Patient Associated Motion Detection with Optical Flow using Microsoft Kinect V2

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Abstract—This work describes our recent work of detecting the patient associated motions in a hospital room. After we had installed the designed Kinect V2 sensor-based health system in the hospital, we began to face big data challenges. The acquired data is big in both size and content. In this paper, we will propose a method to filter the big data using optical flow methods. As a result, we can discard the unnecessary data and quickly target on the data including valuable motion information about the patient. The proposed methodology facilitates the follow-up activity detection and serves for evaluating the amount of the movement the patient generates to allow the caregiver to improve the treatment plan.

Keywords—patient monitoring; motion detection; optical flow

I. INTRODUCTION

The healthcare-associated infection (HAI) appears more than 1 out of 25 hospital patients every day. In 2011, the annual HAI progress report from Centers for Disease Control and Prevention estimated 722,000 HAIs presented in US acute care hospitals and 75,000 of them died during the hospital stay. Preventing HAIs becomes a significant burden for healthcare facilities and systems [1].

In previous works, we addressed solutions in preventing HAIs by providing a better implementation of QA/QC measures to the healthcare sector and evidence-based management using sensing devices. We designed and developed a Kinect sensor-based health system in a simulated hospital room furnished in the same way as a real hospital room at an engineering lab. Some of these efforts have been described on detecting patient bed angle and walking [2, 3]. After we had completed the stage of system design and development using Kinect V2 sensor, we deployed the system in a real hospital room at Northwestern Memorial Hospital (NMH). Currently, the system is continuously collecting data with the consented hospitalized patients.

Recently lots of wearable devices have attracted many spotlights on monitoring health status in daily life, such as push button, Fitbit, smart watch, the sensor on shoes, the sensor on skin, the sensor on chest [4, 5]. These wearable devices have achieved successes in detecting pulse, heartbeat, breath rate, blood pressure, gait count or calorie consumption. Among these examples, Mobile phone based health solutions have been used for analyzing subject’s gait characteristics or personal health management with encouraging results. However, they are not suitable for long-term continuous use for chronic disease patient in the real healthcare facilities, such as senior home [6, 7] or hospital room. This situation will require a contactless solution to avoid risks in infections and devices failures caused by battery issues, or improper use because the subject lost conscious or forgot to wear it after a shower.

Researchers have proposed many methods for detecting moving subjects, such as background subtraction, point features based detectors. The background subtraction is suitable for the case when the region of interests can be segmented out from the scene easily. It lacks robustness when the scene changes. The point feature based detectors work very well for the much complex scenes. However, it has limits when the region of interests does not have texture information. For the hospital collected data, the room lighting condition changes according to the sunlight from the window and lights in the room at different locations.

We need a more general method to handle our cases without limiting the number of moving subjects, texturable appearance and fixed camera view. The optical flow is a velocity field in the image to transform one image into the next image in a sequence. On an image plane, it represents the pattern of apparent motion between two consecutive frames caused by the move from object or camera into a two-dimensional motion vector. In this paper, we use Lucas-Kanade method [8, 9] to filter out the data only including motions from the big data acquired through continuously data collection in the hospital.

II. METHODOLOGY

We assume that a pixel on a moving object does not change brightness between consecutive two frames. For a frame at time $t$, we denote the intensity of a pixel location $p(x, y)$ as $I(x, y, t)$. In the next frame at $t+\Delta t$, this pixel moves to a new location $(x+Ax, y+Ay)$ with an intensity $I(x+Ax, y+Ay, t+\Delta t)$. We can represent the brightness constancy using

$$I(x, y, t) = I(x+Ax, y+Ay, t+\Delta t).$$  \hspace{1cm} (1)
The right side of the equation (1) is approximated by using the first order Taylor series expansion as

\[ I(x + \Delta x, y + \Delta y, t + \Delta t) = I(x, y, t) + \frac{\partial I}{\partial x} \Delta x + \frac{\partial I}{\partial y} \Delta y + \frac{\partial I}{\partial t} \Delta t \]

Then the equation (1) becomes

\[ \frac{\partial I}{\partial x} \Delta x + \frac{\partial I}{\partial y} \Delta y + \frac{\partial I}{\partial t} \Delta t = 0. \]

We define the motion vector \([u, v] = [\Delta x/\Delta t, \Delta y/\Delta t]\). The above equation turns into

\[
\begin{bmatrix}
I_x & I_y
\end{bmatrix}
\begin{bmatrix}
u \\
v
\end{bmatrix} = -I_t
\]

(2)

We call this equation as optical follow equation. The purpose is to find the solution to get motion vector. Lucas and Kanade method assumes this equation is applicable for all neighbors in a window centered at the pixel \(p\).

For a window with \(n\) neighbors, we have \(n\) equations. Least squares principle can solve this equation

\[
(A^T A) \begin{bmatrix}
v \\
b
\end{bmatrix} = A^T b
\]

where \(A\) is a \(n\times2\) matrix and \(b\) is \(n\times1\) vector written as

\[
A = \begin{bmatrix}
I_x & I_y \\
I_{xn} & I_{yn} \\
\vdots & \vdots \\
\end{bmatrix}, \quad b = \begin{bmatrix}
-I_x \\
-I_y \\
\vdots \\
-I_{tn}
\end{bmatrix}
\]

III. RESULTS AND DISCUSSIONS

In the left column of figure 1, these three frames from a video sequence show a scenario that the patient is about to leave the patient bed. In the right column, each image presents the detected motion from the left column original image using optical flow method. A red color bounding box labels the patient body on both original and resulted images. The detected motion blob includes the moving patient body shown in the right column. The detected results from this video sequence disclose patient’s movements including a series of patient activities, such as get out of bed, stand up and walking.

Since motion segmentation is the key to proceed the follow-up data processing on activity detection, we only consider using color information to serve this purpose. The point cloud information is also available due to the fact Kinect device is in use. It is still very challenging to segment the motions from point cloud because the depth sensor yields random sampling with high noise levels. The demonstrated preliminary results are very promising to separate the motion from RGB information.

IV. CONCLUSIONS

Our proposed method of using optical flow to filter out the data with motion is an essential first step for real-world big data processing. The preliminary results have demonstrated the effectiveness of this proposed filtering method. As a result, this method will allow us to target on motion data quickly to build up the activity-rich dataset. Next, we will research on segmenting the patient body parts from the moving objects.

This work will promote further patient activity detection and help us to understand the relationship between patient activity and developed infections in hospital settings.

Fig. 1 The detected motion with the patient. (a)Left column: original image; (b)Right column: detected motion using optical flow.

REFERENCES