Behavioral Observation Through Image Processing

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Abstract- **This project involves observing breathing abnormalities of babies who are less than one-year-old. Optical flow is used for identifying the motion of infants. In motion identifying process, many techniques have been used to filter noise and extract exact breathing motion of infants. Then the identified breathing motion is analyzed using various methods for identifying abnormalities from the breathing of the babies. With these analyzing methods some basic breathing distortions such as stopping of breathing suddenly (apnoea), hiccups, breathing difficulties, and changes in breathing frequency could be identified. By identifying many such abnormalities, this project can be extended to a real system that would help doctors to get warning when some breathing issues occurred on babies under observation.**

Keywords—Image Processing; Optical Flow; Machine Learning; Color thresholding; CUDA; OpenCV

I. INTRODUCTION

Observing human behavior and analysis through computer system has been a challenging task. Observation through image processing is even more challenging. Because of the technological development, people wants to do more using with what their camera gives. As a result, systems that perform features such as face detection and facial expression detection have become popular. Also, there are many pieces of research on observing human behaviors through image processing. In this project, abnormal breathing conditions of babies are the concern. For that, we are going to use existing image processing techniques to identify and analyze breathing patterns of infants.

Currently, there are many methods to detect breathing of infants. Most of them are wearable equipment such as sensors fixed to a bed sheet. In hospitals, doctors use oxygen level when a newly born baby is having breathing issues. However, it takes longer time to give warnings so that there may be bad consequences. Our system can warn the relevant people as soon as the issue occurred. Therefore, it would be helpful for doctors and care takers of the infants.

II. LITERATURE REVIEW

Image processing and video analysis are widely used in research that target medical issues. Bellini and Akullian [1] have done research on Video Self-Modeling (VSM) Involvements for people with Autism Spectrum Disorders (ASD). Parameters of ASD were measured using VSM with nonoverlapping data points. In this study, researchers had revealed that communication and functional skills can be enhanced using video modeling.

Arroyo, Javier and Dergasa [7] have implemented a real-time surveillance system to detect suspicious behaviors in shopping malls. To track trajectories, an efficient background subtraction method was used. Also, they used Kalman filtering and Support Vector Machine (SVM) in their tracking algorithm. This innovative algorithm can detect suspicious behaviors like loitering and unattended cash desk situations.

The concept of optical flow was introduced by the American psychologist James J. Gibson in the 1940s. It was used to describe visual stimulus given for animal movements [4].

There are many methods to determine optical flow

- Phase correlation
- Block-based methods
- Differential methods of estimating
  - Lucas-Kanade method
  - Horn-Schunck method
  - Black-Jepson method [5]
- Discrete optimization methods [8]

Also, there are many research-project based on optical flow method. Guo, Ven and Zhou [6] recently used an optical flow method to track and measure blood cells motion in a human body. Since there were many limitations in the previous method called spatiotemporal image analysis, researchers suggested optical flow methods to do the measuring and tracking. Also, it used special optical flow method called SIFT (Scale Invariant Feature Transform) flow, when there is a large displacement of cells between two adjacent frames. Normal optical flow method is used to track cells when their velocities are unstable.

In this paper, we present infant abnormality detection using optical flow and we have tried various options to keep the detection realtime. Details of our method and implementations are presented in the rest of this paper.

III. OUR SOLUTION

Considering the goals, background, and the existing technologies, we separated this project into two phases. In the first phase, we prototyped the system to test the suitability of different algorithms using Matlab and in the second phase, we built a complete system using C++.

A. Research and Prototyping

In this phase, the existing image processing techniques like the optical flow and background subtraction were used to identify the breathing motion and compared them according to their accuracy and the performance. Furthermore, we used filters to reduce noise. Matlab was used to do the prototypical implementation.

B. System Implementation with C++

Since Matlab implementation of certain algorithms like optical flow were very slow, we implemented the algorithms in C++ with the help of the OpenCV library. Also, we used CUDA library to get the help of the GPU to speed up the optical flow algorithm.

IV. METHODOLOGY

A. Research and Prototyping

During the first phase following steps were carried out.

- Data Collection
- Motion Analysis
- Method Comparison
- Noise Reduction
- Pattern Identification

In Data Collection step, video streams of abdomen area of the infants are taken. Those videos consist of both natural breathing conditions and suspicious breathing conditions. We have used two image processing techniques to identify breathing motion.

1. Optical Flow Algorithm
    a. Black and Anandan dense
    b. Lucas-Kanade
2. Image Subtraction

The Matlab implementation of the Optical Flow algorithms was used to perform the motion analysis.

Figure 1 Sample Video Frame

Fig 1, shows a frame of a sample video, which was used to generate the average magnitude velocity (1) vector.

$$\text{Avg. Magnitude velocity for a frame} = \frac{\sum \text{Magnitude velocity}}{\text{No. of frames}} \quad (1)$$

Values obtained by (1) are plotted against the frame numbers. For each method, signal is obtained. After that cross-correlation (Cross-correlation-method used to find the signal similarity [10]) is performend to compare each method.

The noise was a big drawback when it comes to identifying the breathing patterns with the signal extracted from the video. The noise is generated due to many reasons like changes in the lighting conditions, and background objects movement.

These unwanted noises had to be filtered before analyzing the signal. In the project, three main noise reduction methods were used.

- Cut off average velocity with a threshold value.
- Smooth the signal by using the median filter.
- Color thresholding [9]

Cut off average velocity with a threshold value method was used for ignoring motions with less valued which are not related to breathing motion.

When a signal is with the noise, it makes the values of signal distorted at various points. If the noise is random, then those distorted values do not carry a pattern. For reducing this noise issue, the median filter was used.

Color Thresholding has been applied to images which include color tag pasted abdomen area.

With the pattern identification, breath distortions are identified. For this, the average magnitude velocity gain from optical flow algorithm was analyzed.

B. System Implementation

During the second phase, the client application and server application were implemented.

Client application was designed to identify critical situations that need immediate medical attention and send data to server application for further analysis.

For this approach, the video processing has to be done with lower latency. So that, background subtraction and motion history methods were used together. It gives a very fast analysis with lesser accuracy. That information is good enough to identify critical situations. For this, OpenCV with C++ was used.

The server application is designed to do the advanced and sensitive analysis, store data and improve the system with machine learning.

The advanced and sensitive analysis was implemented using optical flow algorithm in C++ with OpenCV and CUDA libraries. There were four optical flow APIs available in OpenCV which supported CUDA.

- Brox Optical Flow
- Dense pyramidal Lucus-Kanade Optical Flow
- Farneback Optical Flow
- Dual TVL1 Optical Flow

Since the pre-built OpenCV library does not have support for GPU, we had to rebuild the OpenCV 3.0 library with the support of CUDA Toolkit 6.5 in Visual Studio 2013 environment.

After that, we had compared each Optical flow APIs with sample images shown in Fig 2.

Figure 2 Sample Images Used to Compare

The information that was analyzed before was used to improve the system with machine learning.

Attributes like the average magnitude velocity, maximum velocity, maximum frequency, and the number of peaks were used as the attributes to build the machine learning model.

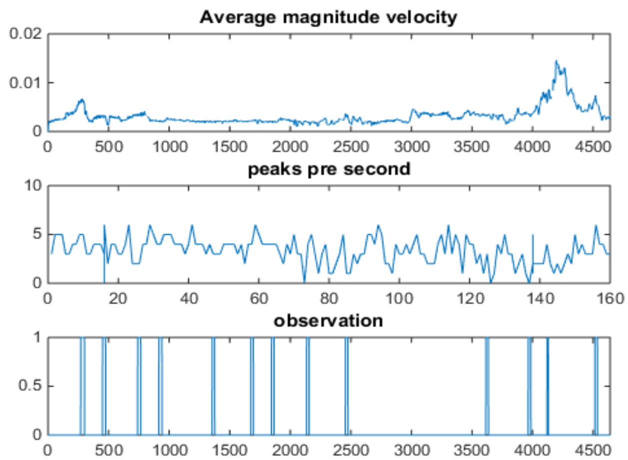

Figure 3 Attribute values and class values

Fig 3 shows some of attribute values and class value used for classification.

V. Results and Analysis

A. Results of Phase 1 (Research and Prototype)

After run the Optical flow algorithm on MATLAB following plot shown in Fig 4 was obtained. This plot consists of the average magnitude value against frame number.

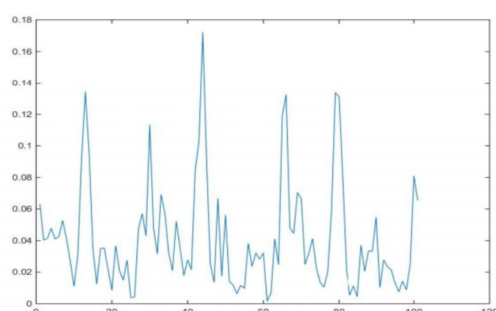

Figure 4 Avg. Magnitude Velocity Graph

Table 1 Maximum Correlation Values

	Black and Anandan	Lucus-Kanade	Image Subtraction
Black and Anandan	-	0.9098	0.2899
Lucus-Kanade	0.9098	-	0.2922
Image Subtraction	0.2899	0.2922	-

Table 1 shows the maximum correlation values taken by cross-correlating each signal obtained by each method. If the maximum correlation value is greater than 0.7, then the two signals consider to be similar signals.

Color thresholding is the most effective noise reduction method. Like in Fig 5, color tags that were pasted on abdomen area were color thresholded. So other parts of the image were filtered out except these color tags. The motion of these color tags are highly related to the breath motion.

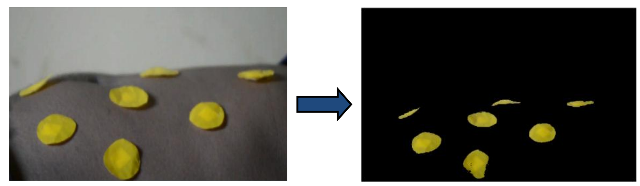

Figure 5 Color Thresholding

By using average magnitude values, we were able to get five plots, which can be used for identifying patterns and distortions in the breath. The plots are:

1. Average magnitude vector plot
2. Cutoff step plot
3. Peak values and its positions in Average magnitude vector
4. Number of peaks per second plot
5. Frequency domain analysis

Figure 6 Prototype GUI with Plots

Fig 6 shows some of pattern identification methods that are shown in plots, used to evaluate babies breathing motion.

B. Results of Phase 2 (System Implementation)

Optical Flow algorithm called Farneback was chosen to use in the server side application. Here is the reason for the decision.

Fig 7 shows the resultant images, which show the magnitude velocity values of each pixel in defined color scale. Table 2 consists of times that are taken to process Fig 2 images using each method.

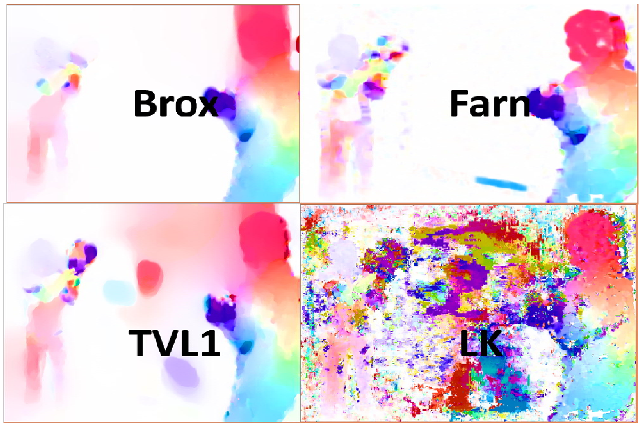

Figure 7 Color Scaled Velocity Images

Table 2 Time Taken to Process in Each Method

Methods	Time taken to process sample images (sec)
Brox	1.34084
Dense pyramidal Lucus-Kanade	0.23434
Farneback	0.20214
Dual TVL1	1.89831

According to Table 2, Farneback and Lucus-Kanade have taken the lowest time. Also considering Fig 6 Farneback is the best one because Lucus-Kanade applied image has noise.

With the analysis methods we used, many distortions can be identified. Every pattern identification method gives separate analysis result that lead to determine various kinds of distortions.

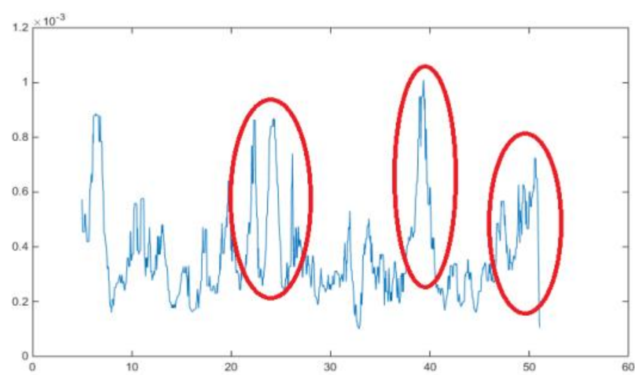

Figure 8 High breathing areas identified Plot

In Fig 8, red colored circles indicate the high breathing stages of the baby. Also, it is clearly shown in Fig 9 which is a plot with Number of peaks per second.

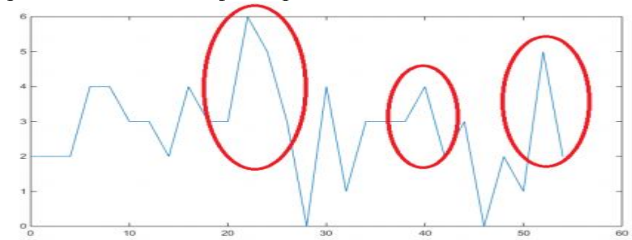

Figure 9 Number of peaks per second plot

VI. CONCLUSIONS

The main target of the project is to build a system that is capable of identifying breathing motion of baby through video stream and find abnormalities.

The system is supposed to be used as a continuous monitoring system that helps doctors to determine the breathing disorders and critical breathing issues that may need immediate medical attention.

The client and server design contributes to achieve many aspects of the project. The client application identifies critical situations without delay and makes it efficient. Server application with detailed and sensitive analysis makes the system more accurate and reliable.

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