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Using Fast Frame Decomposition and Sorting by Contour Tracing Mobile Phone Comic Imaging System

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Abstract — *As one of the mobile phone contents, electronic books and magazine, especially comics, are expected to have great potential. In order to view comics on mobile phones, the resolution and the size of screens must be adequate. A comic then needs to be decomposed into frames and put them in order so that they can be read properly. However, it is known that accurate decomposition is not an easy task. In this paper, we propose a fast and accurate clipping method using contour tracing and evaluate it comparing with an existing commercial system.*

Keywords— Comic, mobile phone, image processing, layout analysis

I. INTRODUCTION

With the spread of the Internet in recent years, the E-book market is growing very fast in Japan as shown in Figure 1.

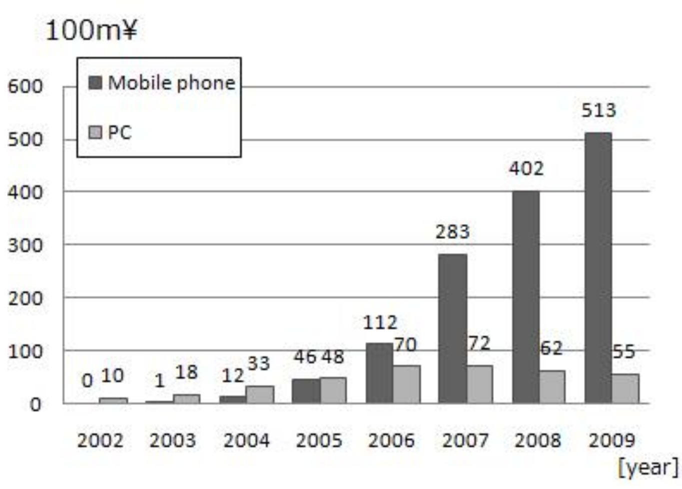

Figure 1: The E-book market in Japan.

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The Japanese market is three times larger than that of the U.S. and more than 70% is comics for mobile phones. It would not be an exaggeration to say that the E-book market in Japan is supported by the comics for mobile phones.

It is difficult to read the comic when the entire page is displayed on the small LCD screen of the mobile phone. For this reason, a method for sequentially reading each of the whole comic pages has been proposed in [1]. In this method, for each frame, the display order and the region information are required. Thus, methods for automatic detection of this information are currently and widely under research [2-5]. One example of such systems in commercial use is the MangaGet service provided by SpicySoft [6] in Japan. However, there are a number of problems with these conventional systems when applied to mobile phone displays.

To address the above-mentioned problems, this paper proposes a new and novel method for frame decomposition and sorting, and evaluates it against commercial methods in use.

II. EXISTING FRAME DECOMPOSITION AND SORTING METHODS AND THEIR PROBLEM

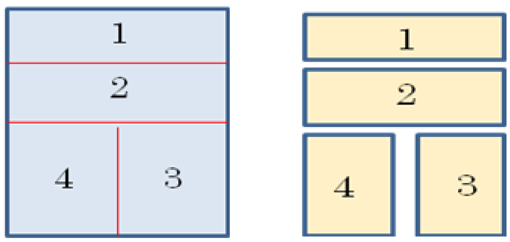
So far, Ishii, et al [2-3] and Tanaka, et al [4-5] have proposed methods for frame decomposition and sorting of comic images.

In these methods, the processing involves recursively bisecting the dividing lines of the comic image, as shown in Figure 2(a).

However, for comic images, there are cases in which there is no information outside the margin to the edge of the frame as shown in Figure 3. The above methods do not take such situations into consideration resulting in some useless margin being included in the divided region. For terminals with not enough display screen size the region of the frame around the margin becomes small and difficult to read. Thus the above approach will not always achieve the appropriate decomposition for mobile phone displays.

Presently the MangaGet system employs a decomposition and sorting method for comics that allows users to browse the comics on mobile phones.

Here, by clipping the part of the comic frame so that it can fit the mobile phone screen, performing necessary corrections, and then uploading it to the server, the user can be able to browse the comic on the mobile phone. This concept is depicted in Figure 2(b). As for the MangaGet system, the above problem is addressed, although not publicly available. However, in some cases, the order in which the regions are displayed is not correct. After automatic detection, it is necessary to make the correction manually. To reduce this burden of manually correcting the frames, a high speed and highly accurate method of analyzing frame decomposition is necessary. In this paper, we consider the margins between the frames of the MangaGet system and propose a highly accurate method of frame decomposition.



(a) The line division method. (b) The MangaGet method

Figure 2: An illustration of existing methods.

Figure 3: An example that shows the existence of margins outside the frame. (Source: Title MAJOR, Publisher Shogakukan, Vol. 1, p.133).

III. PROPOSED METHOD OF FRAME DECOMPOSITION AND SORTING

In this paper, we focus on frame decomposition method that takes into consideration the margins of MangaGet frames that is suitable for mobile phone terminals with small LCD display size. However, the above system is not publicly available. We therefore use the Ishii and the Tanaka methods as the basic methods and aim to reduce the blank margin regions with the goal of displaying comics on mobile phones. Our new method applies weighting to existing region information as part of the comic image processing.

(i) The region in which the comic image information exists is detected by contour scanning. In order to clarify the outline of the closed region obtained, weighting is applied to the pixels using Equation (1).

$$C(x,y)=\begin{cases} a_0 : \text{Contour} \quad \text{pixel} \\ a_1 : \text{Any other} \quad \text{pixel} \end{cases} \tag{1}$$

The parameters (x, y) of above equation represents the coordinates of the pixel on the image. In addition, empirically determined values, $a_0 = 1$ and $a_1 = 0.75$ are used. By this approach, it would be easy to detect regions where image information exists and regions which make up the margin when the line detection for frame decomposition is performed. In this paper, contour scan refers to the operation of raster scanning followed by contour extraction.

Figure 4 illustrates the contour scanning result where the regions containing the image information are determined.

Figure 4: Information-containing regions diagram (Source: Title ONE PIECE, Publisher Shueisha, Vol. 1, p.151)

(ii) We explain the process of using division lines to perform region decomposition. As a property of comics, every frame is bounded by lines. For this reason, in order to detect lines that are almost straight, we use a morphological operator [7] for line thinning and then use the Hough transform [8] for line detection. A point in the Hough space, (ρ, θ), is found and Equation (2) is used to express the equation of the straight line.

$$\rho = x\cos\theta + y\sin\theta \quad (2)$$

In the above equation, ρ is the length of the straight line from the origin and θ is the angle of the line with the x-axis.

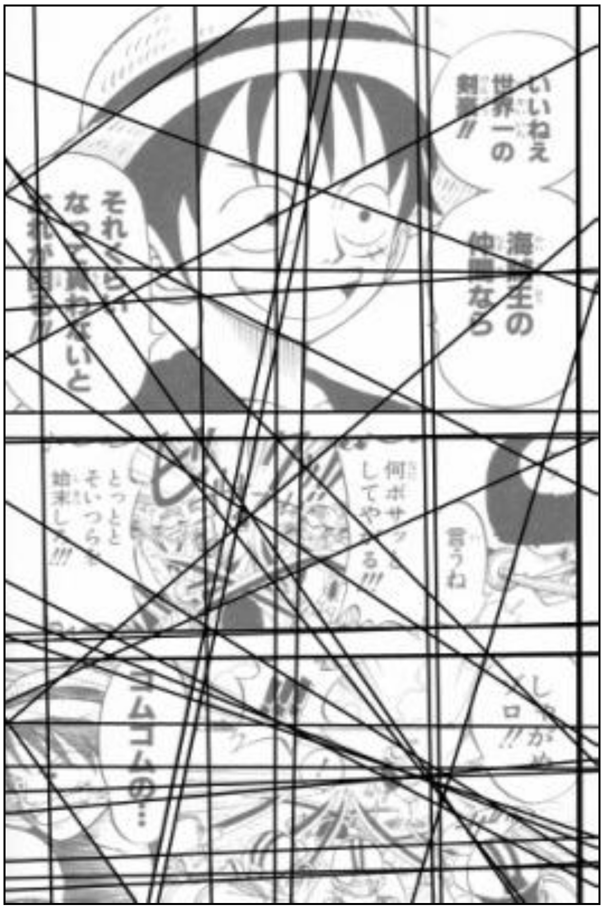


Figure 5: Straight lines obtained by the Hough transform.

For the detected lines, all lines with θ less than or equal to K° and the difference in ρ within M are treated as one line. Here, we use the settings K° =1 and M=10. In this way, extremely narrow blank margins regions between the frames are ignored. The resulting straight line image pixels are denoted by L(ρ,θ). Additionally, by using pixels L(ρ,θ) and the neighboring pixels denoted by M(ρ,θ), the intensity gradient at pixel (x,y) is calculated by Equation (3) as follows:

$$g_\theta(x,y) = g_x(x,y)\cos\theta + g_y(x,y)\sin\theta \quad (3)$$

Where,

$g_x(x,y)$: Horizontal intensity gradient

$g_y(x,y)$: Vertical intensity gradient

There are cases in which part of the picture and the Serif extends outside the frame into the blank margin and cases where the shape of the frame is not polygonal. In these cases, frame division lines cannot be detected well. To deal with these cases, we consider L(ρ,θ)'s neighboring pixels,M(ρ,θ).

Based on our much experience, when frame decomposition is performed, the center of the image is likely to have straight lines. For this reason, the Gauss function given by Equation (4) and shown in Figure 6 is used as weighting for images with straight lines.

$$G(\rho) = \exp(-\frac{\rho^2}{\sigma^2}) \qquad (4)$$

Where,

σ: The height of the image divided by four.

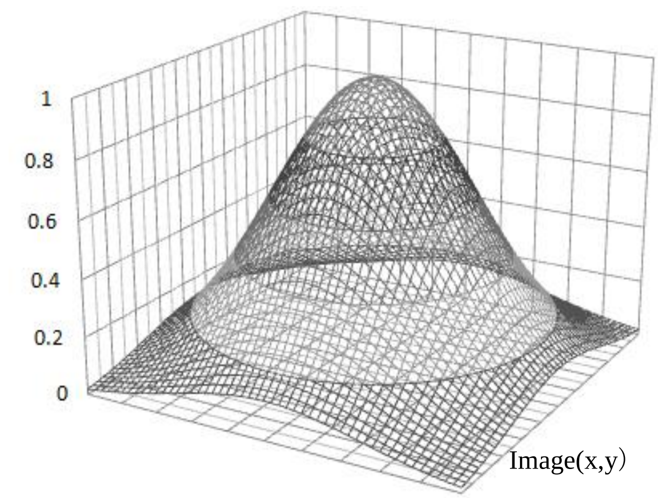


Figure 6: Gauss function used for weighting the image.

By this weighting function, lines that are close to the center of the image are assigned big weights, while those away for the center of the image are assigned small weights.

Using Equations (1), (2), (3) and (4), the values A(ρ,θ) determined by the line division process for straight lines L(ρ,θ) are given by Equation (5).

$$A(\rho,\theta) = G(\rho) \sum_{(x,y)\in M(\rho,\theta)} \{g_\theta(x,y)C(x,y)\} \quad (5)$$

In the above equation, if θ is between 45° and 135° candidate horizontal lines assumed, and if the condition is not satisfied, vertical candidate lines are assumed. Also, since a large weight $C(x, y)$ is added to straight line along the frame, straight lines near the center of the image are detected as candidate frame division lines. In this way, when performing frame decomposition, large blank margins are detected as frames but they are deleted during sorting, resulting in high precision decomposition and sorting of frames.

The frame decomposition and sorting process is done as follows. First, using the comic as input image, the detected division lines with the largest values of A(ρ,θ) are separated. In this case, whether the division lines that will become the target surround the whole rectangular area of the entire image or not, is used as a criteria deciding division lines and non-division lines. In the case of horizontal dividing line, top and bottom edges of the rectangular region are decided, in the case of vertical dividing lines, the left and right edges are decided, and by the focusing on these division lines, the image is partitioned into two. If the above is not the case, then the process is terminated without division. For the divided region, a square surrounding region is again formed, and using the above process recursively to determine the dividing lines, we split the comic image into two. When performing the division, regions that are split into the top and button by a horizontal dividing line are processed from the top to the bottom region. Similarly regions that are split by a vertical line are processed from the left region to the right region. In this way, the frame sorting is performed by a tree structure. At the same time, regions with no information are deleted. The processing flow chart is shown in Figure 7.

The tree structure example is shown in Figure 8. The numbers are shown by the order of the frame.

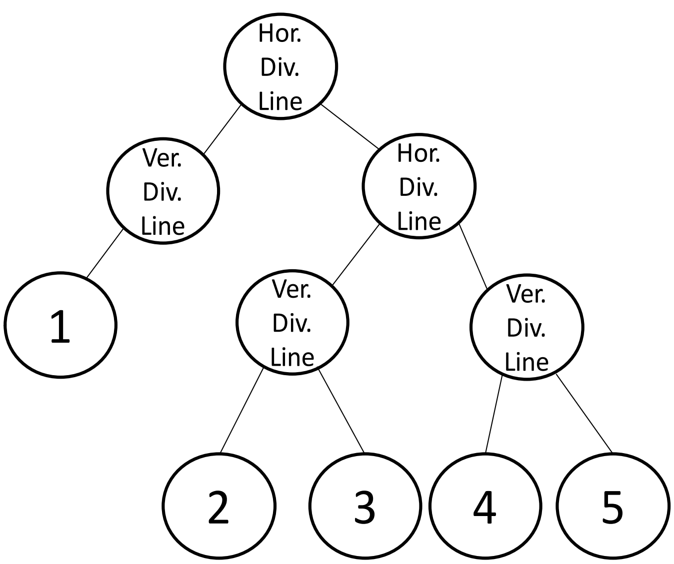


Figure 8: The tree structure that is used for frame sorting (Hor. Div. Line: Horizontal Division Line, Ver. Div. Line: Vertical Division Line).

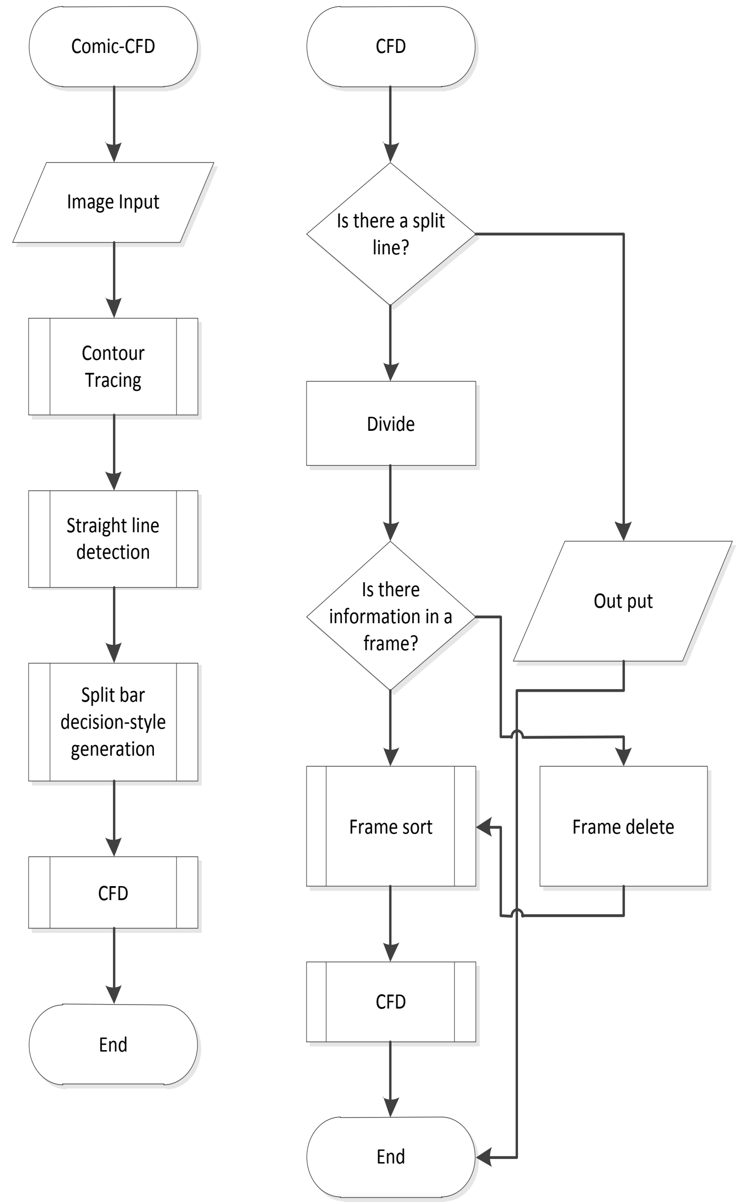


Figure 7: Comic-CFD Processing flow chart.
(Comic-CFD: Fast Frame Decomposition and Sorting by Contour tracing for Comic Image)

The results of comic image processing by the conventional method and the Comic-CFD are shown in Figure 9. In addition, Figure 10 shows a typical example that easily shows the difference between the conventional method and proposed method.

(a) Conventional method.

(b) Proposed method.

Figure 9: Comparison of the conventional and proposed methods.

Figure 10 shows a character with a piece protruding the drawing in which the extra information is excluded and the frame is naturally divided.

(a) Conventional method.

(b) Proposed method.

Figure 10: Comparison of the conventional and proposed methods [2].（Source : Title SLAM DUNK, Publisher: Shueisha, Vol. 1, p.23）

IV. EXPERIMENTS

For the proposed Comic-CFD method, the performance of the method with respect to the required region and the processing order for a mobile phone display was evaluated for each using comic database images.

A . Experiment Setting

In total, 2037 pages of 32 different comics were used in the experiment. The images of cartoon genre boy, girl/woman and youth were selected from published copies [9] in representative genre for young comics. With the assistance of Seikei University's Cartoon Research, Persian Cat members, a database of correct image regions and processing order was built.

Table 1 below shows the quantity and the resolution of the images at the time of scanning. The computing environment is shown in Table 2.

Under these conditions, the Comic-CFD method was run. Table 3 shows the average processing time for each genre of the comics. In this case, multithread processing [10] was carried out, resulting in high processing speed.

Table 1: Number of images and resolution.

Cartoon Genre	Number(page)	Resolution
Boy	961	144dpi
Girl/woman	512	
Youth	564	

Table 2: Computing Environment.

CPU	Intel Core2Quad Q6600 2.4GHz
Main Memory	4GB
OS	Windows Vista

Table 3: Average processing time for each genre.

Cartoon Genre	Average processing time [ms/page]
Boy	44.45
Girl/woman	61.01
Youth	45.05

B. Success Rate of Frame Decomposition

In this section, we verify the accuracy of the proposed frame decomposition method. We compared the frame region information generated by the Comic-CFD with true information generated manually. As shown in Figure 11, if the difference in coordinates of all the four corner points is within a distance of K pixels, then correct region recognition is deemed to have been achieved. Based on our experience, we set the value of K to 30 pixels.

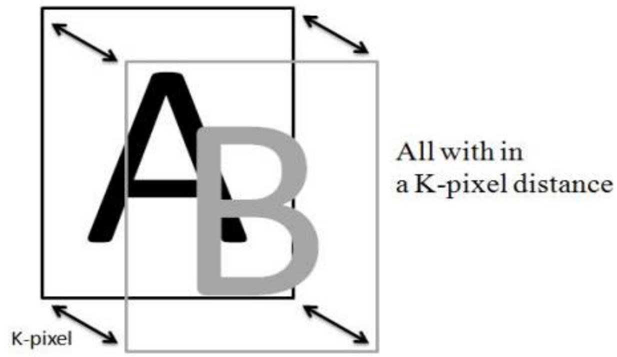


Figure 11: Comparison of frame region distance.

Figure 12 shows the success rate of frame decomposition. For evaluation, the Precision given by Equation (6), the Recall ratio given by Equation (7) and the Degree of Accuracy given by Equation (8) were used.

$$P = \frac{S}{N} \quad (6) \quad , \quad R = \frac{S}{C} \quad (7) \quad , \quad F = \frac{2PR}{P+R} \quad (8)$$

Where,
S:number of correct frames detected
N:number of frames detected
C:number of correct frames to be detected.

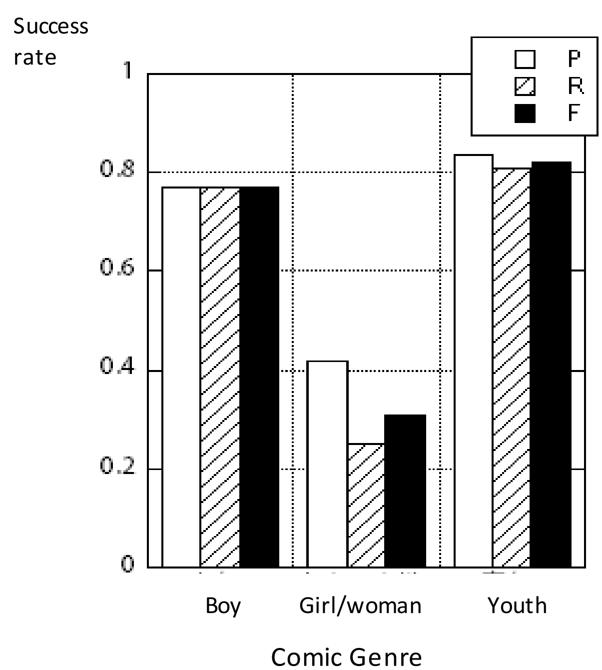


Figure 12: Frame region recognition results by genre.

(a)

(b)

Figure 13: Examples of complex frame division (a) (Source: Title NAISHO NO TSUBOMI, Publisher Shogakukan, Vol. 1, p.89) and (b) (Source: Title ONE PIECE, Publisher Shueisha, Vol. 1, p.113)

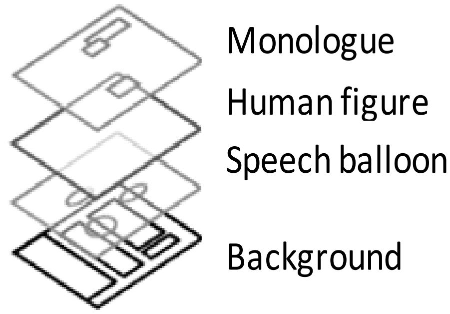


Figure .14: An illustration of the complex layered structure.

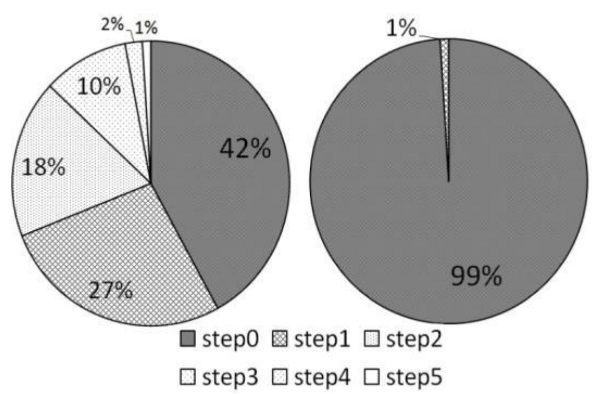
The results show that complex frames give low success rate. Also, the boy and youth genre, where the layered structure is as complicated as shown in Figure.13(b), the success rate of frame region division is low. However, Figure 12 showed in total very high precision in Boy and Youth.

C. Frame Sorting

Based on successful frame division, frame sorting accuracy was evaluated. We use MangaGet method for comparison. In order to evaluate sorting, the order of frames belonging to the same set is changed, and then the number of steps required to restore correct order is used as a performance measure. For example, a comic image having frames with order A, B, C is changed to order A, C, B. By interchanging B and C, the correct order can be restored in one step.

Using the evaluation method defined above, the results are shown in Figure . 15

The verification result shows that the MangaGet method gives a frame sorting success rate of 42% (corresponding to 0 steps) while the proposed Comic-CFD method gives a very high accuracy of 99%. The MangaGet method gives fewer mistakes for sorting from to bottom, but the number of mistakes increase when sorting from left to right. In addition, the Comic-CFD approach only gives sorting errors for the case shown in Figure 16. The error arises in this case since the final result depends on whether the division is done in the vertical direction or horizontal.



(a) Conventional method. (b) Proposed method.

Figure 15: Evaluation of frame sorting for the two methods.

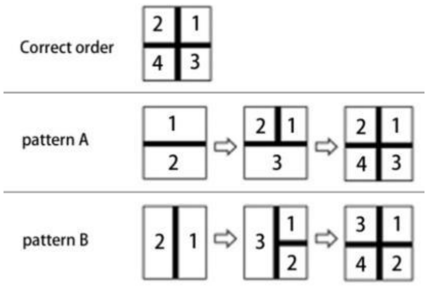


Figure 16: A diagram that illustrates failure of the Comic-CFD frame sorting. Pattern A: Case when horizontal division is performed first (success). Pattern B: Case when vertical division is performed first (failure)

V. Conclusion

In this paper, we proposed and evaluated a method of frame decomposition and sorting using information bearing regions of the comic image for the purpose of displaying comics on a mobile phone screen. Frame decomposition results depend on the comic genre. For example, the girl/woman genre shows low precision while the boy and youth genre gives a high precision of about 80%. In additionn, frame sorting gave a very high accuracy of 99% by the proposed method for all of genre, The boy , Girl/Women and Youth.

In order to develop further this kind of Fast Frame Decomposition and Sorthing System, it will be necessary to compare the perfoamance of the proposed contour tracing method with vector procecssing method[12-15].

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