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Real-Time Supraventricular Tachycardia Monitoring System Using Closed-Loop Control

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Abstract:In this paper a unique issue rising from feedback control of Supraventricular Tachycardia monitoring system with embedded communication channels has been investigated. One of the important factors to measure the performance of the feedback control closed loop system is disturbance and noise attenuation factor. It is important that the feedback system can attenuate such disturbances on the Supraventricular Tachycardia heart rate signals. Since signal estimation is updated on the arrival of new data, its dynamics actually change with the sampling interval. Consequently, interaction among sampling, signal estimation, and the controller will introduce new issues in remotely controlled Supraventricular Tachycardia system. This paper treats a remotely controlled Supraventricular Tachycardia system with one communication channel which connects between the heart rate and rhythm measurements to the remote controller. Typical and optimal signal estimation schemes is represented by a signal averaging filter with its time constant derived from the step size of the signal estimation algorithm.

*Keywords:Supraventricular Tachycardia***,** *Communication channels, closed loop, Estimation***.** *Supraventricular Tachycardia***,** *dynamic behavior*.

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I. Introduction

Supraventricular Tachycardia (SVT) is a condition that causes an irregular heart rate. It is also possible for the heart rate to be within accepted limits or slower and still be in Supraventricular Tachycardia. Supraventricular Tachycardia is the most common heart rhythm disturbance and affects up to 800,000 people in the UK. It is also estimated that more than 2.3 million Americans have SVT [1]. The prevalence of SVT increases with age and approaches 8 percent in patients older than 80 years of age. SVT affects men and women equally; however, approximately 60 percent of patients older than 75 years of age are female [2]. The condition can affect adults of any age or gender but is more common the older you get and it affects about 10% of people over 75[3], [4]. SVT can severely depreciate quality of life by causing shortness of breath and intractable fatigue. Supraventricular Tachycardia is more likely to occur in people with other conditions, such as: high blood pressure, diabetes and coronary heart disease. The cause of Supraventricular Tachycardia is not fully understood, but it tends to occur in certain groups of people and may be triggered by certain situations, such as drinking excessive amounts of alcohol or smoking [5].

The heart rate can be measured by feeling the pulse in the wrist or neck. A normal heart rate, when you are resting, should be between 60 and 100 beats a minute (Fig. 1) [6], [7]. In Supraventricular Tachycardia, it may be over 140 beats a minute (Fig. 2). Supraventricular Tachycardia increases the risk by about four to five times of having a transient schematic attack (TIA) or stroke. This is because when the atria in the heart do not contract properly there is a risk of blood clot formation. Clots from the atria may break off and go to other parts of the body. A blood clot passing up to the arteries supplying the brain may cause a stroke.The impact of SVT is compounded by its known association with significant mortality, morbidity, and health care costs. Not only is

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the risk of death in patients with SVT twice that of patients without SVT, but SVT can result in myocardial ischemia or even infarction, heart failure exacerbation, and tachycardia-induced cardiomyopathy if the ventricular rate is not well-controlled When the heart beats normally, its muscular walls contract (tighten and squeeze) to force blood out and around the body. They then relax, so the heart can fill with blood again. This process is repeated every time the heart beats.Supraventricular Tachycardia occurs when abnormal electrical impulses suddenly start firing in the atria (upper chambers of the heart).These impulses override the heart's natural pacemaker, which can no longer

Supraventricular Tachycardia treatment involves medication to control the heart rate or rhythm, and medication to prevent clots from forming in the blood. Importantly, when ischemic stroke occurs in patients with SVT, it is either fatal or of moderate to high severity in the majority of patients.Physicians will generally choose medication as first course of action in managing Supraventricular Tachycardia, often with rate control medication to slow the heart rate. If rate control doesn't work, then a rhythm control medication may be used to try to restore heart's normal sinus rhythm. Rate control medications are less risky than rhythm control,Rate control medication slows the heart rate to generally less than 100 beats per minute by blocking some of the electrical signals in the atria and preventing them from being transmitted to the ventricles. Rhythm control medication is also called drug cardioversion or chemical cardioversion. Specialized doctor will decide which rhythm control drug is best for the patient based on the type of Supraventricular Tachycardia that the patient, including the presence or absence of other existing heart disease.Healthcare providers give adenosine intravenously for treating surgical pain and nerve pain, pulmonary hypertension, and certain types of irregular heartbeat. It is also given for controlling blood pressure during anesthesia and surgery and for heart tests called cardiac stress tests.

When given for the evaluation or treatment of a supraventricular tachycardia (SVT), the initial dose is 6 mg, given as a rapid parenteral infusion. Adenosine medication can be used for treatment. Due to adenosine's extremely short half-life, the IV line is started as proximal (near) to the heart as possible. The IV push is often followed with an immediate flush of 10-20 ccs of saline. If this has no effect (i.e., no evidence of transient AV block), a dose of 12 mg can be given 1–2 minutes after the first dose. Some clinicians may prefer to administer a higher dose (typically 18 mg), rather than repeat a dose that apparently had no effect. When given to dilate the arteries, such as in a "stress test", the dosage is typically 0.14 mg/kg/min, administered for 4 or 6 minutes, depending on the protocol.

The recommended dose may be increased in patients on theophylline, since methylxanthines prevent binding of adenosine at receptor sites. The dose is often decreased in patients on dipyridamole (Persantine) and diazepam (Valium) because adenosine potentiates the effects of these drugs. The recommended dose is also reduced by half in patients presenting congestive heart failure, myocardial infarction, shock, hypoxia, and/or hepatic or renal insufficiency, and in elderly patients.

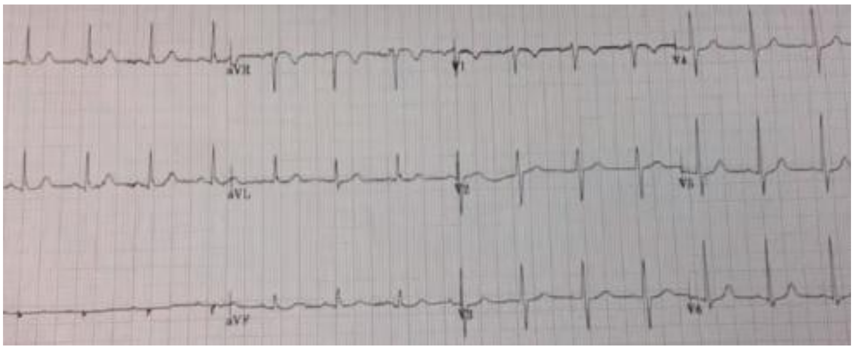

Fig. 1 Patient with SVT after medication

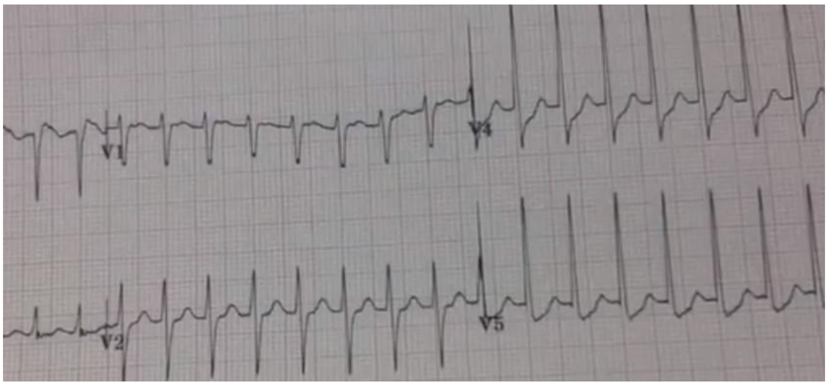

Fig. 2 Patient with SVT before medication

Capturing the dynamic behavior of the heart to improve control performance, enhance robustness, and support diagnosis is very important in establishing real time models for the heart.Control techniques and strategies have been utilized to improve system costs, reliability, and estimation accuracy for different types of systems such as biomedical, industrial, and other systems that required tuning input/output relation and/or monitoring. Simulations are performed to illustrate potential applications of the technology.In this research a new control technology scheme is used to enhance the performance of the SVT system and meet the design specifications.

Nowadays, medical networking such as wireless systems, sensor networks, local area networks, or tele-medicine over a wide area network is very important. This can be used to help patients and physicians managing existing conditions of diseases, therefore it is necessary to study the impact of noise and signal averaging on patient control in SVT networking system. To reduce the noise effect in a feedback closed loop system, it is effective to use signal averaging and determine the stability margins under this technique.Wireless communication channels become an integral part of the feedback loop. Introduction of communication channels mandates signal sampling, quantization, and estimation, and consequently adds new dynamic subsystems into the feedback look. Design variables for the communication systems such as sampling schemes and quantization levels, for signal estimation such as parameter updating step sizes, and controllers such as controller gains, interact and jointly affect feedback performance.

To characterize impact of communication channels, Feedback Control System in Patients with Supraventricular Tachycardia has been employed as a representative system for carrying out our analysis and simulation, although the findings of this paper are applicable to other medical problems which predict the impact of the inputs (drug infusion rates, fluid flow rates, ventilator mode, etc.) on the outcomes (consciousness levels, blood pressures, heart rates, airway pressures, and oxygen saturation, etc.). This system can be used for control, display, warning, predictive diagnosis, decision analysis, outcome comparison, etc.

II. SVT Closed Loop System and Analysis

The overall system consists of the heart transfer function G(z), the PI controller GC(z), communication block in the output side [8]. In this configuration, the output heart rate hk and the control signal uk are communicated through communication channel, and then estimated. In our development, we allow the communication block and signal estimation algorithms to have different sampling intervals and step sizes, in order to accommodate realistic wireless communication networks.

Inserting a communication block to transmit a signal in the feedback loop introduces some errors; and signal estimation leads to dynamic delays. In this paper we aim to study the behavior of the SVT closed-loop system under the communication channel and signal estimation algorithms by analyzing interactions among quantization, sampling, signal estimation, and feedback stability and performance of SVT system. We will also show that there are certain fundamental issues that an engineer must consider when designing remotely controlled SVT system.

When signals must be transmitted through communication channels, they are sampled, quantized, and transmitted; then recovered and estimated at the receiving side [9]. Signal averaging methods are commonly used in such signal recovery schemes to reduce errors and noises on the signals. This is especially true under lower-precision quantization schemes. In principle, low-precision quantization, such as binary-valued quantization, will not transmit sufficient information on the signals for feedback control. However, by employing the smoothing effects of random noises or dithers, more information can be recovered. It was shown in [6] that the algorithms that extract information on the original signals act like averaging filters that introduce new dynamics into the feedback loop. Consequently, they affect feedback stability and performance.

We now explain the methodology of signal estimation which was introduced in [9], [10], [11] and some essential derivation steps that will be relevant in our study.We will use the output heart rate signal υk in describing the algorithms and main features. The estimation steps and features for the control signal uk will be similar.The true heart rate $\upsilon_k$is bounded $\upsilon_{min} \le \upsilon_k \le \upsilon_{max}$. $\upsilon_k$is either measured with a measurement noise or added with a random dither $d_k$to enhance signal estimation.

The noise-added signal$\upsilon_k + d_k$ is quantized to produce a quantization sequence $S(\upsilon_k + d_k)$, where S represents the quantization function. More precisely, suppose that thesignal υk + dk is quantized by m quantization thresholds $\{h_1. . .h_m\}$, which divides therange [υmin, υmax] into $\upsilon_{min} < h_1 < \cdot\cdot\cdot < h_m < \upsilon_{max}$. The output of the quantizer takesm + 1 possible values {1, 2, . . . ,m + 1} and is represented by:

$$\boldsymbol{s_k = \sum_i^{m+1} iI[h_{i-1} < \upsilon_k + d_k \le h_i(1)}$$

with $h_0 = 0$ and I being the indicator function. In the special case of a binary-valued quantization of threshold h,

$$\boldsymbol{s_k = \begin{cases} 1, \upsilon_k + d_k \le h \\ 0, \upsilon_k + d_k > h \end{cases} (2)}$$

For clarity, we will use the binary-valued quantization to derive algorithms and properties. Generalization to m quantization levels can be found in [9], [10]. s_k will be processed to estimate υ_k at the receiver side.

Signal Estimation Algorithms:

For a selected $0 < \alpha < 1$, define the following truncated and exponentially weighted empirical measures:

$$\boldsymbol{\lambda_k^\Delta = (1 - \alpha)\sum_{l=-\infty}^{k} \alpha^{k-1} s_i (3)}$$

where the weight is normalized so that when

$$\boldsymbol{s_l = 1, (1 - \alpha)\sum_{l=0}^{\infty} \alpha^l = 1 \quad (4)}$$

This algorithm can also be written recursively as

$$\lambda_k^\Delta = \lambda_{k-1}^\Delta + (1 - \alpha)(s_k - \lambda_{k-1}^\Delta)$$

$$\boldsymbol{= \lambda_{k-1}^\Delta + \beta(s_k - \lambda_{k-1}^\Delta)(5)}$$

which is a stochastic approximation algorithm with a constant step size $\beta = 1 - \alpha$. To understand the meaning of the weight α and the step size $\beta = 1-\alpha$, we note that (3) is a weighted averaging computation. The smaller the α value, the faster the decaying rate α_{k-l} in (3), which in turn implies the averaging uses mostly the recent data, that is a small data window in the signal averaging. This is equivalent to β being close to 1. This represents a fast updating algorithm. Such an algorithm will be able to track fast changing signals, but will have less capability in attenuating noise effects. However, this is a fast response filter (i.e., less dynamic delay) and hence will have less detrimental effects on feedback stability and performance. This intuitive understanding will help in interpreting case study results. In addition, when we translate the step sizes to the actual time, each updating step in signal estimation means Ts second. Consequently, the sampling period is a fundamental parameter when feedback performance is evaluated. For a technical delicacy, for some small δ satisfying $0 < \delta < 1$, define:

$$\boldsymbol{\lambda_k} = \begin{cases} \boldsymbol{\lambda_k^{\Delta}}, & \boldsymbol{\delta} < \boldsymbol{\lambda_k^{\Delta}} < 1 - \boldsymbol{\delta}, \\ \boldsymbol{\delta}, & \boldsymbol{\lambda_k^{\Delta}} < \boldsymbol{\delta}, \\ \mathbf{1} - \boldsymbol{\delta}, & \boldsymbol{\lambda_k^{\Delta}} > 1 - \boldsymbol{\delta}, \end{cases} \mathbf{(6)}$$

This will not affect system analysis. Then, the estimation of υk is:

$$\boldsymbol{\hat{\upsilon}_k} = \boldsymbol{h} - \boldsymbol{F^{-1}}(\boldsymbol{\lambda_k})\mathbf{(7)}$$

It can be shown [12],[13] that adding the signal estimation algorithm (7) into the SVT feedback loop system can be represented by a signal averaging filter and an equivalent noise source. Consequently the block diagram of the closed loop SVT is expanded with one filter $F_b = \frac{(1-\alpha)z}{z-\alpha}$. Fig. 3 shows the overall closed loop SVT system.

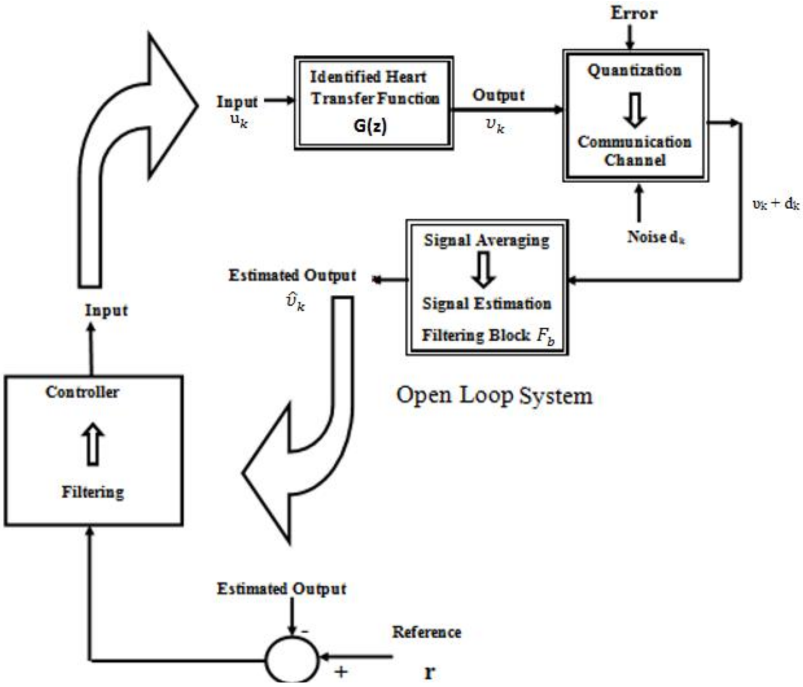

Fig. 3 Closed Loop SVT System

III. SVT Closed Loop System With Communication Blocks

When given for the evaluation or treatment of a supraventricular tachycardia (SVT), the initial dose is 6 mg, given as a rapid parenteral infusion. Adenosine Medication can be used for treatment. Due to adenosine's extremely short half-life, the IV line is started as proximal (near) to the heart as possible, such as the antecubital fossa. The IV push is often followed with an immediate flush of 10-20 ccs of saline (Fig.4). If this has no effect (i.e., no evidence of transient AV block), a dose of 12 mg can be given 1–2 minutes after the first dose. Some clinicians may prefer to administer a higher dose (typically 18 mg), rather than repeat a dose that apparently had no effect. Patient heart rate response during giving medication is shown in Fig.5. When given to dilate the arteries, such as in a "stress test", the dosage is typically 0.14 mg/kg/min, administered for 4 or 6 minutes, depending on the protocol.

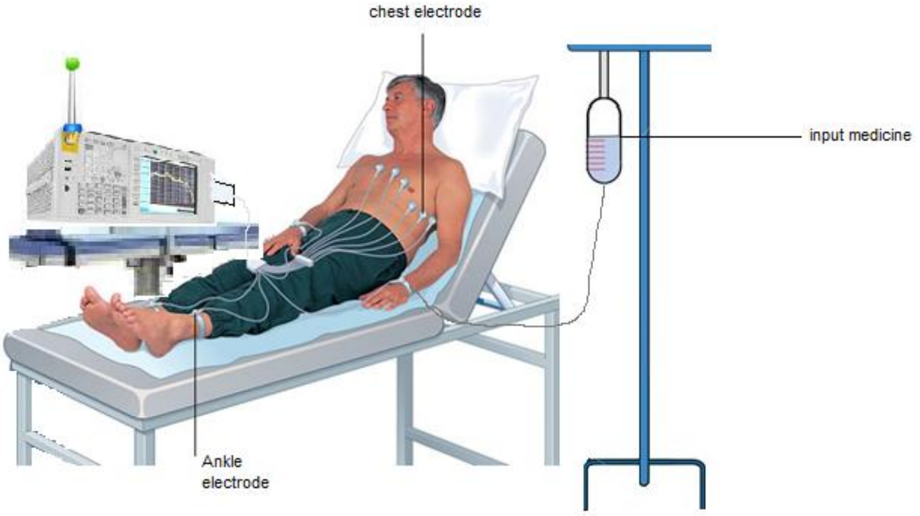

Fig. 4 Patient with SVT closed loop system

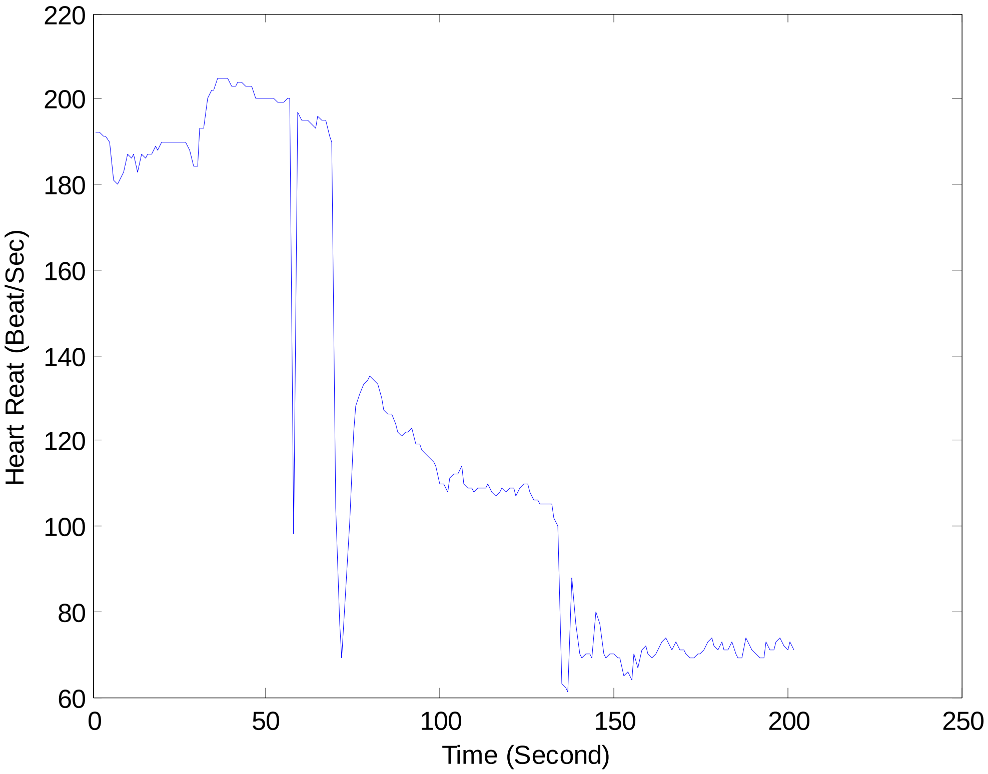

Fig. 5 Patient hear rate response during taking medication at t=1min and t=2 min

In this paper two communication blocks are used as in Fig.6, one to transmit and estimate the Heart beats signal of an SVT patient to the controller and the other to transmit and estimate the controller output signal back to the patients.

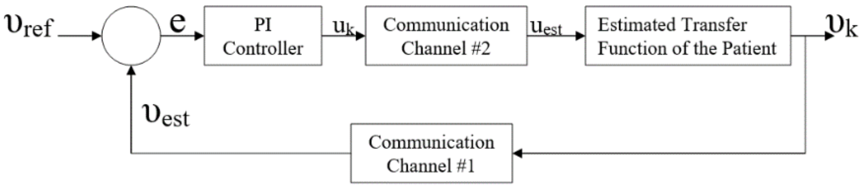

Fig. 6 Block Diagram of SVT monitoring system with communication channels

When signals transmitted through communication channels, they must be sampled, quantized, and transmitted [7]; then recovered and estimated at the receiving side (Fig.7)

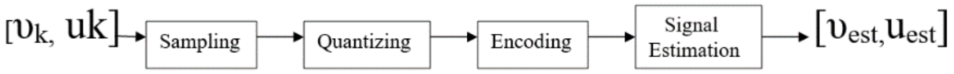

Fig. 7 Signal code modulation and estimation

The SVT patient model with drug rate as the input and hear beats rate as the output was identified as

$$\boldsymbol{P(z) = \frac{0.0788(\,z^4-4z^3+6.5z^2-5z+1.5)}{z^5-3.96z^4+7.02z^3-6.9z^2+3.74z-0.9}} \quad \textbf{(8)}$$

Usually to eliminate steady-state error in tracking control, an integrator is inserted into the system

$$\boldsymbol{C(z) = \frac{1}{z-1}} \quad \textbf{(9)}$$

A stabilizing feedback controller is then designed for the patient model (1) by using a full-order observer and pole placement design, leading to

$$\boldsymbol{F(z) = \frac{z^5-4.44z^4+7.88z^3-6.98z^2+3.1z-0.54}{z^6-4.96z^5+10.98z^4-13.9z^3+10.64z^2-4.6z+0.9}} \quad \textbf{(10)}$$

This estimated model contains sufficient freedom in representing the main features of the patient response.

These system components result in a combined open- loop system

$$\boldsymbol{G(z) = F(z)C(z)P(Z)}(11)$$

The combined open-loop system G(z)has a minimal state space realization

$$\boldsymbol{p(z) = \begin{cases} x_{k+1} = Ax_k + Bu_k \\ w_k = Cx_k \end{cases}} \quad \textbf{(12)}$$

For clarity, we will use the binary-valued quantization to derive algorithms and properties. Generalization to m quantization levels can be found in [8], [9]. s_k will be processed to estimate υ_k at the receiver side.

In many practical systems with communication channels, it is desirable to reduce communication power and bandwidth consumption, and perform signal processing at the receiving side. We shall consider the case of the binary scheme for quantization and communication channels. It is assumed that the closed-loop system under the negative unity feedback $u = -v_k$ is stable. For a (sufficiently small) sampling interval $T_{s1.}$ The channel is characterized by the probability transition matrix taking in consideration the Transmission Errors and Packet Losses

$$\boldsymbol{\Pi = \begin{bmatrix} \pi_{11} & \pi_{12} & \pi_{13} \\ \pi_{21} & \pi_{22} & \pi_{23} \end{bmatrix}} \quad \textbf{(13)}$$

With $\sum_{j=1}^{3} \pi_{ij} = 1, i = 1{,}2. Here,$

$$\pi_{11} = P\{x_k = 0|S_K = 0\}, \pi_{12} = P\{x_k = 1|S_K = 0\}, \pi_{13} = P\{x_k =* |S_K = 0\}$$

$$\pi_{21} = P\{x_k = 0|S_K = 1\}, \pi_{22} = P\{x_k = 1|S_K = 1\}, \pi_{23} = P\{x_k =* |S_K = 1\}$$

For a symmetric channel, we have π13 = π23 (the probability of data loss) and π11 = π22 (the probability of correct data transmission). Then

$$\boldsymbol{\Pi = \begin{bmatrix} p & 1-p-q & q \\ 1-p-q & p & q \end{bmatrix}} \quad \textbf{(14)}$$

Let Under the sampling interval Ts, let vk = H(sk) represent the channel. Signal estimation and feedback control algorithms are

$$\boldsymbol{x_{k+1} = x_k + T_s(Ax_k + Bu_k)}\textbf{(15)}$$

$$\boldsymbol{v_k = Cx_k}\textbf{(16)}$$

$$\boldsymbol{z_k = H(s_k)}\textbf{(17)}$$

$$\tilde{\alpha}_{k+1} = \tilde{\alpha}_k + \beta(z_k - \tilde{\alpha}_k)(18)$$

$$\alpha_k = \frac{\tilde{\alpha}_k-(1-p-q)}{(2p+q-1)}(19)$$

$$\hat{\upsilon}_k = h - F^{-1}(\lambda_k)(20)$$

$$u_k = -\hat{\upsilon}_k \quad (21)$$

Then, the estimation of υ_k is:

$$\hat{\upsilon}_k = h - F^{-1}(\lambda_k)(22)$$

In this algorithm, the channel information p and q are assumed to be known. Joint identification of the signal υ_k and the channel parameters p and q can be derived directly from the joint identification algorithms in [7].

We first consider the impacts of signal averaging weights α_1 and α_2 on the performance of the proposed system. In this paper let the sampling intervals for both communication blocks are T_{s1} = 0.001 sec, Then the signal estimator mentioned before is applied. Three cases are considered with $\alpha_1 = \alpha_2 = \alpha$.

We will employ the step responses in the performance evaluations in which the standard performance measures are the rise time tr, settling time $t_{s,peak}$time t_{max}, and percentage overshoot M_p. Within these measures, the rise time and peak time represent response heart rates; the overshoot represents control accuracy; and the settling time represents control effective duration. All these parameters are desired to be small.Fig.8 shows the step response of the closed-loop system.

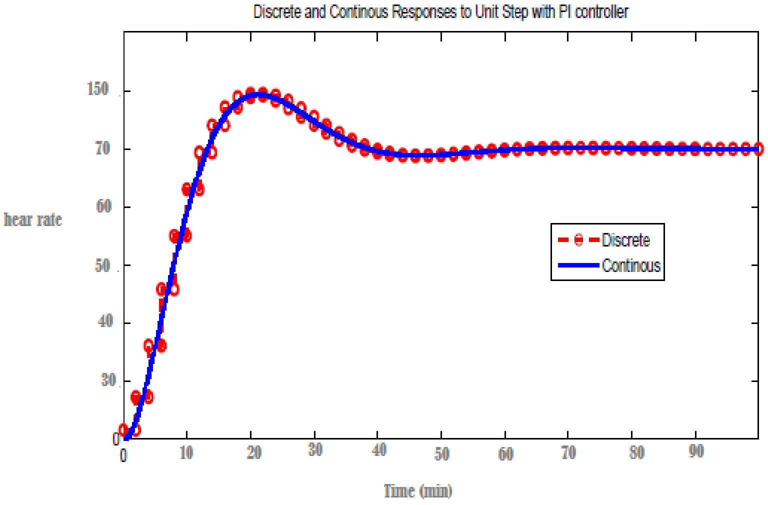

Fig.8 step response of the closed-loop system

In order to study the impact of signal averaging after adding the communication block 1 to the closed-loop SVT system, we will take different values of α1 and assess the corresponding responses.

The sampling period is fixed as T_{s1} = 0.01. Performance evaluations are conducted by using the step input. Fig.9 shows the step response; three values of α1 are used and their impacts on system performance are compared.

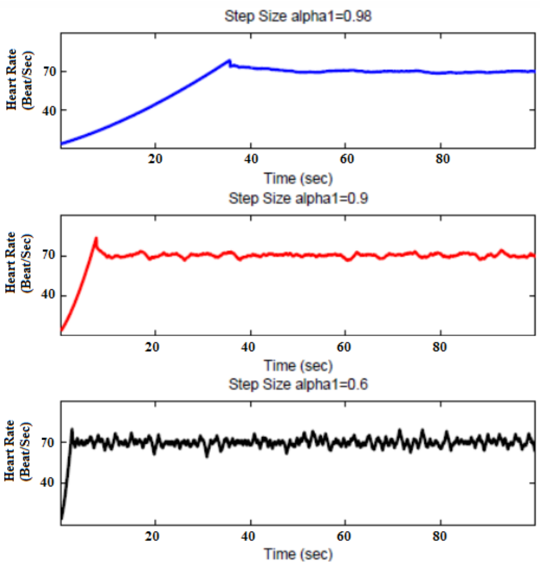

Fig 9: Effects of signal averaging weights: step response

From Fig.9, we can derive closed-loop performance parameters in Table 1. We recall that α_1 represents sizes of data window sizes in signal averaging. When α_1 is large (close to 1), see the top plot of Fig.9, the window size is large. This represents a slower dynamics but has more averaging effect. Consequently, the output noise is attenuated, leading to a smooth heart rate. On the other hand, a slow filter dynamics imply slower responses and less aggressive feedback, resulting in smaller overshoot. These are clearly reflected in Table 1: as α_1 increases, t_r, t_s, and t_{max} increase, but the overshoot reduces. In principle, if output noises are small, then small data windows can be used.

Table 1: Step response Performance of Fig. 9

α1	Settling Time	Max Overshoot	Peak Time
0.98	60	84.7	35.4
0.90	35	86.8	11.4
0.60	15	87.3	4.3

In order to study the impact of sampling rate after adding a communication block 1 to the closed loop SVT system, we will take different values of T_{s1} and compare closed-loop performances. In this example the step size of the filter is fixed $\alpha_1 = 0.95$ and three different values of T_{s1} are applied. Then the signal estimator is applied for the three cases.Fig. 10 shows the step response of the closed-loop SVT system under different values of T_{s1}, with performance comparison detailed in Table 2.

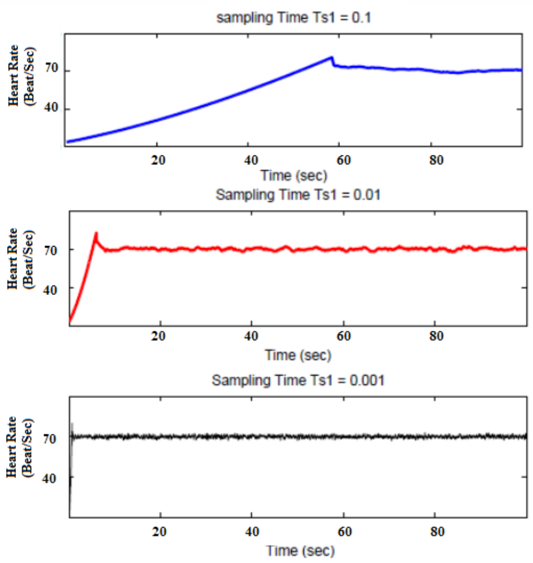

Fig 10: Effects of sampling intervals: step response

Table 2: Step response Performance of Fig.10

Ts1	Settling Time	Max Overshoot	Peak Time
0.1	80	77.5	55.4
0.01	27	84.8	7.4
0.001	5	88.3	1.1

IV. Conclusion

In this paper a new control technology scheme has been developed to enhance the performance of real timeSVTmonitoring system. The impact of communication channels on feedback performance of SVT system is studied and analyzed. The main conclusions of this study indicate that when communications and signal estimations are involved, sampling intervals and signal averaging window sizes (or equivalently signal estimation step size) must be carefully coordinated so that performance specifications can be robustly maintained. The situations are further complicated by the noise attenuation capability and tracking performance of the system which is also substantially affected by the same design parameters. The results of this paper show that there is a basic relationship between the sampling interval and signal averaging weight that can be used to adapt the weight when communication data flow rates change with time.

References

[1]. Fuster V, Ryden LE, Cannom DS, et al., Guidelines for the Management of Patients with Atrial Fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients With Atrial Fibrillation): developed in collaboration with the European Heart Rhythm Association and the Heart Rhythm Society. Circulation. 114(7):e257–354, 2006.

[2]. Go AS, Hylek EM, Phillips KA, et al. Prevalence of diagnosed atrial fibrillation in adults: national implications for rhythm management and stroke prevention: the An Ticoagulation and Risk Factors in Atrial Fibrillation (ATRIA) Study. JAMA. 285(18):2370–5, 2001.

[3]. Furberg CD, Psaty BM, Manolio TA, et al. Prevalence of atrial fibrillation in elderly subjects (the Cardiovascular Health Study) Am J Cardiol. 74(3):236–41, 1994.
[4]. SS; Magdic, KS, "Paroxysmal Supraventricular Tachycardia: Pathophysiology, Diagnosis, and Management". Critical care nursing clinics of North America. 28 (3), 2016.
[5]. J.G. Proakis and M. Salehi, Digital Communications, 5th Edition, McGraw-Hill Higher Education, New York, 2008.
[6]. Ayman M. Mansour, Mohammad A. Obaidat and Bilal Hawashin, " Elderly People Health Monitoring System using Fuzzy Rule Based Approach " , International Journal of Advanced Computer Research (IJACR), Volume-4, Issue-17, pp.904-914,2014.
[7]. Ayman M. Mansour, "A Multi-Agent Intelligent System for Monitoring Health Conditions of Elderly People", International Journal of Health and Medical Engineering, Vol.8 (6), 2014.
[8]. Le Yi Wang, George Yin, Ji-feng Zhang, Yanlong Zhao, System Identification with Quantized Observations, Boston, MA: Birkh¨auser, 2010.
[9]. Mohammad A Obeidat, Le Yi Wang, Feng Lin, Real-time parameter estimation of PMDC motors using quantized sensors, IEEE Transactions on Vehicular Technology, Vol. 62, Issue 6, pp. 1-10, 2013.
[10]. Zhibin Tan, Le Yi Wang, Hong Wang, Signal Averaging for Noise Reduction in Anesthesia Monitoring and Control with Communication Channels, Journal of Biomedical Science and Engineering, Vol. 2-7, pp. 564-573, 2009.
[11]. K. Ogata, Discrete-Time Control Systems, Prentice-Hall, Inc. Upper Saddle River, NJ, 1987.
[12]. Mohammad A Obeidat, L.Y. Wang, F. Lin, Online Parameter Estimation of PMDC Motors using Quantized Output Observations, ITEC IEEE Transportation Electrification Conference, Dearborn, Dearborn, Michigan, June 18-20, 2012.
[13]. Mohammad A Obeidat, L.Y. Wang, F. Lin, "On-Line Parameter Estimation of PMDC Motors using Binary-Valued Speed Measurements, PECI Power and Energy Conference at Illinois, University of Illinois at Urbana Champaign, Illinois, February 24-25, 2012.

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