Original Article

JER

https://doi.org/10.12965/jer.2142474.237

Journal of Exercise Rehabilitation 2021;17(4):287-292

Development of urination recognition technology based on Support Vector Machine using a smart band

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The purpose of this study was to explore the feasibility of a urination management system by developing a smart band-based algorithm that recognizes the urination interval of women. We designed a device that recognizes the time and interval of urination based on the patient's specific posture and posture changes. The technology used for recognition applied the Radial Basis Function kernel-based Support Vector Machine, a teaching and learning method that facilitates multidimensional analysis by simultaneously judging the characteristics of complex learning data. In order to evaluate the performance of the proposed recognition technique, we compared actual urination and device-sensed urination. An experiment was performed to evaluate the performance of the recognition technology proposed in this study. The efficacy of smart band monitoring urination was evaluated in 10 female patients without urination problems. The entire experiment was performed over a total of 3 days. The average age of the participants was 28.73 years (26–34 years), and there were no signs of dysuria. The final accuracy of the algorithm was calculated based on clinical guidelines for urologists. The experiment showed a high average accuracy of 91.0%, proving the robustness of the proposed algorithm. This urination behavior recognition technique shows high accuracy and can be applied in clinical settings to characterize urination patterns in female patients. As wearable devices develop and become more common, algorithms that detect specific sequential body movement patterns that reflect specific physiological behaviors could become a new methodology to study human physiological behavior.

Keywords: Female urinary patient, Urination recognition, Urination management system, Mobile voiding chart, Support vector machine

INTRODUCTION

A variety of tools are used to manage patients with urinary disorders, such as voiding chart. Textbooks also present a voiding diary as one of the most important diagnostic tools for dysuria (Abrams et al., 2002; Klevmark, 1999; McGuire et al., 1996). The voiding chart is a method used by doctors to objectively observe the subjective symptoms of patients with urinary disorders. The voiding chart is considered one of the most important diagnostic methods as it serves as a starting point for the study of urination disorders as doctors objectively evaluate the patient's symptoms before proceeding with diagnosis or treatment. Therefore, it is very important to make an objective diagnosis and the voiding chart is an important diagnostic tool. However, since patients must record daily information in the diary, inaccurate data can occur even if the patient is well trained in diary writing (Jarvis et al., 1980; Kim et al., 2014; Webb et al., 1992). Accurate detection technology that monitors urination can systematically and efficiently manage a patient's urination. In this study, a technology was developed to collect and analyze motion information (magnetic and distance information) sensed from a smart band worn by a patient in order to recognize the urination activity of a female patient. It is expected that this development will implement a urination management monitoring system for users.

The technique proposed in this study is a technique of extracting and learning the characteristics of the urination signal pattern by determining which boundary the newly input urination activity signal is included in, and calculating the final urination activity. Various methods and learning algorithms for motion recognition have been presented. Most studies have used static algorithms

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Received: July 2, 2021 / Accepted: August 4, 2021

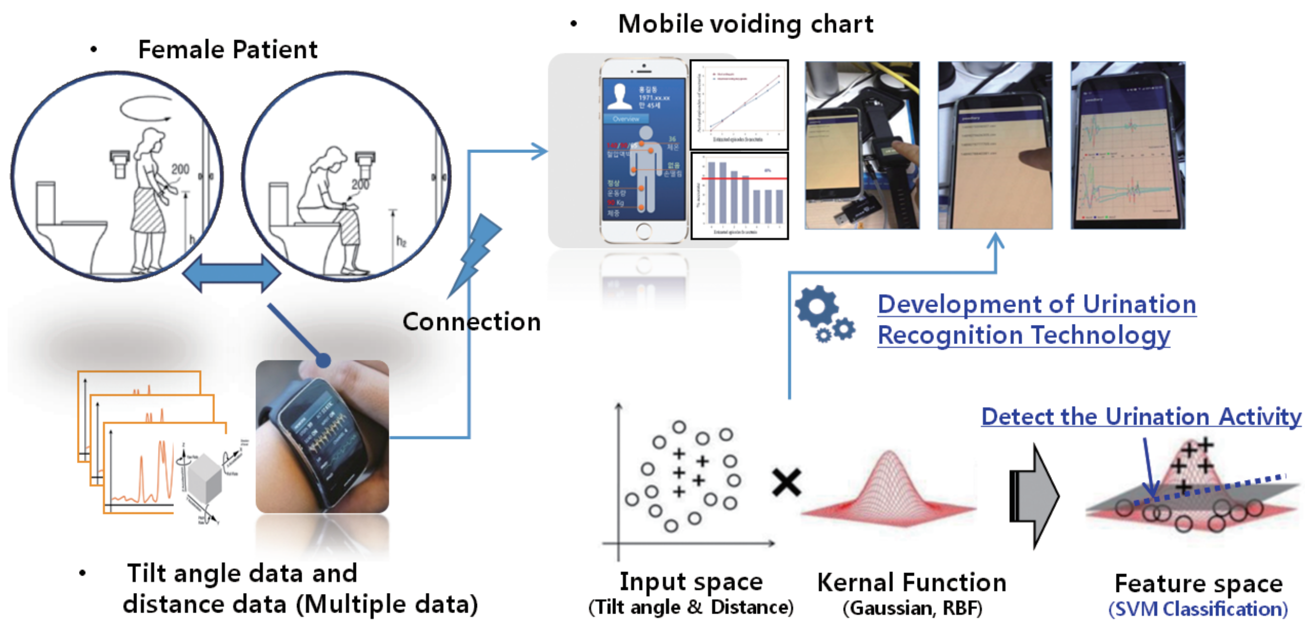

Fig. 1. The whole concept of proposed method.

such as artificial neural networks and K-means, or dynamic time warping in combination with algorithms (Fraley and Raftery, 2002; Karmonik et al., 2019; Nikkola et al., 2020; Prabhakar et al., 2019). However, it is appropriate to use time series algorithms to predict or classify dynamically changing time series data.

In this study, the characteristics of the extracted composite data were simultaneously identified and the Radial Basis Function (RBF) kernel-based Support Vector Machine (SVM) method suitable for multidimension analysis was applied. The goal is to utilize the proposed technology to improve users' perception of urination and to efficiently solve existing problems, such as problems where existing data do not apply. The conceptual diagram used to recognize urination in female patients was processed according to the following steps as shown in Fig. 1.

MATERIALS AND METHODS

This research was approved by the Institutional Review Board of Gachon University Gil Medical Center (approval number: GDIRB2017-096). The average age was 28.73 years (26–34 years), with no sign of urination disorder. The user wrote a urination diary for 3 days and monitored the number of urinations by wearing a smart band. The smart band used in this study recognized the urination activity by combining the female patient's gyro sensor information and the ground height information, the distance information. In this study, based on the changes in the patient's posture and posture, the RBF kernel-based SVM was applied to increase the accuracy in urination study. In the case of an existing study (Eun et al., 2017), SVM was used to solve the problem of a technique that is difficult for multidimensional analysis because it classifies complex data at the same time. This leads to the characterization and classification of the female patient's gyro sensor information and the distance information, which is the height of the ground, and determines the class at which the newly input signal information belongs to the learned boundary. Two urologists reviewed the paper urinary diaries and compared the dates reported by the smart band with the paper urinary diaries results.

Optimize parameters for upgrading classification boundaries

Support vectors are data points located at the boundary between two classes. There is a lot of data, but support vectors among them influence the creation of decision boundaries. However, most data are not ideally separated. In many cases, outliers are observed. In this case, it is impossible to isolate the data linearly and completely. To solve this problem, a strategy has been created to allow some errors. The parameter associated with this is cost. Cost determines how many data samples are allowed to be placed in different classes. The smaller, the more allowed, and the larger, the less allowed. In other words, setting low-cost value will catch a lot of anomalies and find common decision boundaries, while setting a high setting will make the ideal probability smaller, making it

 https://doi.org/10.12965/jer.2142474.237

Table 1. Overall motion date

Variable	Coefficient	Standard error	Best *P*-value	95% CI
Bivariate				
E (Loqitsensitivity)	1.487211	0.2251031		1.046017–1.928405
E (Loqitspecificity)	2.004041	0.0931886		1.821395–2.186688
Var (Loqitsensitivity)	0.0459553	0.1911886		0.0000132–159.8106
Var (Loqitspecificity)	0.0020109	0.0198973		7.60e-12–531998.3
Correlation	-1			
Bayesian summary ROC				
Lambda	5.061915	10.74863		-16.00501–26.12884
Theta	-1.85076	7.325763		-16.20899–12.50747
Beta	-1.56455	5.795478	0.797	-12.92348–9.794379
Summary				
Sensitivity	0.8156593	0.0338463		0.7400094–0.8730728
Specificity	0.8812207	0.0097541		0.8607334–0.8990477
Diagnostic odd ratio	32.82704	7.871636		20.51734–52.52214
Likelihood ratio positive	6.867018	0.6204718		5.752513–8.197451
Likelihood ratio negative	0.2091879	0.0383758		0.1460099–0.2997027
Inverse likelihood ratio negative	4.780392	0.8769697		3.33664–6.84885

Log likelihood = -44.984934. Number of studies = 10. Covariance between estimates of E (logitsensitivity) & E (loqitspecificity) = -0.0009278.
CI, confidence interval; ROC, receiver operating characteristic.

prudent. Also, kernel technology is to think of the given data as a high-level characteristic space. Once you think in high-dimensional space, you can classify them into linear or nonlinear forms that were never seen in the original dimension. For the RBF kernel, the parameter gamma must be adjusted by the user. There is also C, the default parameter for the SVM, so a total of two parameters must be set. Gamma determines the distance at which a single sample of data exerts influence. Gamma is associated with the standard deviation of the Gaussian function, and the larger, the smaller the standard deviation. In other words, the larger the gamma, the shorter the distance a data pointer exerts influence. Through this, a method for recognizing urination activity by simultaneously judging a female patient's gyro sensor information and ground height distance information along with characteristics was proposed. In this study, data from 10 women were studied to optimize the learning model, i.e., the optimal boundary line was trained to establish cost and gamma values. The best criterion is to determine the parameter values for calculating the optimal position of the boundary line for data classification with adequacy of the margins.

Statistical analysis

The performance of SVM-based urination recognition technology was evaluated using statistical analysis based on confusion matrix. The number of manually recorded urination and the number of actual recognized waveforms were compared to measure true positives, false positives, and false negatives. Sensitivity and specificity were calculated to verify the effectiveness and accuracy of the proposed urination recognition technology. Statistical analysis basically included correlation, standard deviation, and analysis of variance. Although the number of pretreatment was different for each female patient, the recognition criteria were the same, so the comparison of actual waveform recognition accuracy was carried out without any problems.

RESULTS

We evaluated the efficacy of smart band monitoring urination in 10 female patients without urination problems. The entire experimental period was carried out over a total of 3 days. The odd percentage of urination reported in smart band was 32.83 (95% confidence interval [CI], 20.52–52.52). The heterogeneity between the participants was not identified (Table 1). Interim analysis of smart medical devices for urinary diagnosis in our latest project showed that human behavior patterns using wearable devices were very reliable and accurate. Fig. 2 showed a pooled sensitivity and specificity of 0.82 (95% CI, 0.74–0.87) and 0.88 (95% CI, 0.86–0.90). However, area under the curve (AUC) was calculated as 0.91, and the degree of dispersion was not bad and was distributed evenly, indicating high reliability.

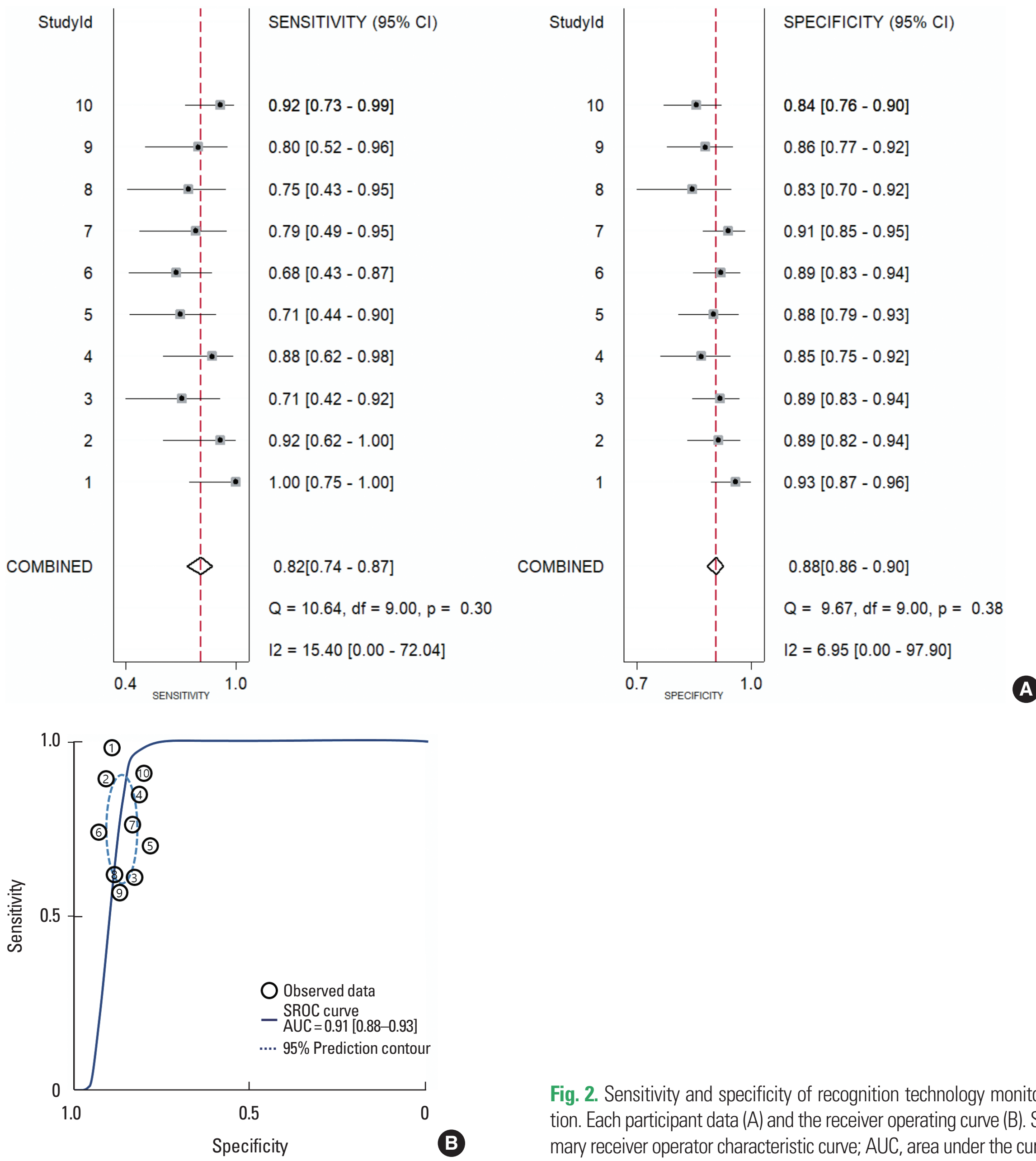

Fig. 2. Sensitivity and specificity of recognition technology monitoring urination. Each participant data (A) and the receiver operating curve (B). SROC, summary receiver operator characteristic curve; AUC, area under the curve.

DISCUSSION

Many studies on the application of mobile health have achieved results in various medical fields. In the field of urology, there are many attempts to develop mobile medical devices for both patients and clinicians. As urination problems limit daily life, urination disorders are prevalent and associated with reduced quality of life due to a variety of urinary disorders (Vaccari et al., 2020).

In this paper, an algorithm development study for recognition of urinary activity of female urinary patients was conducted by applying RBF kernel-based SVM, and the feasibility of urination management system was verified through performance evaluation. Eun et al. (2017) suggested that the k-nearest-neighbors (k-NN) method should recognize the number of urination occurrences. The k-NN algorithm is a kind of supervisory learning that uses labeling data to perform classification. When measuring distance

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at k-NN, the larger the vector size, the more complex the calculation becomes. In addition, k-NN does well for numerical data classification, but a large amount of learning data slows classification. This results in lower accuracy of class classification if it is composed of multiple dimensions of complex data. To address these limitations, this paper applied the RBF-based SVM method, and made optimal boundary detection by utilizing gyro information and height information obtained through smart band as multidimensional features. Boundary detection validated the accuracy of the proposed method by studying the data of 10 women, generating a mean learning model, and verifying the accuracy of the model for 10 women by calculating a confusion matrix equal to the AUC value. Improving the accuracy of SVM is usually based on the determination of cost value and gamma value. In other words, there is a problem in determining how much data interference is allowed and the optimum margin value. This RBF-based SVM has set these cost value and gamma value as optimal parameter value based on the learned model. This resulted in a number of AUC 0.91 with high accuracy that allowed the overall case for the characterization classification of multidimensional complex data. We estimated the efficiency of smart band monitoring urination in 10 days without outlining patients.

Interim analysis of smart medical devices for our final project showed that human behavior objects using wearable devices were highly reliable and efficient. The results were found to be positive and sensitive. In the future, we plan to utilize the Dempster-Shafer theory to increase the recognition accuracy of this algorithm. Additionally, electronic and mobile urination journals have shown several benefits. Previous studies to evaluate mobile medical applications or devices were conducted with people familiar with mobile devices. Current electronic voiding log was not suitable for older adults who could not use mobile devices due to cognitive problems or vulnerabilities (Abrams et al., 2016; Wildenbos et al., 2018). Therefore, new methods of monitoring urination patterns in real life should be explored for dependent and vulnerable old people. For example, we would like to conduct research on how to recognize through Internet of things-based sensors at home. The voiding chart based on urination motion recognition technology through smart band can be a useful tool for monitoring actual urination patterns in female patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

This work was supported by research fund of Chungnam National University Hospital.

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https://doi.org/10.12965/jer.2142474.237