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# EEG Driven Autonomous Injection System For An Epileptic Neuroimaging Application

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*Abstract*— **Seizure episodes are frequently observed for adults and children suffering from medically refractory epilepsy and the events remain debilitating unless treated with a more comprehensive approach. Ictal perfusion studies with single-photon emission computed tomography (SPECT) is one of the non invasive imaging modality that has been extensively used to adequately localize the seizure focus. Current practices include the tracer injection within a short time interval at the onset of seizure to generate desirable SPECT scan quality with accurate information on foci region. However, the onset of a seizure is a highly unpredictable event and also with added subclinical events, the overall procedure makes it difficult to administer the tracer manually within the ideal time frame.**

**Hence a complete autonomous injection of radioactive tracer element without manual intervention is expected to offer a highly accurate epileptical focus region and aids in further management of the patient. Electroencephalogram (EEG) physiological signals in the preictal phase contain sufficient indicators to predict the seizure event. The proposed injection system works on the seizure prediction model from the EEG signals to release the dosage, making the system completely autonomous in action. The accuracy of the prediction model based on the publicly available seizure embedded EEG datasets was designed to achieve 94% accuracy, and the model was deployed on an edge system. The syringe based injection system was characterized to emulate dosage release action with minimum volumetric error, and low injection time, on predicting seizure Ictal event from the EEG signal. The proposed system is a step towards developing an autonomous injection system for epileptic neuroimaging applications in hospital settings.**

*Clinical relevance*— **Autonomous injection of tracer dosage for obtaining accurate and high quality Ictal SPECT scan results is preferred over the manual operation in clinical and hospital residential settings as a part of pre-surgical evaluations. The EEG signal based early prediction of seizure ensures adequate time for radioactive tracer element to reach the brain cells and eventually helps to accurately localize the onset region of seizure in the brain. The EEG driven automated injection system for the noninvasive Ictal SPECT method is clinically important as a pre-surgical evaluation in MRI negative or discordant cases for further surgical actions.**

## I. INTRODUCTION

Epilepsy is a chronic non-communicable disease that affects people of all age groups. According to the World Health Organisation 2019 survey report, around 50 million people worldwide suffer from epilepsy, making it one of the most common neurological diseases globally [1]. And it is estimated that up to 70% of people living with epilepsy could live seizure free if properly diagnosed and treated. The epileptic patients suffer from unpredictable seizures at various instances, which disrupts their activities on daily basis, and in addition brings in a risk of early mortality [2]. The seizure events and the duration of the attack are difficult to predict, thereby related injuries and safety of the patients and their families are a major cause of concern. Hence effective diagnosis and treatment are not only beneficial but also imperative to avoid major consequences. The other challenge is that post detection, the patients do not respond positively to the anti-epileptic medication, primarily due to the untargeted delivery of the drug on the focal epileptic zone [3]. Curative surgical treatment over focused regions of seizure in the temporal lobe is considered an optimum solution showing remarkable results post surgery. However, finding the epileptic zones with a high level of certainty is considered a first step towards the success of the surgery. The pre-surgical evaluation of seizure patients to localize seizure foci via the monitoring of non-invasive video EEG signals of the patient was also proposed in the past. However, the localization of the seizure focus depended on the density of electrodes mounted on the surface, and also on the spatial sensitivity of the electrode [4], [5]. The physiological EEG group signal reflects the transient nature of the seizure events but is not a standardized method for localizing the seizure onset region of the brain.

A reliable, and practiced Ictal SPECT method is preferred over other methods owing to the capability of indicating a change in blood flow of the brain, during a seizure event. The Ictal SPECT study is time consuming process since seizure is a dynamic event and several regions of the brain are involved [6]. Hence a standard practice is to inject Tc-labelled with hexamethylpropylene-amine-oxine (Tc-HMPAO) which is a radioactive dose that offers sharp contrasting SPECT images, showing focal alteration in the cerebral blood flow associated with the seizure focus [7]. A brain SPECT scan presents the onset zone clearly, provided the isotope dosage is timely injected, otherwise, the epileptic discharge is considered to propagate to other regions of the brain leading to ambiguity in the SPECT report. MRI co-registered on the Ictal SPECT report is another useful method to analyze the impact of seizure [4]. The major drawback in the current practiced manual injection driven Ictal SPECT method is that the radioactive tracer dosage needs to be constantly evaluated and administered in an unpredicted seizure event, leading to a certain delay in injection even

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for an experienced and trained medical personnel [8]. The immediate action towards evaluating the accurate radioactive dose and injecting to the patient post seizure is highly stressful to the staff monitoring the patient [9], and also increases the risk of getting exposed to radioactive contamination. Additionally, a time lag between seizure onset and injection process leads to unsuccessful SPECT results for surgical planning. A similar study was conducted in [10], where the dose error, and exposure to dosage, was significantly reduced in remote controlled automated injection mode.

A remote controlled injection system (AIS) proposed in [6], [11], delivers the dosage that is controlled distantly when the patient goes into epileptic seizure state. However, this is still a manually controlled process and human errors and delay in injection lead to irreversible damages. An injection time with a deviation of less than 34 seconds post seizure onset is tolerated for SPECT studies, thereby making the overall injection and release of the tracer elements time critical for successful Ictal SPECT results. The remote controlled injection system offers, several benefits including shortened injection latency time leading to significant improvement of localizing onset region, and more importantly provides a safe option for medical staff to operate the isolated radioactive system [12]. The remote controlled system still mandates the medical staff to be highly attentive and wait for a dynamic seizure event to occur. Instead, an autonomous process where the prolonged wait for seizure event is eliminated by predicting the event earlier will offer an error-free solution. Among all the physiological signals, the EEG signal showcases the running characteristics of the human brain, and includes strong signatures to predict the seizure event [2], [13]–[19]. A controlled drug delivery mechanism for refractory epilepsy is discussed in [20], however, the overall drug delivery actuation model is showcased with no experimental results, neither the autonomous operation is designed in the proposed system. An automated injection system increases seizure focus localization rate by 15% compared to manual injection [11], [21]. Hence a novel system that predicts the seizure event early and triggers the isotope injection system which currently does not exists is required for generating an unambiguous Ictal SPECT report.

The prediction problem of the seizure event is derived as a classification problem to recognize the preictal state from the running interictal phase from EEG signals. Several signal processing techniques [16], [18], and classification techniques were applied in the past, with support vector machine (SVM) method [22]–[24] to obtain moderate accuracy. Other classifiers such as Linear discriminant analysis (LDA), Quadratic discriminant analysis (QDA), and K-Nearest Neighbours (KNN) were attempted on EEG signals to predict the seizure event by 31 minutes prior to the event [15], however high false rate characterized by the stated techniques, is not seen as a reliable solution for integrating to the critical Ictal SPECT operation. In the recent past, several authors have attempted convolutional neural network (CNN) as a classifier on the extracted features of EEG signal, to predict seizure event [14], [25]. In [14], convolution filters were applied on the wavelet transformed EEG signal to learn discrete indicators of interictal, preictal, and ictal stages. The algorithm showcased preictal stage detection accurately by only 10 minutes, which may not be adequate in a real time medical assistance, and a much earlier prediction is preferable. However, extracting features from the running EEG signals is time consuming and process intensive method which does not reliably fit to the real time Ictal SPECT design, hence a unified framework to extract features and classify the preictal stage, was proposed in [19], and same was implemented on the edge computing device. The paper proposes an autonomous injection system driven by EEG signal and the early engineering design is validated. In addition, the dosage measurement and release of the controlled dosage is also automated over time in the injection system. A proof of concept calibration step is introduced to relate the dosage release quantity with that of syringe design parameters. The proposed proof of concept autonomous injection system for a neuroimaging application is stated, for the first time in the literature.

## II. System Design

The proposed design involves a linear electromechanical actuator that dispenses appropriate radioactive dosage (Tc-HMPAO) from a syringe to initiate the ICTAL SPECT study. The actuator is triggered using a deep learning based seizure prediction model that runs on an edge computing device. The overall architecture for automated dosage injection is shown in the Figure 1. In this prototype work, Rapsberry Pi was used as a minimal resource powered primitive edge computing device. The prediction model processes the running EEG signal to predict the onset of seizure event an hour before its occurrence. The electromechanical actuator consists of a linear stepper motor attached to the plunger of a syringe. The Stepper motor has the ability to rotate in clockwise and anti-clockwise direction. The rotational motion provided by the linear stepper motor is converted into translational motion using a threaded rod. This translational motion helps in maneuvering the syringe forward and backward.

On receiving a seizure alert from the prediction module, the actuator injects the appropriate volume of the radioactive dosage into the patients' vein. The radioactive material decays over time and hence continuous adjustment of dosage volume is required before injecting. The actuator controller calibrates the volumetric release of the dosage required for tracer injection. A variation in dosage to the prescribed volume will either lead to non-traceable seizure onset regions or side-effects due to the higher consumption of radioactive dosage. The actuator controller in the edge processor computes injection volume characterized by half-life and radioactivity factor of the Tc-HMPAO dose over the duration of the patient under the pre-surgical evaluation phase.

## III. Seizure Prediction Design

The seizure prediction model is developed in-order to effectively perform Ictal SPECT study and localize the seizure onset of refractory epilepsy. The prediction event is

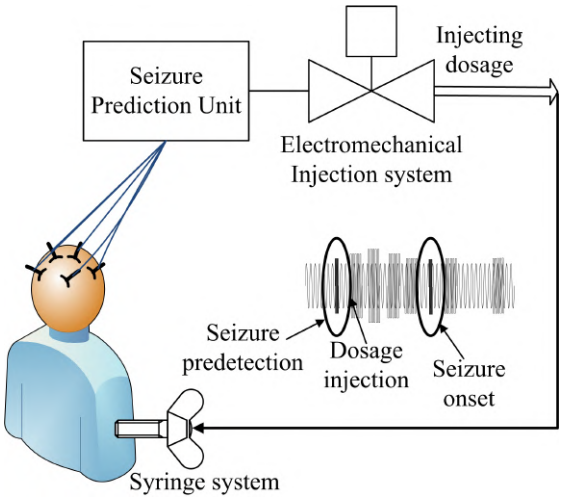


Fig. 1. System architecture showing the prediction model triggering the injection system.

designed to provide a window before the onset of seizure during which the radioactive dosage is injected, and given sufficient time to reach the brain cells. The seizure prediction model is designed using a deep neural network where the the feature extraction is performed by a deep convolution neural network, followed by a fully connected dense network for classification [19]. The prediction model was predefined to yield result, an hour prior to the onset of seizure. The 1 hour of prediction interval was useful for the isotope agents to spread adequately around all regions of brain cells and offer distinct Ictal SPECT scan results. The SPECT tracer agents reach and get fixed in brain cells by metabolic conversion to nondiffusible forms [26], which helps to perform clear SPECT imaging. The nondiffusible form of tracer dosage is sustained for atleast 4 hours [26].

### A. Dataset

The publicly available CHB-MTT EEG datasets recorded at Children's Hospital Boston [27] were utilized to train robust model. The dataset contains raw EEG recordings collected from 22 subjects involving 5 males of age 3 to 22 years, and 17 females between age of 1.5 to 9 years. The raw EEG recordings, contain 23 channel data, that are collected from respective scalp electrodes. During EEG recording, the electrodes were positioned using the International 10-20 system protocol and all signals were sampled at 256 samples per second with 16-bit resolution. Temporal dynamics of brain activity are classified to four phases as shown in the Figure 2 [19]. The four phases are categorized according to an EEG signal of a seizure patient: *Interictal* phase considered as the time span between successive seizure events, *Preictal* phase defined for the region prior to seizure event, *Ictal* phase as duration of a seizure event, and *Postictal* phase referred to as time span post seizure event. For seizure prediction, the primary challenge is in differentiating Preictal and Interictal states within the EEG data. Hence the goal of the prediction model was to demonstrate the existence of

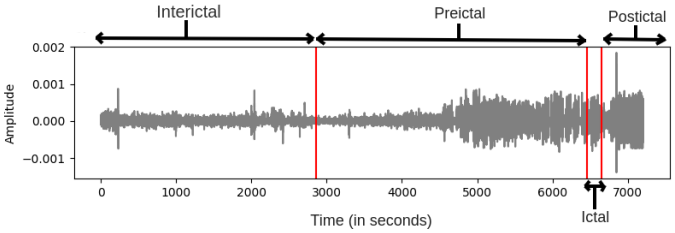


Fig. 2. A sample of EEG data classified to different phases as defined by Ictal Seizure event.

Ictal event and accurate classification of the Preictal state with naturally occurring seizure event within the epileptic patients EEG dataset.

### B. Model

Seizure prediction model was designed by employing deep-learning techniques as proposed by Daoud *et al.* in [19]. The raw EEG data was segmented into non-overlapping batches of 5 seconds containing 1280 samples in each batch. The frames of data were fed to the convolutional neural-network (CNN) architecture for feature extraction. These features were then supplied to a fully connected dense network for classification between Interictal and Preictal states. The CNN architecture consists of 4 consecutive convolutional layers, with each layer consisting of 32 kernels of size $3 \times 2$. Between every two convolutional layers, a maximum pooling layer of dimension $2 \times 2$ was designed. The RELU activation function was applied across all convolutional layers followed by batch normalization to reduce overfitting. The output of the last convolutional layer was passed to a fully connected network consisting of 3 hidden layers of sizes 100, 50, and 20 each. Each of the hidden layer uses RELU activation function followed by a dropout regularization. The final output layer was configured to 2 units of $SOFTMAX$ activaton to ensure that the output values fall between 0 and 1 indicating the predicted probabilities used for classifying between Interictal and Preictal events. More details about the model can be found here [19]. There is an imbalance in the number of Interictal and Preictal segments in the dataset, hence while training, an equal number of Interictal and Preictal segments were selected in-order to eliminate any bias within the original dataset. 80% of the data were used for training purposes, and 20% of the data were used for validating the model. The model deployed on Raspberry Pi (RPi) used as an edge device demonstrated prediction accuracy of 94% similar to results stated in [19].

## IV. Automated Dosage Mechanism

The automated dosage mechanism comprises of two main components: a dosage computation module responsible for computing the amount of liquid to be dispensed, and a syringe actuator to release liquid from the syringe.

### A. Dosage Computation

Since the Ictal SPECT study employs radioactive material, dosage computation module incorporates radioactive

disintegration over time for evaluating the dosage volume to be released. The dosage ($A_{cal}$) in milli-Curie (mCi), was calibrated to volume ($V_{cal}$) in milliliters (ml), as a function of injection time $t_{injection}$. $t_{injection}$ is considered as the instance of first seizure attack on the patient under observation over the duration of 6 hours, where the dosage injection is planned. The specified shelf life of 6 hours for $^{99m}Tc$ isotope [6], beyond which the tracer element bonds become weaker, was also incorporated in the dosage computation. The edge processor estimates the injected volume ($V_{inject}$) to be released as a function of initial volume ($V_{ini}$), and initial dose activity ($A_{ini}$) that is loaded in the syringe system. The prescribed dose activity ($A_{inject}$) set by the radiologist in the system, was modeled with the dispensing volume released over the duration, accounting for the disintegration of radioactive material over time as expressed in the equation 1, where $\lambda$ is disintegration constant, $t_0$ is the initial time when the system was started to monitor the patient under evaluation, and $t_{inject}$ is the time of injecting dosage, on prediction of a seizure event.

$$V_{inject} = \frac{A_{inject} \times V_{ini}}{A_{ini} \times e^{-\lambda(t_0 - t_{inject})}} \tag{1}$$

Few estimated injected volume of $^{99m}Tc$ over time was presented in Table I to observe the increase in the isotope volume over time. The initial activity $A_{ini}$ was taken as 60 mCi and the prescribed activity $A_{inject}$ of 20 mCi, also mentioned in [6] was considered. The initial volume $V_{ini}$ of 4 mL and the disintegration constant $\lambda$ of $3.197 * 10^{-5}$ for the $^{99m}Tc$ isotope was considered in our proof of concept work.

TABLE I

COMPUTED ISOTOPE VOLUME TO BE INJECTED AT DIFFERENT INJECTION TIME STARTING FROM $t_0$, TO DELIVER PRESCRIBED DOSAGE OF 20 MCI.

| Time of Injection | Injection Volume (ml) |
|---|---|
| 30 minutes | 1.41 |
| 1 hour | 1.49 |
| 2 hour | 1.67 |
| 3 hour | 1.88 |
| 4 hour | 2.11 |
| 5 hour | 2.37 |
| 6 hour | 2.65 |

### *B. Syringe Actuator*

A linear actuator, driven by a stepper motor was designed for dispensing liquid from the syringe. The clockwise and anti-clockwise rotation of the stepper motor - NEMA17 was transformed to linear motion via a threaded rod that moves the actuator forward and backward accordingly. The actuator was further attached to the plunger of the syringe which allows to maneuver the syringe as shown in Figure 3. Stepper motors provide high precision and control over the speed and angle of rotation. The General Purpose Input/Output (GPIO) pins of edge computing Raspberry Pi (RPi) were wired to the stepper motor to control the linear motion of the syringe plunger. The GPIO pin was programmed to a pulse width modulated signal (PWM) with a time period ($t_{pw}$) of 20 $ms$ and 50% duty cycle to drive the stepper motor.

The output of the dosage computation module was provided as an input to the syringe actuator module. Based on the specified volume, the syringe actuator was characterized over the number of steps to move and release the volume appropriately and is expressed in the equation 2, where $V_{dispense}$ is the volume dispensed by the syringe, on actuation of the stepper motor by $N$ number of steps, and $\gamma$ is the calibration constant, empirically calibrated for the specific syringe and actuator utilized. Each step movement of the stepper motor is powered by a pulse width signal. For the proposed system design, the stepper motor should move optimum $N$ steps so that $V_{dispense}$ matches the established $V_{inject}$ at time $t_{inject}$. With the particular syringe and motor setup, $\gamma$ was calibrated by performing multiple trials in an experimental environment and the average of the volume dispensed $V_{dispense}$ over the number of motor steps, $N$ was estimated. Deionized water was utilized in the syringe to calibrate $\gamma$ and few of the experimental data was presented in the table II. Experimentally, $\gamma$ was deduced to a mean of 0.041 ml/steps with a variance of $3.47 \times 10^{-6}$.

$$V_{dispense} = \gamma * N \tag{2}$$

TABLE II

VOLUME DISPENSED MEASUREMENT OVER NUMBER OF STEPS ROTATED BY THE STEPPER MOTOR IN THE SYRINGE ACTUATOR DESIGN TO CHARACTERIZE $\gamma$.

| Number of Steps | Volume Dispensed | $\gamma$ |
|---|---|---|
| 25 | 1.07 | 0.043 |
| 50 | 2.15 | 0.043 |
| 100 | 4.30 | 0.043 |
| 150 | 5.89 | 0.039 |
| 200 | 7.96 | 0.040 |
| 250 | 9.88 | 0.039 |

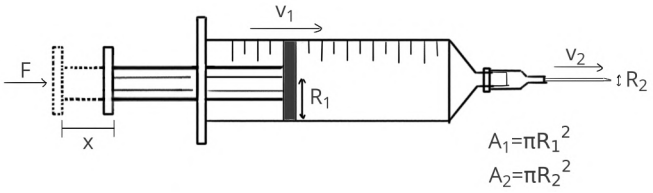


Fig. 3. Block diagram representation of the syringe system used in the design.

Additionally, $\gamma$ is a function of syringe design parameters including cross-sectional area of the syringe ($A_1$), cross-sectional area of the needle ($A_2$), holding torque of the stepper motor ($F$), time period of pulse width modulation signal ($t_{pw}$) and density of the injecting fluid ($\rho$). The calibration constant $\gamma$ which is a function of syringe setup parameters is derived from Bernoulli's principle [28] and conservation law. The Bernoulli's principle applied to the syringe setup is expressed in Equation (3), and the continuity

equation of fluid dynamics adopted from the conservation law is stated in Equation (4), where $\nu_1$ is velocity of fluid near the syringe plunger and $\nu_2$ is velocity of fluid emerging out of the needle.

$$P_0 + \frac{F}{A_1} + \frac{1}{2}\rho\nu_1^2 = P_0 + \frac{1}{2}\rho\nu_2^2 \tag{3}$$

$$A_1\nu_1 = A_2\nu_2 \tag{4}$$

Considering equations (4), and (3), $\nu_1$ is expressed as a function of setup parameters also expressed in the equation (5).

$$\nu_1^2 = \frac{2F}{\rho A_1}\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)^{-1} \tag{5}$$

For a given $F$, $A_1$, $A_2$ and $\rho$, the velocity $\nu_1$ of the fluid near the syringe plunger is constant and expressed as $\frac{x}{t}$, where $t$ is the time span for the plunger to move $x$ distance in the syringe. The time span for displacing the plunger by $x$ distance is expressed as $t = t_{pw} \times N$, where $N$ is the number of pulse cycles which is equivalent to the number of steps driven by the stepper motor, and $t_{pw}$ is the time period of the pulse width signal configured in the edge computing device. $N$ is replaced with $V_{dispensed}/\gamma$ according to Equation (2), and considering the dispensed volume $V_{dispensed} = A_1 \times x$, $\gamma$ is further expressed as a function of syringe design parameters and fluid property as stated in Equation (6).

$$\frac{1}{\gamma^2} = \frac{\rho}{2FA_1t_{pw}^2}\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right) \tag{6}$$

The equation comprehensively signifies that the calibrated $\gamma$ is dependent on the design of syringe, fluid used, and pulse width signal programmed by the edge device.

## V. Experimental Results

The deep learning based prediction model was deployed in the RPi established as the edge device, and the proof of concept syringe actuation system was integrated to the same system as shown in the Figure 4. The overall autonomous injection system designed, presents a real time latency. The edge processing device turns on the linear actuator which pushes the syringe to release the tracer element. The autonomous seizure prediction model was applied on the dataset picked from CHB-MTT and which was not utilized for training purpose. The dataset was continuously fed in batches of 5 seconds to simulate the realtime settings of a hospital residential environment. The overall delay for the seizure prediction model running on the edge computing device was characterized to 600 $ms$. The seizure prediction model triggers the release of the isotope fluid post computation of the injection volume, which presents additional delay. For the academic laboratory setup with no radiation protection facility, deionized water was employed instead of the radioactive material to successfully demonstrate the working of the overall autonomous system. The viscosity of tracer element in bolus solution is likely to have similar viscosity as that of body fluids, which is having viscosity comparable to deionized water [29]. Currently the duration of the injected liquid is controlled by the pulse width signal programmed by RPi device. A pulse width ($t_{pw}$ of 20 $ms$ with 50% duty cycle was designed to drop a volume of $\gamma$ $ml$ (0.041 $ml$), which was verified repeatedly. The volumetric flowrate was also determined by the speed of the injection shaft movement, which is controlled by the motor driver current driving the linear actuator. The motor driver current determines the linear actuation speed, thereby controlling the flow rate of the dosage.

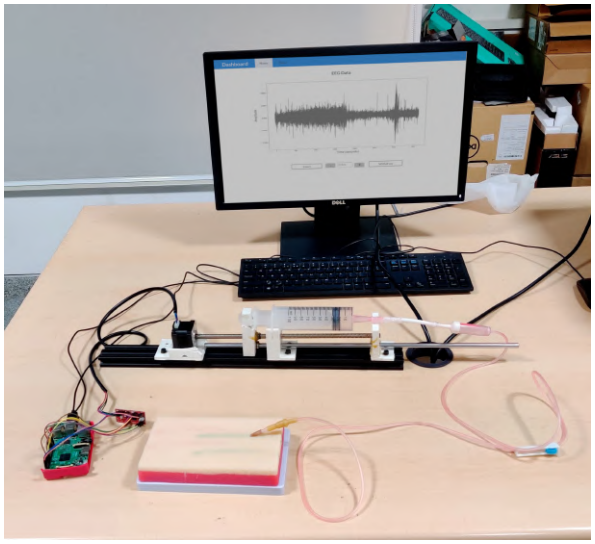

Fig. 4. The complete setup of EEG driven Autonomous Injection system connected to venipuncture pad through Intravenous tube.

Multiple trials were performed to compute the overall latency in dosage delivery. Each trial involved computing time taken to deliver $V$ volume of the dosage. The volume ($V$) was varied from 0 to 30 $ml$ in-order to capture the trends in delay. The trials were performed on a realistic environment where the output of the syringe actuator was connected to an Intravenous (IV) tube which was further injected into a venipuncture training pad. The training pad consists of 4 embedded veins that simulates 3 skin layers involving a layer of skin, subcutaneous tissue, and muscle. Figure 5 shows the the time taken to inject different volumes of deionized water from the syringe actuation system. The overall time consumed to inject liquid to the venipuncture is linearly proportional to the quantity of the volume dispensed. The average time taken to release 1 $mL$ is 0.505 seconds with a variance of 0.33 $\mu$s for the proposed syringe injection setup.

Due to various irregular internal resistive forces including friction, and surface tensions in the syringe and IV tube, the system suffers from minor deviations in the dispensed volume. Therefore, multiple trials were performed to capture the characteristic error in the volume dispensed. Figure 6 shows the volumetric error conceded for the targeted dispensed volume. For a given target volume $V$, the system dispenses between $V \pm \Delta V$, where $\Delta V$ is the maximum absolute error determined post 5 trials. The red region highlighted in the Figure 6 indicates the observed error $\pm\Delta V$ for a

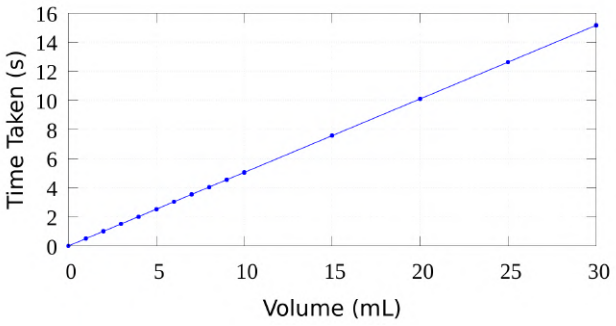


Fig. 5. Time taken by the proposed system to deliver different volume of the fluid used.

given targeted volume $V$, with a maximum volumetric error of 0.2 ml. The blue region indicates the $\pm 12\%$ acceptable volumetric error under manual injection practice [21]. Figure 6 characterizes lower volumetric error than the acceptable one. A similar range of error is expected to lie between the acceptable blue region for the radioactive tracer element in bolus solution, considering the viscosity of tracer element with bolus has to match body fluids, which is close to the water viscosity [29]. The volumetric error and injection latency parameters are not likely to vary much on usage of tracer element with bolus.

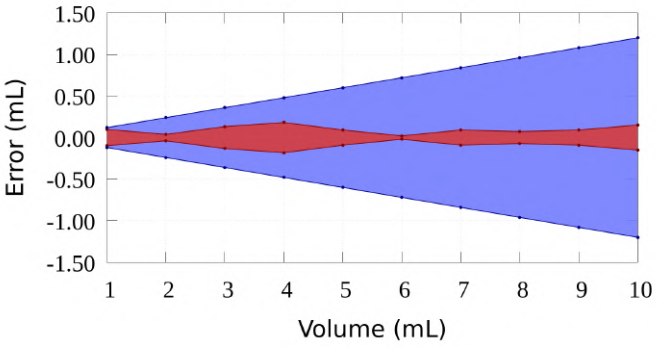


Fig. 6. Volumetric error conceded by the autonomous system with respect to the target volume.

The autonomous injection system was observed to successfully trigger the dispensing of 2.65 ml of deionized water to the venipuncture training pad, when the prediction of seizure was made at 6 hour. With a volumetric error of less than manual injection error of $12\%$, and overall classification time of around 600 $ms$, and dispensing time of less than 2 seconds, the edge computing system demonstrated real time performance. The experiments were repeated 10 times to validate the autonomous function of the injection system, at different seizure occurrence time. The injection time characterized by the proposed autonomous system to deliver tracer fluid for a maximum monitored time of 6 hours was found to be acceptable and comparable with that of manual injection and remote controlled operated mechanisms which was stated around 8 seconds and 19 seconds respectively [30], with an additional benefit of injecting an hour prior to the seizure event.

Although the prediction model has accuracy greater than 90%, there is a small probability of error in the prediction model which can result in a false positive outcome and can lead to unnecessary injection of the radioactive dosage without any actual occurrence of seizure. The safety can be improved by the addition of an extra protection layer such as awaiting for a doctor's approval before triggering the injection. However, in case of an accidental injection, the study conducted by The Royal Children's Hospital Melbourne [31] reported no side effects, as the total body radiation dose from technetium (Tc) injection is very small, being less than that which the chest or brain receives with an x-ray or CT scan.

## VI. Conclusions

A proof of concept autonomous injection system driven by a seizure prediction model was designed and characterized on an edge computing device. The EEG signal driven prediction model has the ability to detect the onset of seizure an hour before it's occurrence. The model is used to trigger a syringe actuation system which delivers the optimal radioactive dosage ($^{99m}Tc$) for Ictal SPECT. The injecting volume of the Tc-HMPAO isotope was calibrated to account for the radioactive decay. The ability to inject the radioactive dosage an hour before the onset of seizure helps in a successful staging of the ICTAL Spect study, to yield unambiguous result. The ICTAL SPECT is a very effective clinical tool in localizing the onset region of the seizure in presurgical evaluation. The overall functionality of the autonomous injection system was calibrated and demonstrated for deionized water as a proof of concept. The characteristic error of less than $\pm$ 0.2 ml in the injected volume was observed to be low and acceptable in the IctalL SPECT practice. EEG based prediction model with 94 % accuracy on forecasting seizure event was successfully integrated to the syringe actuation system to offer injection time less than that of the best case under manually operated practise. The proposed autonomous system not only enables early injection of tracer element towards identifying focal zone effectively, but also eludes prolonged nursing struggle and any lapses towards scanning procedure. The prototype engineering design based on EEG signal is envisioned for various other surgical and diagnostic interventions.

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