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15/ENG04/038

1. AN EXPLICIT REFERENCE GOVERNOR SCHEME FOR CLOSED-LOOP ANESTHESIA.

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3. Title.
   Abstract.
   Introduction.
   Modelling of the System.
   Fig. 1. PKPD model block diagram.
   Control Architecture.
   Pre-stabilizing the Propofol Delivery System.
   Fig. 2. The iControl closed-loop anesthesia system.
   Fig. 3. Block diagram of the propofol control system.
   Enforcing Constraints Handling Capability.
   Fig. 4. Approximation error for different hypnosis levels.
   Results and Discussion.
   Fig. 5. The unconstrained simulated responses of the 44 patients.
   Table 1: Comparison of the obtained Induction Table.
   Conclusion.
   Fig. 6. The simulated responses of the 44 patients with the ERG scheme.
   References.

4. ECC – European Control Conference.
   IEEE – Institute of Electrical and Electronics Engineers.
   FNRS MIS – Fonds de la Recherche Scientifique Mandat d'impulsion Scientifique.
   SAAS – Service d'Automatique et d'Analyse des Systemes.
   ERG – Explicit Reference Governor.
   PK – PharmacoKinetic.
   PD – PharmacoDynamic.
   PKPD – PharmacoKinetic PharmacoDynamic.
   DOH – Depth of Hypnosis.
   TIVA – Total Intravenous Anesthesia.
   PID – Proportional Integral Derivative.
   LBM – Lean Body Mass.
   DSN – Dynamic Safety Margin.
   NF – Navigation Field.
   KF – Kalman Filter.

5. The PKPD model labelled Fig. 1. is made up of two part or models; PharmacoKinetic (PK) and PharmacoDynamic (PD) models. I also observed that the PK model is a known model while the PD model is an unknown model but the main reason why they are combined is to express the drug-response relationship of the Propofol.

6. The paper aims at prioritizing the safety of the patient while still possessing control of the depth of hypnosis required.

7. PARAGRAPH 1: It defines anesthesia, the fact that anesthesia has been done manually and the popularity of automatic control in recent times.
   PARAGRAPH 2: It names the components of the paper and its goal which is to safely control the depth of hypnosis.
   PARAGRAPH 3: It names the phases of hypnosis, the challenge of overdosing and proposed risk reduction techniques.
   PARAGRAPH 4: It shows that overdosing can be prevented by defining some suitable safety constraints.
   PARAGRAPH 5: It proposes ERG as the control scheme to be used and emphasizes its strength over other control schemes.
   PARAGRAPH 6: Outlines the rest of the paper's structural organization.

8.

FIGURE 5	FIGURE 6
The DOH percentage drops from 100 to 40 in 5 minutes from start time.	The DOH percentage drops from 100 to 40 in 10 minutes from start time.
In I(t), it peaks at 400 ml/h in less than 5 minutes from start time.	In I(t), it peaks at around 250 ml/h in about 6 minutes from start time.
In Cp, it peaks at 8 in about 11 minutes from start time.	It peaks at 8 in 20 minutes from start time.
In Ce, it peaks at 8 in about 11 minutes from start time.	It peaks at 8 in 20 minutes from start time.

I observed the results and I noticed that the DOH in figure 6 does not fall below the red line, thus no undershoot like the figure 5.

9. I see the organization of the conclusion section.
   I understand the conclusion.

10.

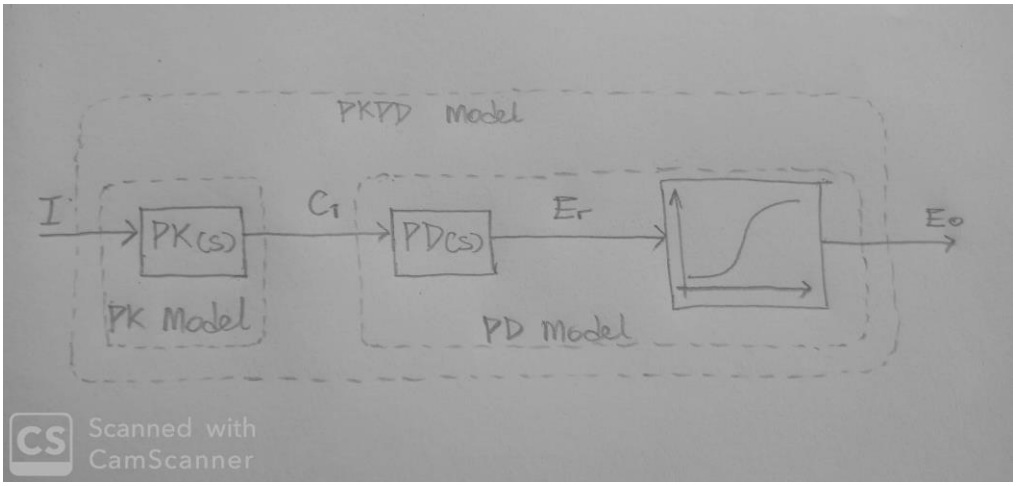

Figure 1: PKPD model block diagram.

PK MODEL: It shows the relationship between plasma concentration and administered dose. It takes into consideration the plasma compartment, the shallow peripheral compartment and the deep peripheral compartment. The infusion rate I(t) is the input variable while the propofol concentration (C) is the output variable.

The state-space representation of the PK model is expressed below as

$$\begin{bmatrix} \dot{C}_1 \\ \dot{C}_2 \\ \dot{C}_3 \end{bmatrix} = \begin{bmatrix} -(k_{10} + k_{12} + k_{13}) & k_{12} & k_{13} \\ k_{21} & -k_{21} & 0 \\ k_{31} & 0 & -k_{31} \end{bmatrix} \begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix} + \begin{bmatrix} \frac{1}{V_1} \\ 0 \\ 0 \end{bmatrix} I$$

$$k_{10} = \frac{Cl_1}{V_1}, k_{12} = \frac{Cl_2}{V_1}, k_{21} = \frac{Cl_2}{V_2}, k_{13} = \frac{Cl_3}{V_1}, k_{31} = \frac{Cl_3}{V_3}$$

C_1, C_2 and C_3 represents the propofol concentration in the plasma, fast peripheral, and slow peripheral compartments respectively. V_1, V_2 and V_3 are the volumes for each compartment respectively. Cl_1 is the elimination clearance while Cl_2 and Cl_3 are inter-compartmental clearances.

PD MODEL: It shows the relationship between the plasma concentration and the pharmacological end-effect. The model is expressed below as

$$PD(s) = \frac{C_e(s)}{C_p(s)} = e^{-T_d s} \frac{K_d}{s + K_d}$$

where $Cp(t) = C1(t)$, and Td (in [s]) and kd (in [s−1]) are transport delay and rate of propofol distribution between the plasma concentration and the brain.

11.

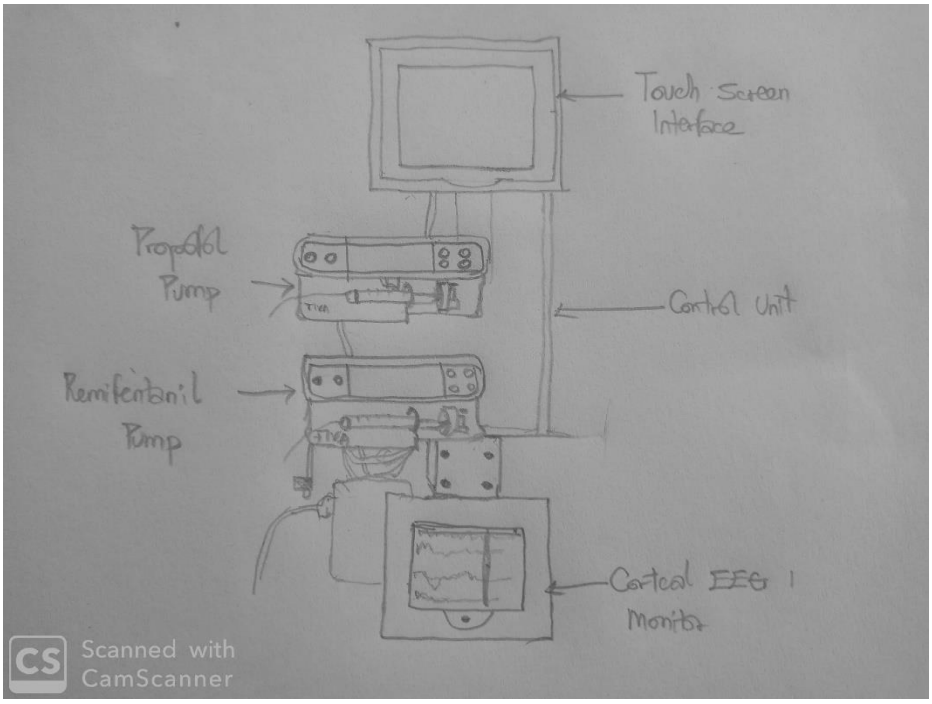

Figure 2: The iControl closed-loop anesthesia system

I have read the PID section of the Experience Controls application.

$$G_{ff}(s) = k + \frac{k_i}{s}$$

$$G_c(s) = \frac{k_d N_s}{s + N}$$

$$LBM = 0.3281 \times W + 0.33929 \times H - 29.5336$$

Using W=56 kg H=169 cm

$$LBM = 46.19001$$

$$k = 0.0243 \times LBM, k_i = 0.000165 \times LBM, k_d = 1.35 \times LBM$$

$$k = 1.122417243, k_i = 7.62135165 \times 10^{-3}, k_d = 62.3565135$$

The iControl system is used for clinical evaluation of control schemes. It is useful because it ensures that all the constraints are satisfied.

Integrator windup is a phenomenon that occurs when the integral gain is set too high, thus causing the actuator to be oversaturated which ultimately results in large overshoots in the output response. It is undesirable because it breaks the feedback loop and, thus makes the system unreliable.

The equation represent a nonlinear system.

It ensures that the issue of overdosing is eliminated.

The aim of the ERG is to determine an invariant set that would contain the state trajectory if the currently auxiliary reference were to remain constant.

Its primary function is to ensure that constraints are satisfied. It achieves this by providing the block diagram with the constraints required to be satisfied in the process.