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Fast Fourier Transformed Twin Table Ladder Modulation on Recognising Non Invasive Blood Glucose Level Measurement Optical Device Spectral Responses

Renan P. Jenie[123*], Evy Damayanthi[1*], Irzaman[2*], Rimbawan[1*], Dadang Sukandar[1*], and Husin Alatas[2*]
[1]Community Nutrition Department, Bogor Agricultural University, Bogor, 16680, Indonesia
[2]Physics Department, Bogor Agricultural University, Bogor, 16680, Indonesia
[3]Child Growth and Development Cohort Study, Ministry of Health, Bogor, 10560, Indonesia
E-mail: qwerty_user1983@yahoo.com

Abstract.. A comparative trial conducted between February 2017 and April 2017, at Electronic Material Physics Laboratory, Department of Physics, Bogor Agricultural University, West Java, Indonesia. Blood spectral data from participant older than 17 years were assigned to single measurement group. Blood spectral data previously taken from All participant modulated using Twin Table and Ladder (TTL) methods, and further transformed using Fast Fourier Transform (FFT) Methods, and inferred using Fast Artificial Neural Network. The data contained blood glucose level measurement using both prototype of non invasive blood glucose level measurement optical device (prototype) and veni puncture spectrophotometry (veni). The objective was to measure effect of FFT on accuracy of TTL based optical spectral parser engine for prototype compared to veni for fasting normo glucose participants (participants). Main outcome measure: accuracy as rooted means squared error (RMSE) of either TTL and FFT - TTL inference method, smaller is better. Clarke error grid analysis (ega) and Parker ega, and sensitivity and specificity are calculated from the outcomes, larger is better. No randomization of records. The data was inferred using TTL method, and further transformed using FFT method. Analyser are not blinded for either measurement methods. 120 blood spectrum data from volunteerd included in measurement group. The trial is completed for current prototype version, and shall be reopened for future versions. 110 datums were included in the analysis of the primary outcome. RMSE of FFT-TTL 5.16 mg / dl is smaller than TTL 5.27 mg / dl. No difference between Parkes ega of FFT-TTL and pure TTL.. There is insignificant increase in Clarke ega, 99.5 % group A in FFT-TTL compared to 99.3 % group A in TTL. There significance increase of specificity (0.76) but also decrease of sensitivity (0.65) of FFT-TTL compared to TTL. (0.67 and 9.72). Diagnostic accuracy (0.71) and odd ratio (5.83), and Youden index (0.41) remain not changed. No apparent possible case for adverse effect for either methods. No Significant Performance Difference on Fast Fourier Transformed Twin Table Ladder Modulation on Recognising Non Invasive Blood Glucose Level Measurement Optical Device Spectral Responses.

Keywords: comparative study, Fast Fourier Transform, light modulation, optical device, blood glucose level

1. Introduction

To address the problem that current blood glucose level measurement methods is invasive and painful to the user. We proposed to develop alternative that non invasive and thus not painful to the user [1,2]. Spectrophotometry methods known for its potential for non invasive blood glucose level measurement. Several attempts have been made [3,4], None already giving satisfactory result compared to established blood glucose level measurement methods. We have proposed our methods [5], But We did not yet satisfied with the inference engine performance when using plain Bert Lambert Methods or combining it with Twin Table Ladder (TTL) Methods in our previous study [6], so, we use the well known Fast Fourier Transform (FFT) methods for widening the input variance [7], and feed the data using same inference engine to compare the performance [8].

2. Materials and Methods

This a single centre comparison trial, with participant between 17 years to 65 years, purposive sampling, no randomization, no blinding, gold standard controlled, single group trial conducted at Dramaga, West Java, Indonesia. Participants were assigned purposively to one group, focused to fasting range of blood glucose level. Eligible participants were adults from Bogor Agricultural University, aged 17 yo to 65 yo, which are not smoking, hard drinking, undergoing pregnancy, or had done near intervention hard labour. The study took place at Nutrition Services Clinic, Department of Community Nutrition, Bogor Agricultural University, Dramaga, West Java, Indonesia, from December 2016 to January 2017.

In this study, participans sign the informed consent statement and fill each basic profile data. Each participant undergone measurement using prototype first and veni later. In prototype measurement, the device probe is mounted on the distal phalanx, and the results are stored in the local database. In veni measurement, trained practitioner perform blood sampling according to standard laboratory procedures [9] for blood glucose level measurements.

The primary expected endpoint was rooted means squared error (RMSE) below what mandated in ISO 15197:2016, which is 10 mg / dl [10,11]. For proper measurement of sensitivity and specificity of prototype, based on equation by [12] and sensitivity and specificity data by [10,11], with power of 90 % and drop out margin of 20 %, a sample size of 120 participants was necessary. participants, enumerators, and health practitioner informed about prototype and veni methods before trial. As primary endpoint, we use accuracy, defined by RMSE of prototype output while compared to veni output, and compare the RMSE to ISO 15197:2016 standard. Clarke and Parker ega between prototype and veni are calculated using [13] Sensitivity and specificity between prototype and veni are calculated using Stevenson [14]. We utilize R [15] with RStudio [16] and RKward [17] for statistical analysis.

For either TTL and FFT TTL, we use Fast Artificial Neural Network (FANN) [8]as inference engine, as per our previous research [6]. Our tools built on Raspberry Pi 3B [18], and implementing WiringPi [19] for GPIO control. We procure the LED and photodiode for sensor from Thorlabs [20,21], and use I2C protocol for communication [22]. SQLite [23]and Qt [24] are used to build the software needed.

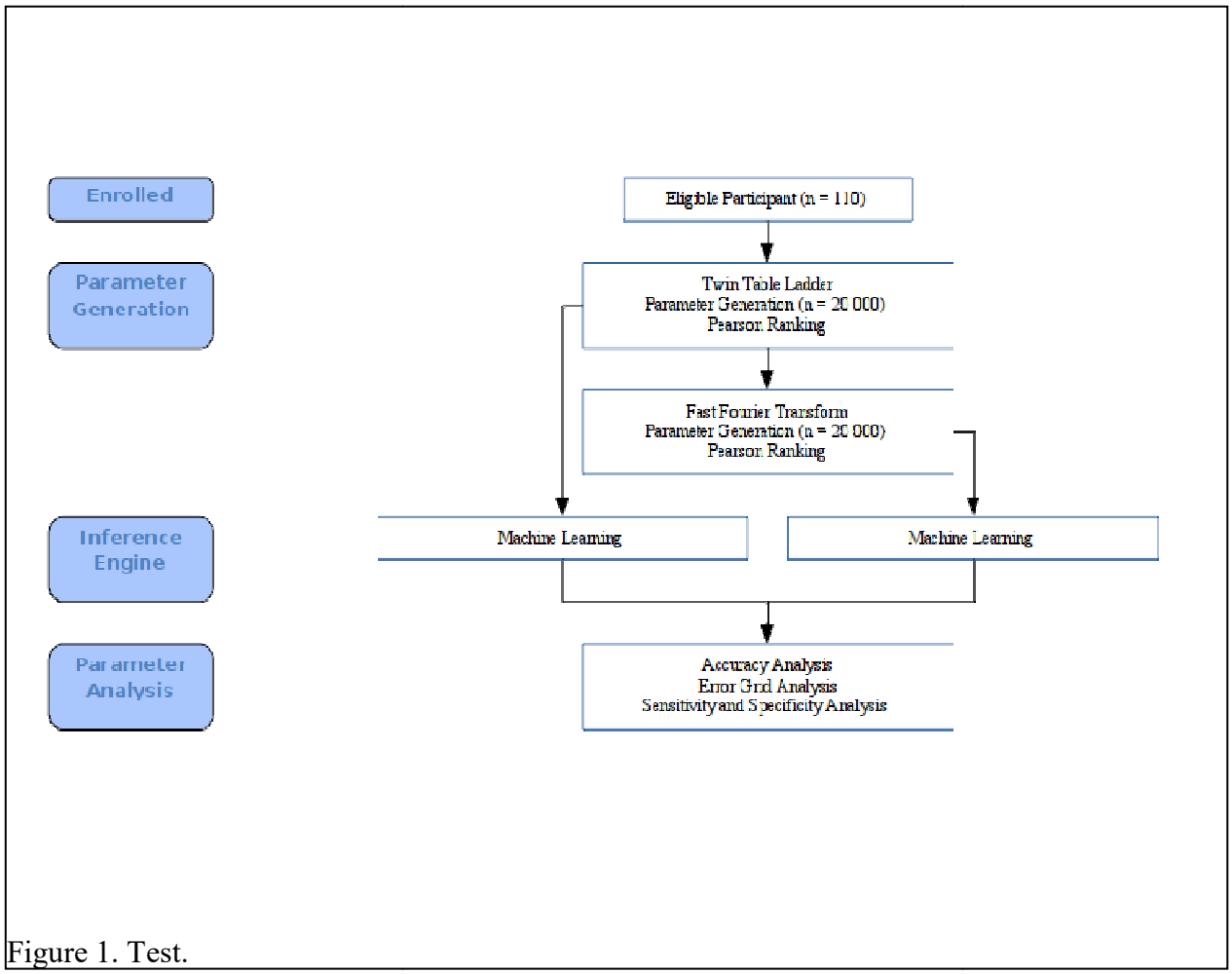

Figure 1. Test.

3. Results and Discussions

Age-eligible participants measured between December 2016 to January 2017. We use 110 participants data out of 120 participants (Figure). The reference measurement range are 60 mg / dl – 10 mg / dl. TTL LED modulation made according to our previous reports [5,25]. FFT equation made using FFTW [7]. We generated 20 000 parameters and uses the 5 best correlation parameters using ALGLIB [26].

Table 1. Competitive matrix.

Parameter	Twin Table Method	Fast Fourier Transform	Reference
Rooted Means Squared Error	5.2672 mg / dl	5.1607 mg / dl	10 mg / dl [27,28]
Clarke Error Grid Analysis (A - E)	99.3 % 0.0 % 0.0 % 0.7 %	99.5 % 0.2 % 0.0 % 0.4 %	100.0 % 0 % 0 % 0 %

Parameter	Twin Table Method	Fast Fourier Transform	Reference
	0.0 %	0.0 %	0 %
Parker Error Grid Analysis (A - E)	100.0 % 0.0 % 0.0 % 0.0 % 0.0 %	100.0 % 0.0 % 0.0 % 0.0 % 0.0 %	100.0 % 0.0 % 0.0 % 0.0 % 0.0 %
Apparent Prevalence	0.51 (0.46, 0.55)	0.43 (0.40, 0.48)	
True Prevalence	0.47 (0.43, 0.52)	0.47 (0.43, 0.52)	
Sensitivity	0.72 (0.66, 0.78)	0.65 (0.59, 0.71)	
Specificity	0.67 (0.62, 0.73)	0.76 (0.70, 0.80)	
Diagnostic Accuracy	0.70 (0.66, 0.74)	0.71 (0.67, 0.75)	
Diagnostic Odd Ratio	5.53 (3.83, 7.98)	5.83 (4.02, 8.44)	
Number Needed to Diagnose	2.49 (1.96, 3.49)	2.44 (1.94, 3.40)	
Youden's Index	0.40 (0.29, 0.51)	0.41 (0.29, 0.52)	
Positive Predictive Value	0.67 (0.61, 0.72)	0.71 (0.64, 0.76)	
Negative Predictive Value	0.73 (0.68, 0.78)	0.71 (0.65, 0.76)	
Positive Likelihood Ratio	2.25 (1.88, 2.71)	2.67 (2.14, 3.33)	
Negative Likelihood Ratio	0.41 (0.33, 0.50)	0.46 (0.38, 0.55)	

For either TTL and FFT TTL, for inference engine, assisted by FANN [8] we pick the best pick setting. We found out that the best accuracy for TTL achieved using reverse propagation training, Gaussian hidden activation function, and Elliot symmetric activation function, and for FFT-TTL achieved using reverse propagation training, Gaussian hidden activation function, and sigmoid symmetric activation function. Both inference engine built in 6 – 24 – 2 formation. Training and testing result as in (Figure). No severe adverse effect of prototype usage found.

Intervention was implemented for both sexes and all ages, in 50 mg / dl to 100 mg / dl range. No significant difference between accuracy of TTL (5.27 mg / dl) and FFT-TTL result (5.16 mg / dl). Either methods yieds accuracy lower than mandated ISO 15197:2016 10 mg / dl [10,11]. That means either methods can be used as inference engine for non invasive glucose measurement. No difference between Parkes Error Grid Analysis (EGA) [13] of FFT-TTL and pure TTL, as both yields 100 % Zone A. There is insignificant increase in Clarke EGA, 99.5 % group A in FFT-TTL compared to 99.3 % group A in TTL. The difference did not powerful enough to determine whether FFT implementation is beneficial. There significance increase of specificity (0.76) but also decrease of sensitivity (0.65) of FFT-TTL compared to TTL. (0.67 and 0.72). Diagnostic accuracy (0.71) and odd ratio (5.83), and Youden index (0.41) remain not changed. No apparent possible case for adverse effect for either methods. FFT-TTL output not giving significant difference to TTL method alone.

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