Biomedical Signal Processing and Control 41 (2018) 129–139

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

journal homepage: www.elsevier.com/locate/bspc

A novel data acquisition and analyzing approach to spermiogram tests

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ARTICLE INFO

Article history:
Received 16 May 2017
Received in revised form 17 October 2017
Accepted 19 November 2017

Keywords:
Video stabilization
Descriptor
Spermiogram
Sperm counting
Speed up robust features
Binary robust invariant scalable keypoints
Features from accelerated segment test

ABSTRACT

Spermiogram tests are currently performed in two ways; computer assisted and visual assessment. Computerized techniques are costly and parameter dependent. Therefore, it is not preferred in many laboratories. Analysis based on visual assessment technique is subjective. In this study, we proposed a new computerized approach in which data acquisition is performed as in visual assessment, but analysis is done by computer. This approach provides more generalized results, requires less parameters due to the usage of standard counting chambers as in visual assessment technique, and cheaper than the other computerized techniques. Proposed approach includes two modules; video stabilization and motile sperm detection module. Stabilization is a requirement because it is impossible to fix proposed approach in ocular part completely. Otherwise, vibration affects the detection process of motile sperms. In this respect, feature-matching video stabilization idea is firstly utilized within the video-microscopy concept. Several feature extraction techniques were tested to sustain more stable videos in stabilization module. Motile sperm detection algorithm is then adapted to evaluate the efficiency of video stabilization and analyzing part. In case of vibrated frame sequence, the detection of total motile sperms concludes immediate peak values while it is around average values in stable frames. Samples were also evaluated by an expert with the visual assessment technique. Comparative tables and figures emphasize that the proposed approach can be employed in laboratories due to the high correlation with the visual assessment results.

1. Introduction

Infertility is a quite common health problem affecting people mentally and physically. According to World Health Organization (WHO), infertility rate is increased 50% in last 50 years [1]. Normal sperm number was reported as 120 billion/ml in 1938 [2]. However, in 1990, it decreased to 58 billion [3]. Infertility is caused by many reasons such as unhealthy diet, adverse living conditions and radiation effect. Understanding the reason behind the problem is still a challenge. In this respect, medical doctors recommend the semen analysis tests called spermiogram as a first assessment.

Spermiogram is a technique involving sperm counting and morphology analyses. Infertility is highly related with the sperm numbers, hence, counting process is crucial. Detection of motile sperm cell rate over given sample is the main criteria in counting analyses. Infertility zone is described in the manual published by WHO as the presence of the immotile detected sperm number as more than 70% of all sperms [1]. In this sense, correctly identified of motile sperm number mostly reveals the possible infertility problem. Morphology test is also important process in selecting good quality sperm in vitro fertilization for the evaluation of fertility efficiencies. Tests are carried out using two evaluation techniques based on computerized or visual assessment [4]. Some laboratories utilize an automated analysis system named as Computer Aided Sperm Analysis (CASA) in computerized techniques. It is costly due to being an integrated system including embedded camera, microscope and computer. Additionally, system is a black box system. The parameters and results can not be reconfigured and verified by experts/doctors [5]. In visual assessment technique, different standardization equipments can be employed such as Makler [6], Hemocytometer [7], Neubauer [8] to generalize the cell numbers in per ml. According to [9], Makler is one of the promising materials and the most employed chamber in laboratories.

There are several CASA systems in medical market. However, laboratories mostly prefer visual assessment technique due to their cost. Even if they utilize the CASA system, they also verify the results using visual assessment. However, it is impossible to observe all sperm cells over microscopy by manually. The error rate might depend on the expertness and the experiences of laboratory assistant [10]. In this sense, improving a computer based sperm counting system is a necessity to obtain more consistent and trustful evaluation process.

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https://doi.org/10.1016/j.bspc.2017.11.009
1746-8094/

Computer based analysis are mainly performed on two different microscope types in literature. Several studies focused on morphological assessment of sperms by using phase-contrast microscopy [11–13]. However, counting results of sperm in those kind of microscopic images are impossible to generalize to per/ml because of the used narrow scale and/or low resolution embedded camera systems in data acquisition step. There are many in/out problems and occlusion. In another type of microscopy imaging technique named as fluorescence dying, studies are generally related with motility analysis [14]. The field of view is wider, but the details disappear due to the dying process in that scenario. Additionally, plasma includes different organisms besides the sperm cells such as blood cells, debris or leukocyte. In this kind of images, segmentation can't be perfectly maintained. Additionally, it is emphasized in [15] that the substances used in the dying process spoiled the purity of sample.

Considering the current disadvantages of microscopy imaging techniques in sperm analysis, we aimed to develop a system that use the idea of visual assessment evaluation technique. The system should be cheap, re-configurable, and provide a wide field of view compare to existing CASA systems. Basically, the proposed system combines data acquisition step of visual assessment and computerized analysis step of CASA systems. The idea of using Makler counting chamber as in visual assessment technique is aimed to be adapted in our approach on computer side. Additionally, in this system, laboratory assistant can still observe the samples and count the sperms visually if necessity. This also eliminates the mistakes, oversight or any other user dependent errors. In this approach, the main challenging issue is stabilization of the video-microscopy. Even if a stabilizer designed and mounted, there is still vibrations during the recording. In case of vibrations, motile semen counting results vary according to utilized counting algorithm. To this end, software based video stabilization is a necessity in our system. Several stabilization studies were reviewed as a first phase of this study.

Kwon et al. adapted Kalman Filter in video stabilization problem [16]. They mainly focused on the jitter effect in real time cameras. So, they extracted the motion vectors to estimate the jitter effects on motion. They emphasized that the technique is not only for camera vibration, but also can be employed in elimination of the effects occurred by other motile objects. Another Kalman based study has been proposed by Tiko and Vahvelian [17]. They formed a practical system constraint with respect to the amount of corrective motion. They performed Kalman based approach between constants and each video frame. Matsushita et al. proposed motion impainting technique to maintain a video stabilization problem [18]. They mainly aimed to stabilize videos in good quality. Normally, stabilized images are in low resolution due to the effect of technique. Spatial and temporal consistency of the video sequence in both static and dynamic image areas were performed in their technique. Additionally, they utilized sharpening idea by using the deblurring algorithm as post-processing between consequent frames. As a result, their technique provided more quality stabilized videos. Piva et al. proposed color based segmentation [19]. They extracted two one-dimensional characteristic curves to form an efficient motion estimator. They, then, analogise the consequent extracted curves to predict image displacement. As a validation test, they compared the results of proposed approach to feature based segmentation techniques. Most video stabilization techniques have complexity. The implementation of video stabilization techniques on low resource devices is important as much as its robustness. Auberger and Miro presented a stabilization technique especially for low cost devices [20]. They formed binary motion estimation on some key points in frame to decrease the complexity. Consequently, technique consumes less power than many techniques. Additionally, they adapted technique to use in not only displacement detection, but also rotation based movement. They evaluated technique in realistic problems. Video stabilization is implemented in many different applications in literature. Liang et al. employed global feature extraction technique of the lane lines and the road vanishing points for the camcorder stabilization mounted on car [21]. They formed a system using priori information of traffic images to reduce the computational and time complexity. Each frame features were combined with one previous frame. According to results, they predicted the stable frame location. Another work made by Oreifej for the moving object detection in turbulence [22]. During object detection process, they faced with nonuniform deformation occurred by turbulence. They extracted background, turbulence and the object as the initial part. Different norms were utilised to eliminate the noises and detect the objects. Similar to [22], Brandon et al. focused on the stabilization of hand-held light field video camera [23].They implemented video camera array to stabilize video from the shaky input in static scenes by employing a space-time optimization between the virtual camera and the camera array. Evaluation has been performed by comparing their algorithm to state-of-the-art stabilization software. Liu et al. proposed depth based video stabilization technique in [24]. Feature point tracking idea for video stabilization is fragile in videos having no texture, severe occlusion or camera rotation. In this sense, they employed a dept sensor camera by combining normal camera to avoid noise effects. The fusion of both camera provided much better results but it requires more time to process. Battiatto et al. proposed a block matching technique for local extracted motion vectors [25]. They filtered motion vectors by similarity and matching effectiveness to speed up stabilization process. They emphasized the speed of the algorithm as the novel side of technique.

Rong et al. utilized scale invariant features (SIFT) in stabilization problem with the combination of Gaussian kernel filtering and parabolic fitting [26]. They reported that their technique is effective not only in high frequency noise motion, but also minimize the missing area as much as possible. Sebastiano et al. employed the same feature extraction technique in feature-based motion estimation algorithm idea [27]. They used the features in matching concept to estimate inter-frame motion. Different from direct feature matching idea, Yang et al. used particle filters in stabilization idea [28]. Particle filters are mainly employed to estimate posterior states of nonlinear systems. They roughly extracted scale invariant feature points and then estimate their next important states by particle filters. Shen et al. also utilized scale invariant features and particle filter in their work [29]. Differently, they decreased the feature size by Principle Component Analyses (PCA). They, then, composed block mean squared error metric to use in particle filter. Binoy and Anurenjan utilized another feature extraction technique in their study [30]. They used speed up robust features (SURF) in stabilization for the global motion estimation with Kalman filter as post processing to smooth the result.

In medical application, Xia et al. used one of the stabilization technique to clear the Rician noise effect on 3D MR data. They employed forward and inverse variance-stabilizing transformations (VST) for the Rician distribution [31]. Another stabilization study on medical imaging made by Aghajani et al. [32]. They compensated for global transformation between two consecutive frames. Then, they dedicated a local deformation for stabilization. As a result, they eliminated the motion-based artifacts on iris image set [32]. Sauvea et al. utilised stabilization idea on robot-assisted beating heart surgery [33]. They estimated the motion of the heart using two technique: motion estimation and texture tracking. To the end, they efficiently achieved to the estimation of heart beat and provided more stabilized robot-assisted surgery [33].

In this study, obtained images have grid texture of Makler, hence; we employed feature matching based video stabilization technique such as in [26,27,22,21]. We extracted Speed Up