Video Surveillance of Epilepsy Patients using Color Image Processing

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***Abstract*— This paper introduces a method for tracking patients under video surveillance based on a color marker system. The patients are not restricted in their movements, which requires a tracking system that can overcome non-ideal scenes e.g. occlusions, very fast movements, lighting issues and other moving objects. The suggested marker system consists of twelve unique markers that are located at each joint. By using a color marker system, each marker (if visible) can be found in every frame disregarding the possibility that it was occluded in the previous frame, compared to other tracking systems.**

I. Introduction

This paper presents an attempt to detect epileptic seizures using video surveillance. The basic principle at the Danish Epilepsy Centre, Denmark, is to make the patients feel well during their hospitalization, which has an average duration time of 2-3 weeks. In that period, there are almost no restrictions on the patient's movements. This means that the patients can move freely around in the ward of the neurophysiology department while still being under video surveillance. The patients do not have to lie in bed or sit in a desired position. Their only restriction is to stay within the range of the EEG-transmitting cables of 10m length.

Karayiannis et al. [1-5] and Cunha et al. [6]. Karayiannis et al- work with neonatal seizures while Cunha et al. work with lying adults. The Karayiannis et al algorithms for extracting and quantifying movements from video recordings of neonates have been reproduced and an attempt has been made to apply them on real and simulated seizure recordings. One main problem with the existing recordings from the center is that there are no standardized recording routines. Videos were only made to be handed to doctors, in order to be able to examine the behavior of the patients during seizures. Another problem is the environment in which patients (of all ages) go about, which leads to tracking problems. Examples of tracking problems include occlusions and movements of other persons than the patient under surveillance. To overcome the main problem, a database of simulated seizures and random movements was recorded to use for test purposes. To account for the tracking problem, a marker system based on color recognition has been developed. The idea with the marker system is to make use of the existing video surveillance equipment at the center. The color video cameras that are used have a resolution of 640x480 pixels.

The problem with using optical flow is shown in the Figure 1. The figure shows that the optical flow will register all movements that happen in the video even if the movements are from another person.

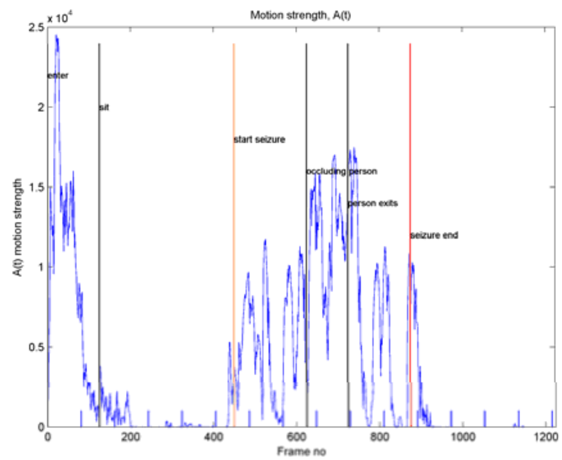

Figure 1 Optical flow for a seizure with a person occluding at frame 600.

II. Methods and Materials

A. Marker System

Twelve different markers are attached to a patient's clothing. Each marker consists of three strips with different colors and different order, see Table 1. There are in total five different colors used to create the twelve combinations. The colors have been selected so that no two markers are each other's inverse. This ensures that body and limb rotation do not pose an ambiguity in terms of pattern recognition.

The position of the marker on a patient can be seen in Figure 2. The markers are wrapped around each joint in order to be detectable from all angles since it is not possible to restrict the movement of the patients in a way so that they are always facing the camera.

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Figure 2 Illustration of a person with markers.

TABLE I. COLOR COMBINATIONS FOR MARKERS

Marker no 1	Blue	Green	Red
Marker no 2	Blue	Red	Green
Marker no 3	Yellow	Blue	Green
Marker no 4	Red	Blue	Yellow
Marker no 5	Red	Green	Yellow
Marker no 6	Magenta	Blue	Red
Marker no 7	Magenta	Blue	Green
Marker no 8	Blue	Red	Yellow
Marker no 9	Yellow	Magenta	Green
Marker no 10	Blue	Green	Magenta
Marker no 11	Yellow	Magenta	Blue
Marker no 12	Red	Green	Magenta

B. Marker Detection

In order to locate the position of each marker in the image the recorded video is first transformed from RGB to an L*, a*, b* color space. For each color, a mean value in a* and b* is empirically determined.

For each color, a layer is created that specifies where in the image the layer color is represented. Each layer is then filled by thresholding the transformed image using the determined mean values.

$$L_n = (a - \mu_{a,n} < T) \cdot (b - \mu_{b,n} < T) \quad n = 1 \ldots 5 \qquad (1)$$

where L is the layer, n is the color index, µ is the mean value and T is the threshold. Both µ and T are determined empirically. After thresholding the layers, each layer is morphologically dilated using a 5x5 dilation mask, A.

$$L_n = L_n \oplus A \quad n = 1 \ldots 5 \qquad (2)$$

In order to find the position of each marker the dilated layers are logically OR-ed.

$$L_{all} = \sum_{n=1}^{n=5} (L_n) \qquad (3)$$

The process is illustrated in Figure 3.

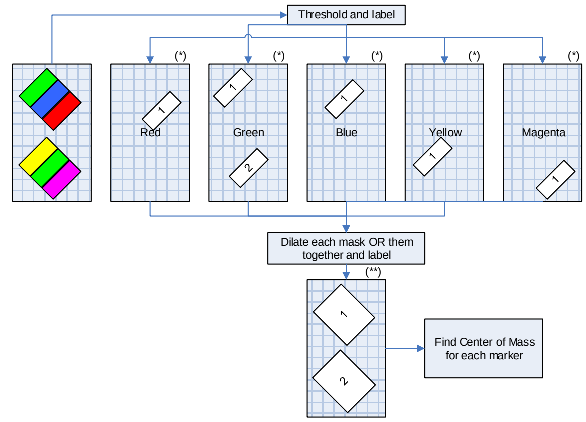

Figure 3 Determination of marker position.

From L_{all} it is possible to determine the location of each marker as being the center of mass of each of the areas obtained.

For each dilated layer every area is labeled and a center of the mass is determined.

$$COM_n = \sum_W (x, y) \cdot l_n(x, y) \qquad (4)$$

Where x, y are the coordinates in the image, W. COM_n is the center of mass for the n^{th} layer.

The last thing left, is to determine which marker the center of the mass belongs too. The colors in the current area are determined by a logical AND between each color layer and marker layer. Only the three largest intersection areas are used to determine the colors in each marker. This is illustrated in Figure 4.

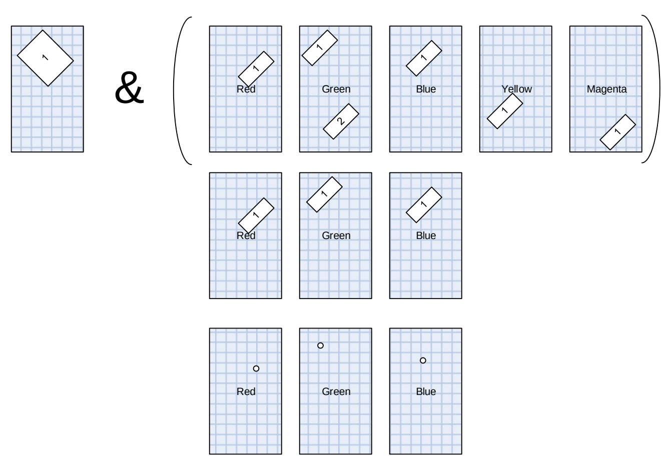

Figure 4 Determination of marker position.

The three Euclidian distances between the three centers of mass (Figure 5) are calculated and the largest distance is used as the classifier for which two centers are lying on each edge of the marker.

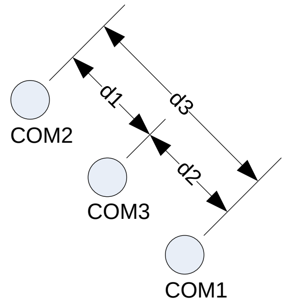

Figure 5 Euclidian distances between center of mass for each color.

One of the advantages of this method is, that the occlusions that may occur do not stop the algorithm, since there is no need for every marker to be located at each frame to be able to continue tracking. As soon as the marker is visible, it will be located. Disadvantages of this marker system are that the patients are not allowed to wear clothing that contain marker colors, and that the room has to be well lit in order for the system to be able to recognize colors.

III. Results

In order to test the marker system, 60 videos of one minute duration have been recorded. The recordings contain simulated seizures (after studying some recordings of real patients), and random movements with and without different occlusions.

One example result of this method applied on a non-seizure recording can be seen in the Figures 6–8. The figures illustrate a person that has entered the camera field of view, sits on an exercise-bike and starts riding it, first fast and later slow. Exercise bikes were seen used by epilepsy patients during hospitalization and therefore serve as a good tracking example. It can be seen from the graphs in Figure 7 and Figure 8 that the position of the markers can be followed very accurately. The graphs show only the estimated marker position for markers 9-12 that are located at knees and ankles for better visualization.

Figure 6 Image series of the recording of a person on a bike.

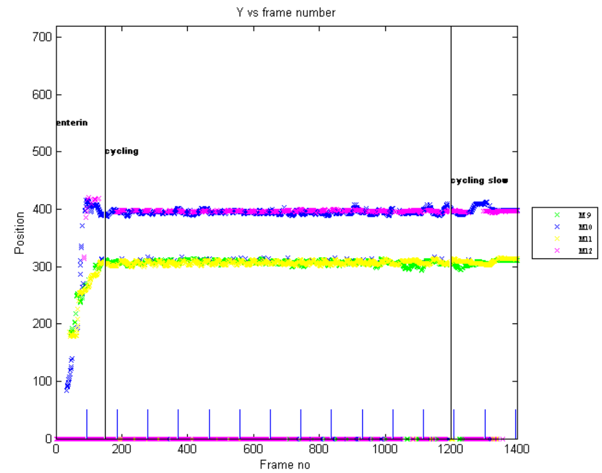

Figure 7 Movement in horizontal direction.

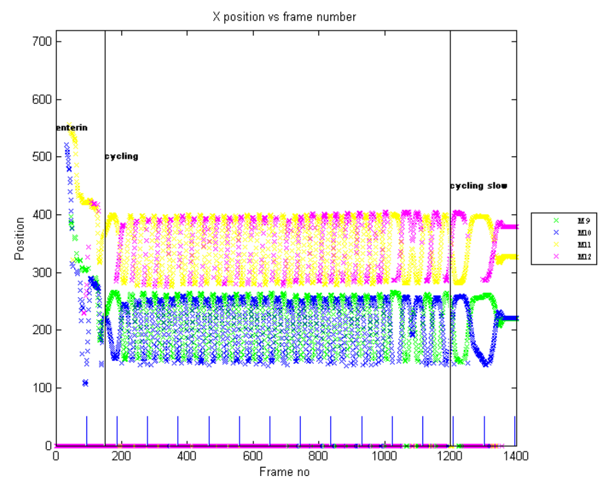

Figure 8 Movement in vertical direction.

The system is also tested on a simulated seizure recording. Figures 9-11 show a case where a test person with markers is lying and simulating a seizure.

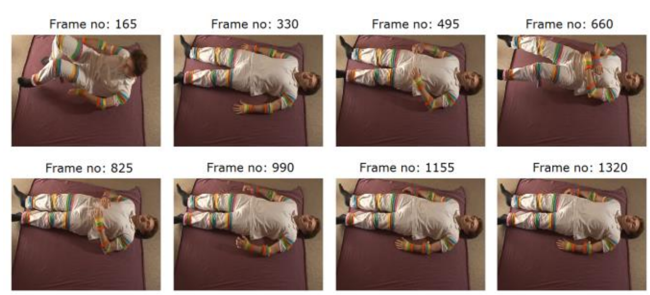

Figure 9 Image series of a recording with simulated seizure.

It can be seen that when the seizures occur some of the markers cannot be found (holes in the graphs). The reason is that when moving the right arm in Figure 9 the body acts as an occlusion due to the position of the camera. Furthermore the markers are sometime located very close to each other and the classification is not possible.

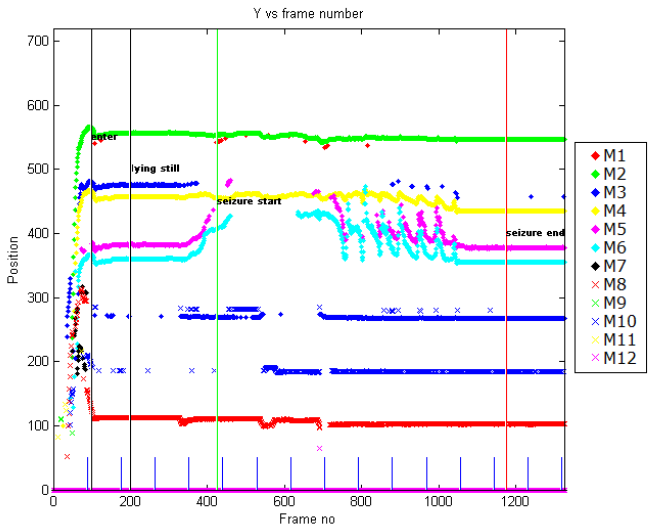

Figure 10 Horizontal movement.

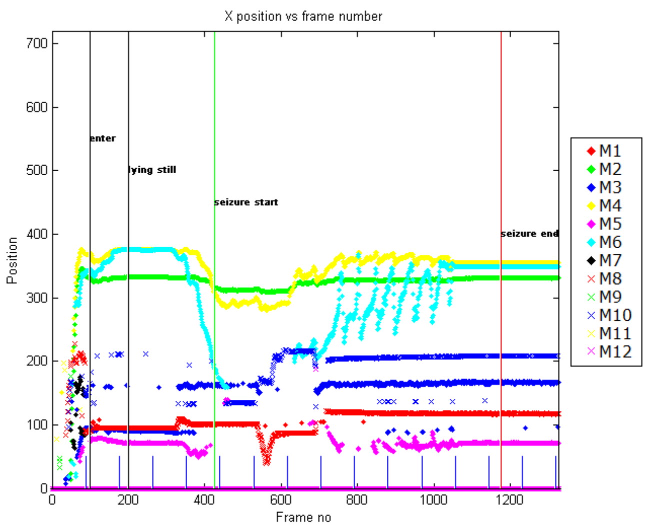

Figure 11 Vertical movement.

IV. Conclusion

Compared to the Karayiannis et al system, the marker system has the advantage of working on all patients. When present, occlusions will make the markers undetectable. As soon as the occlusions are gone, the markers will be redetected regardless of their position in the visible field. Movement of other obstacles in the visible field will not interfere with tracking of the patients since only markers will be tracked.

The drawbacks of the marker system are the marker size and color, which may let patients feel uncomfortable. The marker system's limits are the need for light to be able to classify colors, and the patient clothing must have a different shade of the color than each of the colors used in the marker system.

Improvements to this system could be the realization of markers that are smaller and that contain one more color. The first improvement is giving patients more comfort and fewer classification problems when markers are too close together. The extra color would enable markers with only two colors in each since more combinations are then allowed.

Other improvements could be to apply markers containing patterns. Finally introducing heuristics into the system could be beneficial in the detection of markers since anatomical sites are stiff.

References

[1] N. B. Karayiannis, G. Tao, Y. Xiong, A. Sami, B. Varughese, J. D. Frost Jr, M. Wise, E M. Mizrahi, "Computerized Motion Analysis of Videotaped Neonatal Seizures of Epileptic Origin", *Epilepsia*, vol. 46, no. 6, pp. 901-917, 2005.

[2] N. B. Karayiannis, B. Varughese, G. Tao, J. D. Frost Jr, M. S. Wise, E. M. Mizrahi, "Quantifying motion in video recordings of neonetal seizures by regularized optical flow methods", *IEEE Transactions on Image Processing*, pp. 890-903, 2005.

[3] N. B. Karayiannis, Y. Xiong, J. D. Frost Jr., M. S. Wise, E. M. Mizrahi, "Quantifying Motion in Video Recordings of Neonatal Seizures by Robust Motion Trackers Based on Block Motion Models", *IEEE Transactions on Biomedical Engineering*, vol 52, no 6, pp. 1065-1077, 2005,

[4] N. B. Karayiannis, A. Sami, J. D. Frost Jr., M. S. Wise, E. M. Mizrahi, "Automated Extraction of Temporal Motor Activity Signals From Video Recordings of Neonatal Seizures Based on Adaptive Block Matching", *IEEE Transactions on Biomedical Engineering*, vol 52, no. 4, pp. 676-686, 2005.

[5] Y. Xiong, N. B. Karayiannis "Automated Recognition of Videotaped Neonatal Seizures Using Robust Motion Tracking Methods that Adjust to Illumination and Contrast Changes", *Biomedical Imaging*, pp. 1300-1303, 2006

[6] Z. Li, A. M. D. Silva, J. P. Cunha, "Movement Quantification in Epileptic Seizures: A New Approach to Video-EEG Analysis", *IEEE Transactions on Biomedical Engineering*, vol 39, no. 6, pp. 565-573, 2002.

[7] B. K. P. Horn, B. G. Schunck, "Determining Optical Flow", Artificial Intelligence Laboratorz, Massachusetts Intitute of Technologz, Cambridge, MA, 02139, U.S.A., March 1980.

[8] A. M. Tekalp, "Digital Video Processing", Prentice Hall Signal Processing Series, ISBN: 0-13-190075-7, 1995.