android Studio 1.3.2.

The performance to be tested is the ability of the system to reconstruct an object using the limited information of object boundaries. Figure 7 is the image that was used in this test.

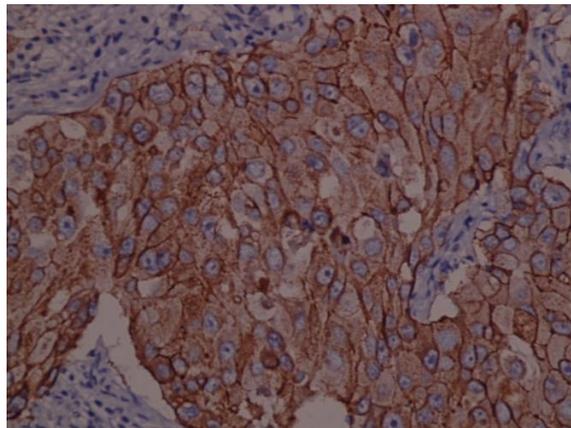


Figure 7. Microscopic image that was used has a resolution of 1175 x 881 pixels and is 299 KB.

Two objects in the image in Figure 7 were annotated to test the performance of the prototype, as shown in Figure 8.

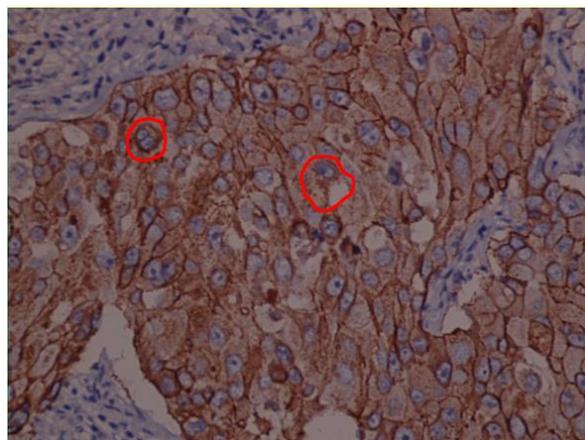


Figure 8. Two objects are annotated in the image in Figure 7: object one (left, Figure 9), object two (right, Figure 10).



Figure 9. Object one



Figure 10. Object two

Table 1 shows the performance details of the proposed prototype when performing object reconstruction.

Tables 1. Performance details for object reconstruction

Process	Object 1	Object 2
CPU Usage	51.39 %	51.79 %
Memory Usage	17.04 MB	19.82 MB
User Input Point	45 points	33 points
B-Spline Control Point	47 points	35 points
Bézier Control Point	176 points	128 points
Reconstructed Point	316 points	414 points
Time to reconstruct	2428 milliseconds	1835 milliseconds
Time to save object	45 milliseconds	56 milliseconds

5. Discussion

The proposed system has been running according to the required functions. The system has been able to display the selected image. The system has also successfully responded to the user dragging on the screen and has translated that into object boundary information, as shown in Figure 11. From that information, the system has been able to reconstruct the object into a simple closed curve, as shown in Figure 12.

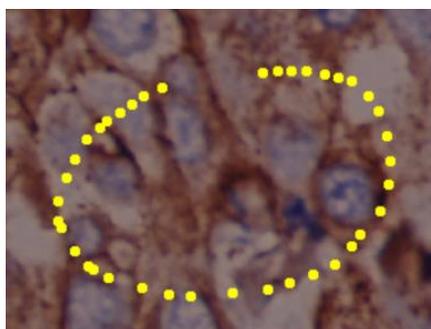


Figure 11. System responses to a user's continuous touch (dragging) on the image in Figure 7.

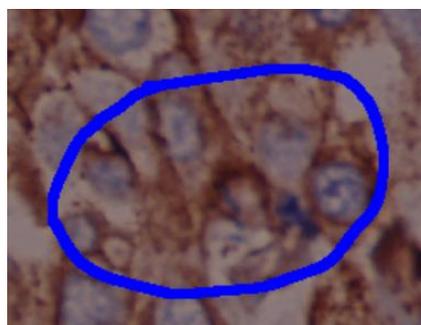


Figure 12. Simple closed curve generated by the system on the image in Figure 7.

The system has also been able to store the results of the object reconstruction in a .txt file. The stored results have demonstrated that the system can perform automatic incremental numbering of objects. In other words, this prototype can be used to annotate multiple objects in a session, as can be seen in Figure 8. As the stored coordinates were provided by experts, they can be used further as "truth" when comparison between any automatic segmentation results were needed. Moreover, this information can also be used as boundary in any feature extraction steps.

6. Conclusions and Further Works

The proposed prototype annotation system has been able to annotate an object and reconstruct it. The reconstructed curve was in the form of a smooth simple curve. The object can be reconstructed even if the boundaries of the object given by the user are limited. The development of this system has also

demonstrated that Android devices are capable of performing computing processes adequately. It can be seen that Android devices can do work in the field of computer graphics.

While the curves are programmed to be closed, the resulting shape should also accurately represent the original shape of the object. The expert opinions on the reconstructed objects will be evaluated. The proposed prototype can also be used by doctors to collect images of individual cells or objects. These collections can serve as a knowledge base of the selected objects.

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