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Active Contour Model with Splitting Characteristics for Multiple Area Extractions and its Hardware Realization

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Abstract: In this paper, a new Sampled Active Contour Model (ACM) and its hardware realization method are proposed. The proposed Sampled-ACM is a virtual closed curve with some contour points to extract a specified area in images. Forces, such as “pressure”, “attraction”, “repulsion” and “vibration factor” work on every contour point of the proposed Sampled-ACM. The proposed Sampled-ACM only accesses the memories on which the contour points locate, the number of the memory access is reduced, and the faster processing speed is performed than ordinal contour models such as Snakes. The proposed Sampled-ACM has characteristics which reverses direction of attraction by the basis of specific conditions and also has splitting characteristics for multiple area extractions. The proposed Sampled-ACM is realized on FPGA (Field Programmable Gate Array) to construct a real-time hardware equipments. The experimental results to confirm the fast processing abilities of the proposed Sampled-ACM are also included.

Keywords: Active Contour Model , Splitting characteristics , FPGA

1. INTRODUCTION

In these days, TV conferences are frequently held by means of fast communication networks. In most of the current teleconferencing systems, full view images of a conference room and voice of speakers are bidirectionally exchanged between distant places. In teleconferencing situations, face images of speakers are also requested to perceive facial expressions. One solution for taking both full view images of a conference room and face images of speakers is a multi camera system with human operations. Such a multi camera system is usually adopted and is easy to construct, however, switching images from cameras is troublesome task and costs a great deal. Considering these points, we have proposed a camera with speaker-oriented face extraction functions as another solution for this problem.

Face extraction is one application of area extraction techniques and is developed by several methods such as spatial filtering methods. Active contour model, originally proposed by Kass et al., is one of such area extraction techniques. Kass’s Active Contour Model (Snakes) solves image energy minimization problems. Various features of images, such as color of pixels or sharpness of specified areas, can be considered as image energies in Snakes, and flexible area extraction systems are easily constructed.

Area extraction systems can be realized flexibly by using Snakes, however, Snakes require large amount of calculations and long computational times to solve energy minimization problems. Large amount of calculations and long computational times make it impossible to implement area extraction functions based on Snakes in stand-alone system. Considering these points, Hashimoto et al. proposed new type of Active Contour Model named as Sampled-ACM to decrease computational costs[1]. In this model, area extraction problems are assumed as force balancing problems of sampling points on the closed curves. By using the Sampled-ACM, fast area extraction is available because of they just calculate sum of forces which works on each contour points.

A new force called a vibration factor is introduced by Sugahara et al. for improving accuracies against noises in images and they have tried to realize Sampled-ACM with vibration factor as hardware circuits in FPGA (Field Programmable Gate Array)[2]. The Sampled-ACM realized as hardware circuits makes easy implementation of area extraction function in the stand-alone systems, however, it extracts only one area in the images.

Cameras used for teleconferencing mentioned above are requested to have abilities to extract multiple faces in images of attendees. In this paper, a split-ACM is proposed to extract multiple area extraction in images. The model is realized as hardware circuits on a FPGA chip for easy equipment to embedded real-time image processing systems. Experimental results of real-time video signal processing are included to confirm effectiveness of proposed split-ACM.

2. SPLIT ACTIVE CONTOUR MODEL

2.1 Sampled Active Contour Model

Conventional Snakes are energy minimizing closed curves guided by external constraint forces. However, they have outstanding abilities for area extractions, and cost large computational complexities. For decreasing the computational costs, Sampled Active Contour Model (Sampled ACM) is proposed by Hashimoto et al. and is improved by Sugahara. Sampled ACM is a virtual closed curve with some contour points to extract a specified area in images. Forces, such as “pressure”, “attraction”, “repulsion” and “vibration factor” work on every contour point of the proposed Sampled-ACM. The proposed Sampled-ACM only accesses the memories on which the contour points locate, the number of the memory accesses is reduced, and the faster processing speed is performed than the ordinal contour models such as Snakes.

2.2 Four Forces work on Contour Points

Figure 1 shows the appearance where a closed curve is shrunk by four forces which work on contour points of a closed curve.

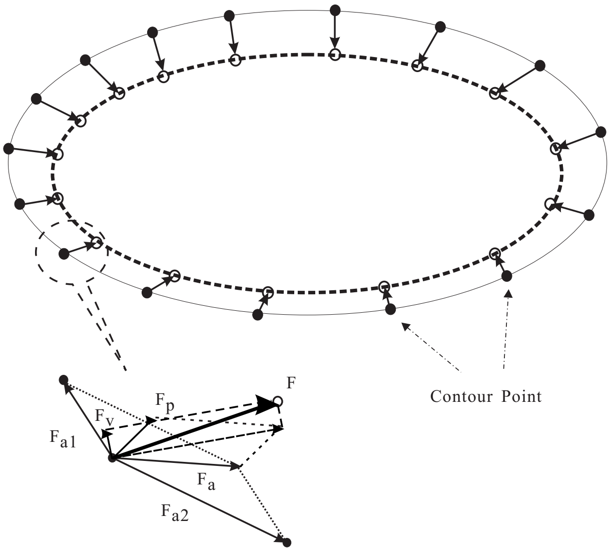

Fig. 1 Sampled-ACM

The pressure F_p affects every contour point, and F_p points in the direction to bisect the angle made of the target point and its adjacent points. The magnitude of F_p is represented as K_p which is the pressure constant. The two attractions F_{a1} and F_{a2} also affect every contour point and their magnitude are proportional to the distance between the target point and its each adjacent contour point. The vibration factor F_v has constant magnitude and it works perpendicularly to the sum of F_p and $F_a = F_{a1} + F_{a2}$.The direction of the vibration factor reverses each turn of convergence.

When a contour point hits the edge of a specified area in an input image, the repulsion F_r works to cancel the vertical component of $F = F_p + F_a + F_v$ and the contour point stays at the edge of the area.

2.3 New pressure and split ability

Sole area in images is able to be extracted by means of the contour model mentioned above. However, when targets area are multiple in images, the areas are not able to be extracted correctly by using the conventional models. In Fig.4(b), a typical example of the converged contour points of the model without split abilities is shown. As shown in this figure, forces on contour points between multiple areas balance forming a concave curve. Such a balance is caused, because attractions F_a at this moment works in the direction of the outside of the closed curve and cancels pressure F_p as shown in Fig.2.

To avoid this problem, a new type of Sampled-ACM is introduced here. The new model has following new characteristics, that is, 1)as shown in Fig.3 (b), the direction

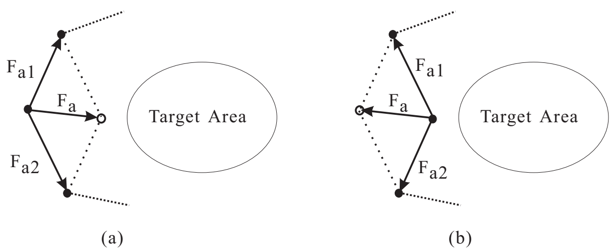

Fig. 2 Conventional attraction

Table 1 FPGA specifications

Manufactured	ALTERA Co.Ltd.
Model number	EP1C20F400C7
Number of logic elements	20,060
Max. I/O port number	301
Package	400-Pin FineLine BGA
Package size	21×21 [mm]
Frequency	48[MHz]

of the new attraction always faces inside of the closed curve and its magnitude is equal to $F_{a1} + F_{a2}$, 2) when any two contour points come close, the closed curve is split as shown in Fig.4.

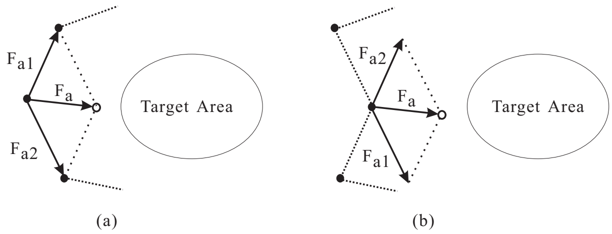

Fig. 3 New attraction

Figure 4(a) shows the initial Sampled-ACM. Figure 4(b) shows the Sampled-ACM before splitting behaviour and the same result can be obtained by using conventional Sampled-ACM. Mesuring distances between contour points, when they become shorter than certain distance given as threshold value h, Sampled-ACM starts splitting behaviour as shown in Fig.4(c) and (d). Same process is continued until getting final results as shown in Fig.4(d) and (e).

3. HARDWARE REALIZATION OF ACTIVE CONTOUR MODELS

The proposed Sampled-ACM is realized on a FPGA chip as hardware circuits for easy constructions of embedded real-time systems. FPGA is LSI that has reconfigurable inner circuits. The operation clock applied to the FPGA is 48MHz. The Logic Element number is 20,060. These specifications are summarized in Table 1.

For experiments, a video signal processing system is developed by using a FPGA, a video decoder and encoder LSIs, and memories. The block diagram of the developed system is shown in Fig.5.

In this system, the memories are constructed as three banks and these banks can be read/written by FPGA simultaneously. By using three bank memories, inputting,

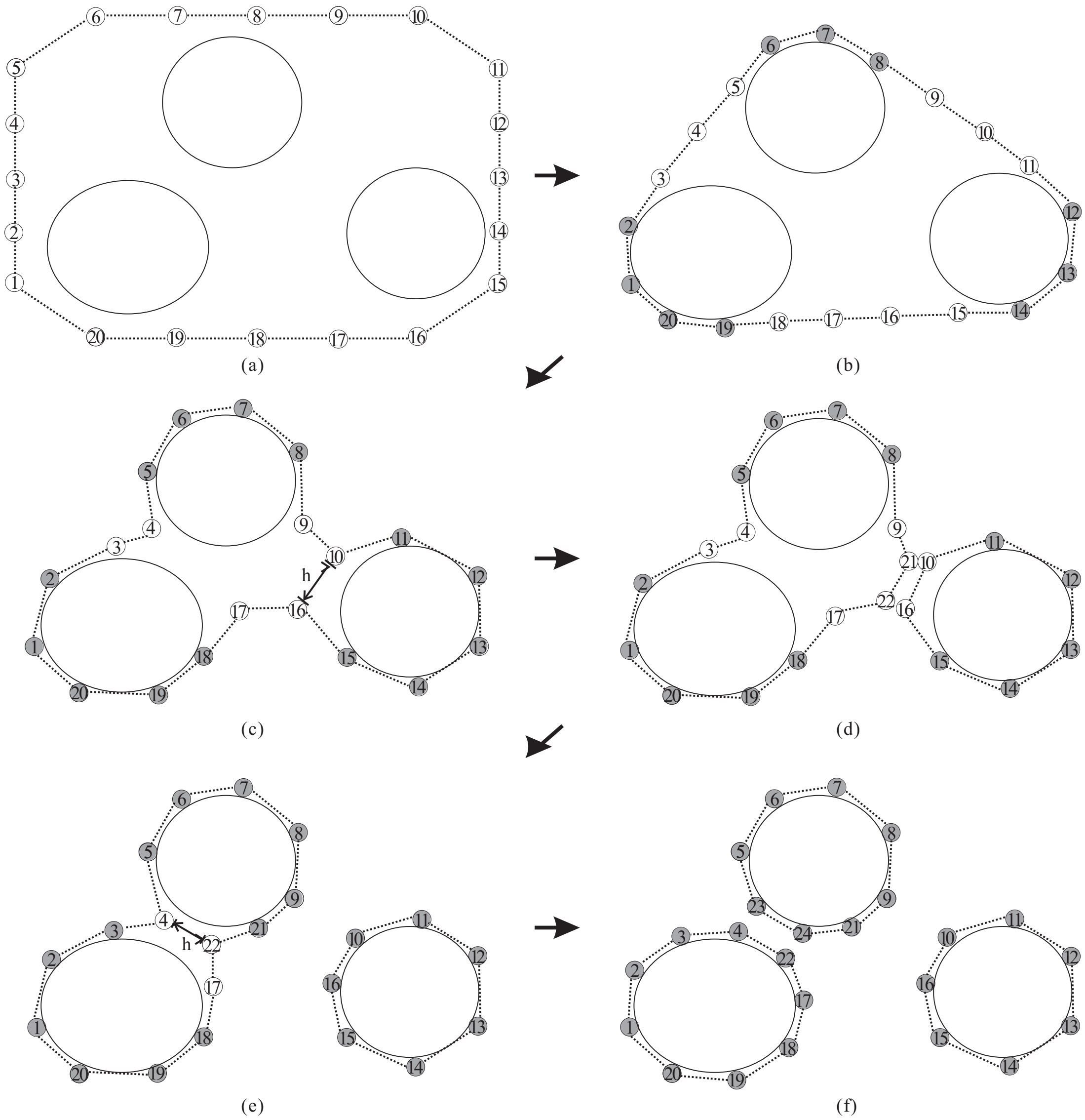

Fig. 4 Split ability of Active Contour Model (a) Initial state, (b) Before splitting behaviour, (c) Some contour points locate between two objects, (d) First splitting behaviour, (e) Second splitting behaviour, (f) Final results.

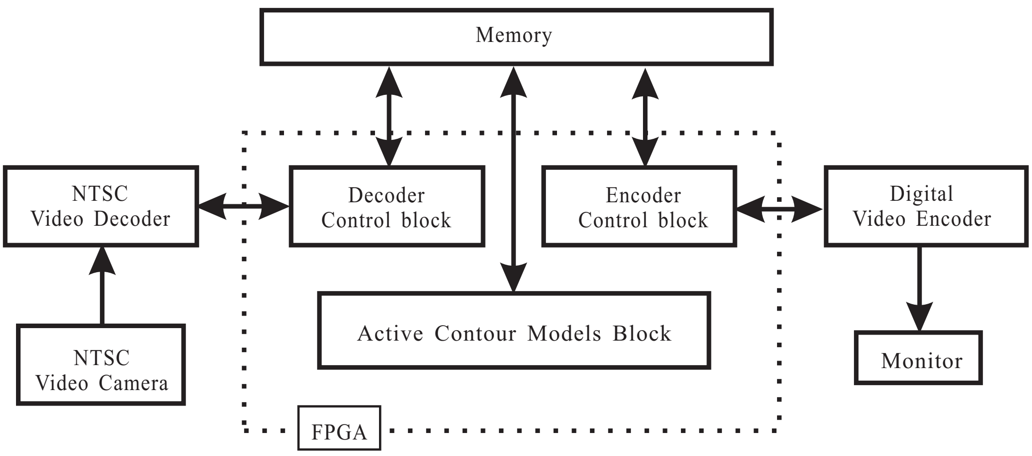

Fig. 5 Block diagram of the realized system

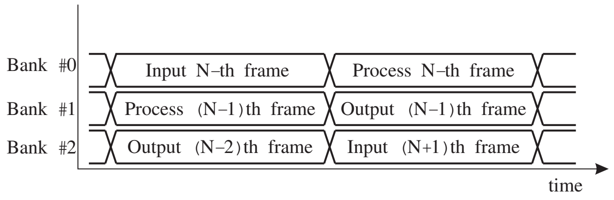

Fig. 6 Three bank memory

processing and outputting data are accomplished at the same time as shown in Fig.6. Each frame of images from the NTSC video camera are decoded by the decoder LSI and the obtained digital data are stored in one bank of memory on the FPGA board. The Sampled-ACM is applied to the frame stored in a bank of memory.

Here, the maximum iteration number for convergence of the Sampled-ACM is assumed as 80. The location of the contour points on the converged closed curve is stored in the memory as final area extraction results. And the results are displayed in the monitor with input images.

4. EXPERIMENTAL RESULT

To confirm the behaviours of the proposed Sampled-ACM, experiments to extract two faces in video signals are performed. Figure 7 shows the shrinkaging processes of the proposed Sampled-ACM. The Sampled-ACM before splitting behaviour is shown in Fig. 7(a). Figure 7(b) shows the Sampled-ACM just after the time when it splits. The final results are shown in Fig. 7(c). In Fig. 7, we can confirm that the converged Sampled-ACM correctly extracted two persons' faces.

The circuit scale for construction of the proposed Sampled-ACM is 40% of the FPGA. Clocks required for processing of each frame are 173,000. In other words, 3.6 [msec] is required for processing each frame, which is fast enough for real-time processings.

5. CONCLUSION

New Sampled-ACM is proposed for extraction of multiple specified areas. New type of attraction forces are introduced in the model and the model has splitting characteristics. The behaviour of the proposed Sampled-ACM is confirmed by constructing real-time video signal processing system. By using the system, extraction of two persons' faces is examined. The obtained results show that the proposed Sampled-ACM is applicable for construction of real-time area extraction system.

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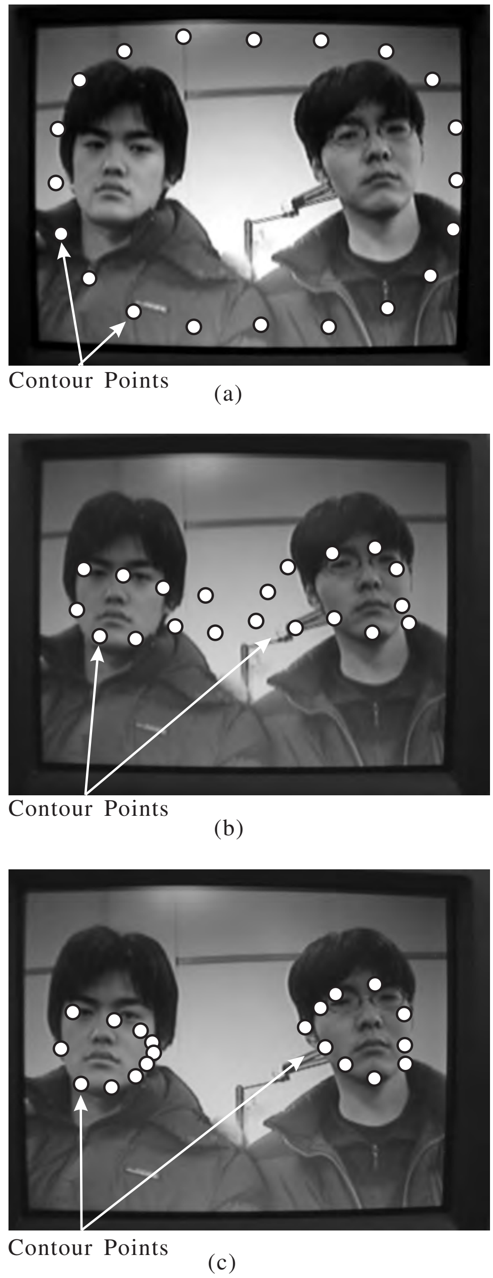

Fig. 7 Extraction result of multiple areas

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