manually programmed and preprogrammed. The dosing errors are more manually programmed, and reports on misleading drug delivery, flow rate, miscalculations have been recorded in past years. To avoid smart infusion pumps with a drug library in a preprogramming environment, warnings, soft alarms, dosage limits have been incorporated. The implementation is done based on the FDA guidelines for the infusion pump manufacturer. Even though the software, drug delivery guidelines are existing, the functioning and pumping mechanism should also be concentrated [3]. The survey on control strategies of the infusion pump, the essential component, which is an electric motor connected to the device, has been considered in this paper. The optimal control of the motor should be preprogrammed in a smart infusion pump as it will trigger the entire pump to perform flow control precisely. Suppose the precision flow control and the drug delivery guidelines are incorporated together as per the guidelines of the medical council. In that case, the dosing errors, flow control, hardware errors can be handled with care. The paper is structured with the sections on MCPS, Infusion pump, infusion techniques, infusion pump control and its parameters, control strategy for an infusion pump, infusion rates, electric motors for medical devices, control system for electric motors.

3. Medical Cyber Physical System

The cyber-physical system towards the medical sector is known as Medical Cyber-Physical System (MCPS). MCPS is prominent and powerful for healthcare services nowadays. The development of embedded computing, micro, and Nanotechnologies for sensors, actuators are developing quickly. The MCPS is about integrating sensors, embedded controllers, Final control elements, actuators with required software that performs monitoring, decision making on clinical information with the medical devices that will be associated with the patient [4]. The concept of MCPS relies on hardware components of the medical device, system, communication, cyber-attack, security threats, trust management for patient monitoring, data transmission as per e-health record standards, data phishing [5]. In this paper, the concentration is made on the survey of physiological modelling for a medical device. The design, modelling, verification of the MCPS for smart medical devices are essential [6]. These are performed with the aid of formal modelling and related software tools. Manufacturers perform the verification, testing of hardware and software related to the smart infusion pumps before releasing the final product. Many MCPS based formal models have been designed and verified on Patient Controlled Analgesia (PCA), artificial pancreas, insulin infusion control system, dialysis system, wireless medical analyzers [7]. The overall objective of the survey has relied on infusion pump control, which is a subset of the MCPS. The objective is represented in figure 1. In the next section, the concepts based on the infusion pump, its techniques, and control strategies are discussed.

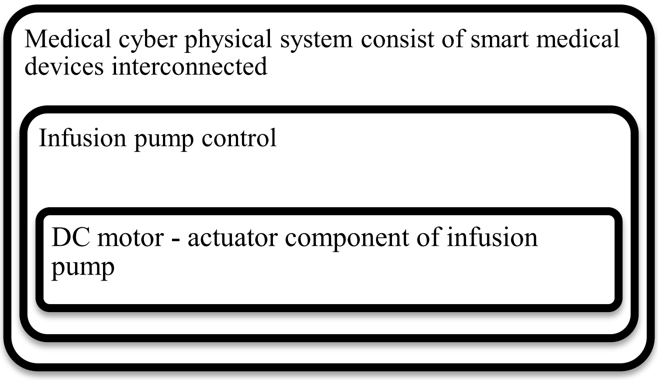

Figure 1. The overall objective of the survey

4. Infusion Pump

Infusion pumps are devices that deliver a precisely specified quantity of fluids to a patient. The pump regulates the discharge of the fluid, drug to the patient's body from an IV bag through a tube and syringe. Many forms of infusion pumps are available, including large capacity, PCA, elastomeric pumps, syringe, enteral pumps, and insulin pumps [8]. Such pumps are used with effectiveness in clinical settings, hospitals, and in the home. The pumping mechanism utilized in infusion pumps varies based on the application. Almost all the device uses peristaltic and syringe pumping mechanism. For all the type of mechanism, the accurate fluid delivery is driven by an electric motor. When designing the infusion pump, the biomedical engineer should be keen in identifying the appropriate flow sensors, occlusion sensors, air-line sensors, power, batteries, preprogrammed embedded controller, signal conditioning interfaces, and most importantly, the electric motor with its gear mechanism [9]. The parameters such as rotational count, motor position, speed, torque, and current have to be monitored and controlled by the processor embedded in the infusion pump. The motors widely used are stepper motors, PMDC, and BLDC motors [10]. In this paper, a survey on infusion pump, parameters associated for precise delivery of the drug, fluid are the prime focus.

4.1. Infusion Techniques

Driving mechanism and pump types: Providing a constant flow of the fluid and drug to the bloodstream requires an external force. The different infusion pumps are gravity-driven, electromechanical pumps, syringe pumps, peristaltic pumps, cassette pumps, passive mechanical pumps [11]. These pumps are designed with tubing, drive mechanisms with flow controllers, interfaces, and IV catheters for single and multiple infusion devices [12]. Even though the design and implementation are done very accurately, in practical situations, when the drug flow towards the infusion systems, unforeseen delays based on carrier flow, the flow rate of the drug can lead to autonomic dysfunction in the administration of drugs to the patient [13].

4.2. Infusion Pump Control and Its Parameters

The drug infusion parameters are purely based on the pharmacokinetic compartment models, which deal with the rate at which the drug concentration, absorption, distribution, metabolism, and excretion with physiological factors. The pharmacokinetic principle is essential for the safe and successful therapeutic administration of drugs for the patients. The rate of change of concentration c is given as dc/dt. The Law of mass action states that the rate of the kinetic process, such as chemical reaction, is proportional to the molar concentration and is given as dc/dt = k. where k is the molar concentration [14]. The reaction will undergo process change as per pharmacokinetic compartment models such as single, double, and multiple models. The reaction also varies as the first order, second-order, and multiple orders as per the IV dosage that gets concentrated, absorbed, eliminated, etc. The infusion flow rate, drug distribution, volume delivered, carrier flow, plasma concentration over time duration will be analyzed [15]. These are the essential parameters for the design and implementation of smart infusion devices by biomedical engineers. The manufacturers set the pharmacokinetic parameters based on the inputs and suggestions given by the practitioners. The clinical parameters and setting will be performed by the clinician and the nurse in the hospital environment. These parameters must be controlled and monitored very precisely, as mentioned earlier. Implementing a closed loop control system as an optimal control strategy is the monitoring and control of pharmacokinetics. The classical control system has many control strategies to handle optimum, stable flow rates. Any one of the existing control algorithms can be preprogrammed to the microcontroller and processor chip available in the infusion pump [16].

The tremendous growths of recent advances assist the drug delivery for continuous infusion based on the automated systems. The physical signals, dead volume, clinical errors during the complex process can be handled. The highest pump alerts have been observed for surgery, critical, and oncology care. The usage of the wireless smart infusion pump system is increased to 99.7% in neonatal care. The smart alarm, safety, and verification measures are done by formal model techniques using new software.

4.3 . Control System Strategy for Infusion Pump

Feedback control on physiological response is vitally essential for an infusion pump. Application of Linear Quadratic Gaussian with Loop Transfer Recovery (LQG/LTR) design methodology on the frequency domain analysis on anaesthesia devices has been verified to obtain stable response [17]. The dosing errors based on various pump flow rate settings with the Poiseuille flow profile have been verified experimentally. In that time delay of 14% in the catheter, 13% of the dosing error bolus was observed. Usually, the automated regulation of the anaesthesia drug concentration is targeted on propofol and remifentanil. The control strategy such as PID and the fuzzy controller is implemented. Using Pharmacokinetic (PK) model [18] and Pharmacodynamics model (PD) has been instated with the drug dosage, concentration, and depth of anaesthesia.

Large-volume infusion pumps (LVPs) are designed to infuse fluids and medicines at the programmed rate continuously. User manuals for infusion pumps typically report flow accuracy of ±-5%, which is an average in the laboratory environment. Flow accuracy and continuity of LVPs for patient care is important. Manufacturers provide these values over a 60-minute interval. The fluid is propelled by peristaltic movement, and it is discontinuous as the pump components come in contact with the tube; this impacts the flow variation [19]. When infusion rates are higher, flow rate variation is short duration and does not register noticeably in trumpet curve testing. When infusion rates are lower, the duration of pumping stroke increases further flow variations are noticeable in curve analysis. Due to these implications, the LVPs are designed with electric motors to provide accurate actuation and safe for the patients [20]. To handle the discontinuous and inaccurate flow, adaptive and control mechanisms should be implemented in the actuating system [21]. It is inferred clearly that researchers have reported feedback control, usage of pressure and flow sensors, flow rate, implementation of smart alarms with statistical analysis.

The design of portable, lightweight infusion pumps with miniaturized components with battery-powered motors is suitable for treating patients in clinical and home environments. The research focus should be based on caretakers and nurse opinion, infusion pump setting for the required flow rate, compact system design focusing on all the sensors, actuators, and most importantly, tubing, pumping mechanism inclusive of the electric motors associated, assessing the pump by practitioners and engineers [22]. In the case of home infusion pumps, statistical analysis is performed to ensure the drug delivery and the component usage along with the alarming system [23].

Investigations are done based on the valves that impede the maximum flow rate of crystalloid in intravenous infusion systems when administered under gravity, or 300 mmHg added pressure [24]. 16G cannula used shows the reduction in flow rate of 19–38% and usage of 20G cannula, flow rate reduction was not observed with a 20G cannula, no significant reduction inflow. Westcott Sae-flo valve was used that produced a lower reduction in flow rate [25]. In some situations, the IV infusions are done in primary and as well as secondary infusion. Usually, the primary IV is continuous, and the secondary is intermittent [25]. Under this scenario, the volume infused, residual volume, medication lost, and percentage error must be analyzed thoroughly. For the analysis, ANOVA has been done as part of the quantitative analysis [26].

Research has focused on developing a smart drug library on Drug concentration, type of infusion Dosing unit, dosing ranges, and integration of Electronic Health Record (EHR) [27]. This concept leads MCPS environment. Apart from the optimal control strategies and the hardware design of the infusion pump, the volumetric flow rate, dead volume, lag time variation is based on other external factors like catheter size, the height of the fluid column, and carrier flow [28]. In general, flow can be laminar or non-laminar flow, but the infusion process's precise drip rate and safety are based on other parameters of fluid-like viscosity [29]. High precision and optimum flow are vital for all the types of fluid and drug to be infused. The regulation is made based on the volumetric flow in terms of ml/h. The pump controls the number of drops per time (drip rate in drops/min) and the infusion velocity. The volume depends on the drop's size, varies with the type of equipment, temperature, liquid viscosity, and density [30]. The parameters and the control strategy used in infusion pumps are listed in Figure 2 below.

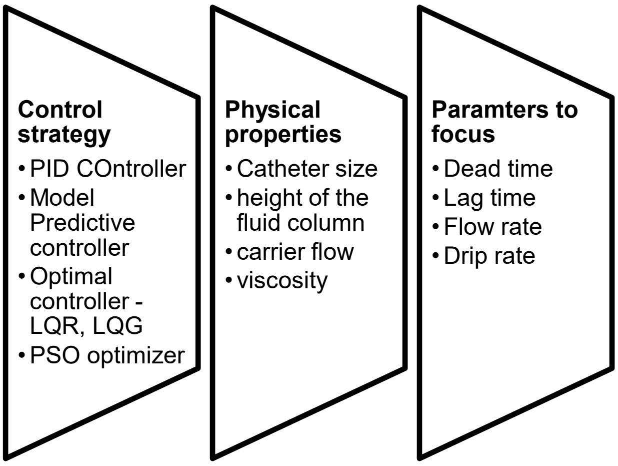

Figure 2. Control strategy and parameters need in infusion pumps

4.4 . Infusion Rates and Its Calculations

To understand the parameters associated with the smart infusion pump, drip rate, drop factor, the flow rate must be calculated based on the dosage and drug concentration [31].

Drip rate is the rate of applying a liquid drug required to provide a certain dosage per unit. Flow rate is similar to drip rate and is measured in gtts/min, and it's a product of drip rate and drop factor. The drip rate is calculated as per equation 1.

$$Drip\ rate = \left(\frac{60 * desired\ dosge}{1000}\right) * \left(\frac{weight\ of\ patinet * bag\ volume}{1000 * drug\ in\ bag}\right) \quad (1)$$

Here, the desired dosage is the drug dosage for a particular treatment, and bag volume is the total volume of one bag of the liquid drug in ml, drug in the bag is the mass weight of the medicine in the drug solution in mg. Further flow rate is identified from drip rate and drop factor, which is given in equation 2.

$$Flow\ rate = drip\ rate * drop\ factor \quad (2)$$

where, drop factor is based on the carrier flow, which is calibrated to 10, 15, 20 at gtts/ml.

Drip rate and flow rate can be obtained based on the practitioner's predefined protocol and the infusion pump. Even though these settings are preprogrammed, lag time may cause interruption for the drug delivery to the patient. The next parameter of interest for infusion pumps is lag time. Lag time is determined as given in equation 3.

$$Lag\ time = {}^{V_d}/_{Q_d} + Q_c \quad (3)$$

Where v_d is the dead volume, Q_d is drug flow, Q_c is carrier flow. Further, the total flow Q_t is determined as given in equation 4.

$$Q_t = Q_d + Q_c. \quad (4)$$

The dead volume will range from 0.2 to 4.0 based on different catheters used. Equation 5 and 6 are provided to calculate the flow rate and speed of the motor based on the number of revolutions. The revolution varies as per the design of the motor.

The motor in the pump must be optimally controlled at a flow rate, and they are related as,

$$Q_t = K \times \theta \quad (5)$$

where K is the proportionality constant and θ is the speed of rotation.

Specifically, the speed of the motor is calculated as

$$\theta = Q_t \times 10\ \text{rev/ml} / 60\ \text{min per hr}. \quad (6)$$

The infusion rates and related information will be usually updated in the smart drug library in smart infusion based on the type of infusion pump mechanism. The pumping mechanism with dead volume and lag time flow rate should be analyzed carefully for different drugs and fluids that have to be administered to the patients. In clinical practice, the distance between the patient and pump is approximately 1m hence the dead volume of 1.5ml will be considered. The dead volume reduction leads to minimized errors in the usage of a smart infusion pump. Usually, the information on dosage in terms of mcg/kg/min, mg/hour or equivalent unit will be provided. The infusion flow rate will be provided with ml/hour. The lag time usually varies based on the carrier tubing provided and in the infusion pump. The flow rate, the lag time for different drugs as sample infusion template (for adults) is shown in Table 1. The values listed are obtained based on the dosage to be infused for a patient weighing 60 kgs. The data are extracted from the electronic Medicines Compendium (eMC) website.

Further, the nursing calculations are used to convert to the infusion flow rate in ml/hr. To complete the infusion flow template, the lag time with a specific dead volume has been calculated. The dead volume will range from 0.2 to 4.0.

The current smart infusion pump maintains the data provided by the different manufacturers as a smart drug library. The development of a smart drug library is based on other parameters related to the infusion pump mechanism, and it can be computed. A complete infusion flow template library can be developed. These parameters should be created in the drug library in smart infusion pump settings for all the types of the drug, and its corresponding flow rate for different carrier flow [32].

Table 1. Sample for few drugs for a carrier flow rate of 10 and 50 ml/hr.

S.No	**Dosage (µg/kg/min) or (mg/hour)**	**Infusion Flow rate (ml/hour) ***		**Lag time (carrier flow with drip rate of 10 sec)**
		Minimum	**Maximum**	
1.	Noradreline	3.5	135	0.081-0.010
2.	Morphine	1	12.5	0.136-0.066
3.	Dopamine	4.5	225	0.103-0.006
4.	Fentanyl	3.6	216	0.11-0.006

* varies as per dosage and available solution in hand.

5. The electrical motor in the medical field

The usage and implementation of electrical motors in medical equipment are unlimited. Different manufacturers design and fabricate a wide range of precision micromotors. These motors are compact, precise, efficient, and have high torque density. The micro electric motors are widely used in active implants, insulin pumps, prostheses for hand & foot, surgical robot, handpieces, grippers, robot-assisted rehabilitation, and medical analyzer [33]. Electrical motors such as brushed DC motor, brushless DC motor, and stepper motor are preferred for their smooth running and long-service [34]. Nowadays, the design and creation of medical graded DC motors are tailored to the customer specifications and requirements.

The micromotors are preferred over conventional DC motors because of the difference with the rotor. The rotor has no iron core but is made of a self-supporting skew-wound copper winding. There is an exceptionally small moment of inertia in this featherweight rotor, and it rotates without cogging. Because of their low contact resistance, commutation systems using precious metals are the ideal solution for low-power micromotors. Most of the motors range from6 mm to 22 mm in diameter. The performance of the motor is almost linear and easier to control.

5.1 Motor selection

The choice of the DC motor is based on its characteristic for torque, speed, current, voltage, and power rating. It is also mandatory whether the system is an open or closed-loop control system based on velocity and position [35]. Apart from these, the storage and operating ranges with threshold ranges are needed. Based on the medical device and its applications, the load will vary. For fixed loads and speed, the speed torque curve of the motor should be within the operating range. If the speed and load are variable, Root Mean Square (RMS) torque must be calculated. RMS torque is calculated for each time increment. Further, the speed-torque curve will be plotted, and it should be within the operating limit [36].

The motors can be custom designed based on their usage. For instance, if the motor is coupled with a gearbox, the torque is higher at low speed. If a device requires relatively low torque and high speed, the motor alone can actuate the entire device. The decision on a single motor or gear motor should not be based solely on speed - torque requirements and the type of motion control. For position control applications such as linear actuators, the motor alone is desirable. A gear motor is chosen for speed or current controlled applications, such as pumps or wheel drives [37]. A closed-loop control system should be applied for the DC motors employed in the medical devices to obtain the required speed, position, and proper torque curve in the operating range.

5.2 Control strategies for electric motors

Monitoring and controlling the parameters of the micro-DC motor employed for medical devices are very important. The implementation is done based on the manufacturer specification and the datasheet available. The control speed, position monitoring power rating, torque, and current rating are crucial [38]. The medical devices designed nowadays are smart, precise, and highly efficient. For instance, in the case of sensorless BLDC drives, rotation of the motor should be minimal to generate sufficient back-EMF for the drive and if there is a drastic change in the load, the back–emf loop may lose sync and results in loss of torque and speed control. Hence the actuators like miniature motors employed should function very precisely and optimally [39].

To achieve these, different controller strategies have to be incorporated. In this section, the controller strategies incorporated for medical devices and their motors are discussed. The control strategies are very important as the exact output of the device based on its actuation can be studied and viewed. The control strategies are used to improve the performance of the motors, in turn, helps in the overall performance improvement of the device.

Different control schemes, optimization, and estimation techniques are adopted to obtain the required position, speed control of the DC motors needed for the different medical devices [40]. To implement this, time response and frequency response analysis of the motor should be verified. Further, it should be programmed to the microprocessor or microcontrollers of the smart medical devices. Numerous papers are available in this aspect.

In [41], the transient response of three different DC motors was verified for speed control using PID controller. The PID's gain parameters were tuned using the modified Ziegler-Nichols method. These three motors were verified for minimum rise time, settling time, and overshoot. It was found among three motors, two are preferred for high power applications, and another is suitable for low power applications. Most medical devices are low-power devices that should follow the characteristics mentioned.

The authors of the paper [42] have analyzed stability with the Lyapunov method, which theoretically guarantees the prescribed tracking output in the presence of various uncertainties essential for the high precision control of motion systems. In the paper [43], the error minimization is focused on evaluating IAE, ISE, and ITSE for the DC motor. Further, to perform tuning of gain values of the PID controller such as K_p, $K_{i,}$ and $K_{d,}$ the Particle Swarm Optimization (PSO) technique was used. To verify the DC motor's minimum rise time, PID with PSO and fuzzy-based PID was implemented, and the PID-PSO controller has shown better performance. Rise time has been compared with PSO and Fuzzy based PID where in PSO resulted with 0.00285sec and 0.0087 sec for fuzzy controller [44].

The authors have incorporated [45] modified PID controller with PSO to minimize the steady-state error, rise time, maximum overshoot, settling time. These parameters are minimized based on the objective function along with the load disturbance ranges from 5 N-m to 10 N-m. In [46] all the transient response analyses, Integral errors are identified with the conventional PID and fuzzy PID controller for armature controlled and field controlled DC motors. The armature-controlled DC motor position control with the fuzzy logic controller has taken 58%, and field control has taken 43% less duration than the traditional PID controller. Apart from these techniques, DC motor control is implemented with Genetic Algorithms (GA) in combination with PID controller [47]. Since GA is adopted, the optimal performance on the transient response of DC motor control was achieved with rising time, settling time for 0.1 sec, and mean square error is 0.0033.

Several kinds of research have been done in soft computing based on the combination of ANN and PID controller in [48] paper position control of DC motor focused with ANN and compared with PID controller. The error minimization was achieved to 0.0015 with 500 epochs by computing with ANN. In another paper [49], the comparison is done with deep learning for the performance of the system and error minimization and is also compared with the PID controller. Here, the RMSE was calculated; it was found as 0.054 for a simple step input and 0.3659 for a cascade step input. Authors have focused [50] on the experimental results of the simple tuned fuzzy controller of Pulse Width Modulation (PWM) applied to regulate the revolutions per minute (rpm) of a DC motor. The results were verified for PID controller with Zeigler – Nichol's method for tuning of PID gain values, Integral square error. It is inferred that the fuzzy logic-based tuned DC motor control has an Integral square error of 9818ms which is a lesser value. Apart from position and speed control of DC motor, torque estimation for DC motor for industrial application was concentrated in [51] using fuzzy PID controller. The torque estimator was validated practically and compared with the theoretical estimations. From the paper [52], it is inferred that DC motor control is implemented using fuzzy logic by combining armature voltage and field current. The results are proof that the combination method performs better wherein the peal overshoot is 0.8%.

The authors have proposed a cascade control system [53] to track the motor speed, further determined the armature current without and with torque load of 30Nm, 12Nm. The results of transient response analysis indicated cascade controller performs better with less noise and overshoot. In a paper [54], authors have examined the DC motor speed control by implementing self-tuning of fuzzy PID algorithm and analyzed the values of overshoot, rise time, and settling time for different combinations of PID controllers like conventional PID controller, self-tuned PID controller, and hybrid self-tuned PID controllers. The results show that the hybrid controllers perform better for self-tuning the control parameters of DC motor control, such as settling time and peak overshoot. The authors have identified that the maximum overshoot is 3.646%, and the settling time is 486ms.

Apart from conventional PID controllers and hybrid controllers, the finding of the research based on Artificial Bee Colony (ABC) optimizer [55] was used to verify the transient response analysis for motor speed control. It is found that ABC has reduced the settling time to 0.012sec, rise time as 0.006 with zero overshoot. It is evident from this paper that based on the requirement of an application and usage of the DC motor, the type of control strategies and optimization techniques have to be incorporated to obtain better results.

Optimal control for the electric motor has been performed using Grey Wolf Optimizer (GWO) Algorithm. In this work, the GWO and PSO have been compared to better values for maximum peak overshoot and settling time to achieve optimal speed control. The overshoot and settling time are found to be 0.0043 and 1.1021 sec. In another paper, the authors compare the maximum peak overshoot and settling time using an adaptive PID controller. Controller error and adaptation error were also computed. The rise time and settling time achieved with this technique range from 0.44 to 1.15 sec and 1.29 o 3.2 for different iterated values. PWM-based speed control is computed for few applications, using conventional PID, fuzzy PID controller, and Neural network tuned PID controller [56]. It is identified that fuzzy and neural network-based PID controller response on tracking curve is smooth.

The research has been done in a similar way for brushed DC motor and brushless DC motor. A typical real-time application disturbance is another factor that has to be considered, which may lead to several uncertainties [57]. A robust controller with an extended state observer has been synthesized for highly accurate motion control of DC motor to enable the system adaptive. In some of the applications, where it is nonlinear [58] based on Coulomb friction Hammerstein nonlinear system approach has been used to handle the bidirectional movement of the DC motor. The renowned estimation technique Kalman filter [59] had been used to estimate the load torque and speed when susceptible to the noise when DC motor and its drives are used for different electrical and electronic applications [60]. In this paper, dynamic speed tracking and steady-state error reduction have been addressed, and the model predictive controller has been implemented.

An adaptive control technique named online tuning grey fuzzy PID was instigated to estimate the torque for a DC motor. With PI controller, the Flux, torque, and speed are estimated for a full load, 6 Nm at 1200 rpm, to estimate the specified parameters for a synchronous machine [61]. In [62] for BLDC motor, a simple hysteresis current control strategy is implemented to control motor torque. Experimental results have been shown to verify the drive's performance, built with a single-sided matrix converter for electro hydrostatic actuation. The inclusion of hardware with BLDC motor or PMDC motor and verifying its functionality with hardware, simulation, and both are purely based on the applications. In some situations, the speed and position control with and with our disturbances can be handled with optimal control techniques such as LQR [63] and LQG [64]. These techniques provide responses based on their programming capability. LQR being an optimal controller results in quick settling and rise time for the given system. The DC motor control implemented with LQR [65] or in combination optimization techniques such as PSO, PID provides precise speed, positioning, and torque control.

The overview on-time response analysis of DC motors with different control strategies is shown in graphical form in Figure 3 below.

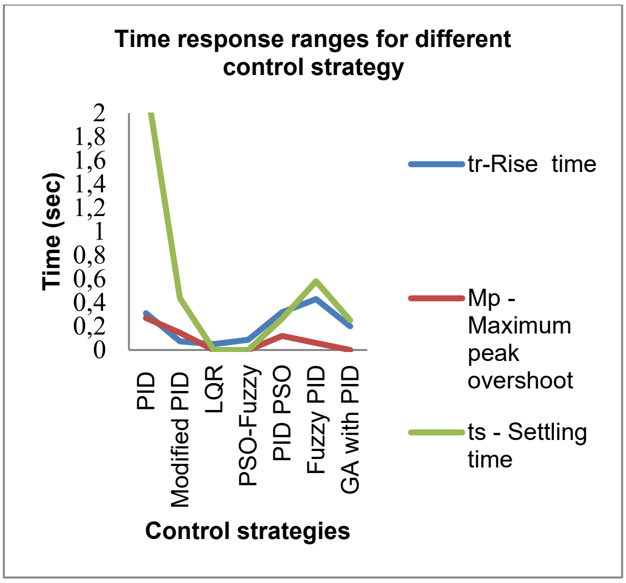

Figure 3. Comparison on control strategies with transient response of DC motors (as per literature)

5.3 . Motors for medical devices

It is evident from the literature that many controller strategies, which can be conventional or hybrid with optimization techniques, are implemented to obtain the desired outputs to maintain speed and position control with different parameters. The DC motor driver has been custom designed for a haptic device that supports medical devices [66]. The parameters such as position, velocity, and current values are controlled. To have stability under disturbances because of noise, a DC-DC converter is utilized. In wheeled mobile robots, the usage of the DC motor was prominent, and the parameters like speed, torque, and current are controlled [67]. In this work, the modelling and closed-loop control system have been designed and developed. From the literature, it is evident that the design of the Modified Harvard Apparatus Model 1423 pulsatile blood pump has been designed with the shunt wound DC motor technology. Based on the investigations done by the authors, it was found that the maximum torque is needed for that application [68]. The researchers have addressed that for a typical biomedical device-based application, the position control of the DC motor should be appropriate [69]. To obtain this, PSO with a Proportional Integral controller was implemented to reduce the overshoot to 1.04 and settling time to 0.038 sec. In particular, the design of wireless capsule endoscopy has been designed with a vibrating motor which is a micro motor. In this work, the reduction of the frictional force has been verified when vibration increases according to the motion of the capsule [70-75]. The reduction of frictional forces up to 31% was observed as the vibrating motor is miniaturized [76]. Further, several computational techniques, prediction techniques have been discussed in different applications [77-79]. In this paper, parameters to focus on electric motors with control strategy employed in a medical device are shown in Figure 4.

Parameters for electric motor	Optimization technique and controller strategy	Control parameters to analyse
• Position • Speed • Frictional forces • Torque	• PID • PSO • ANN • Fuzzy logic • Genetic Algorithm • Different combination of different algorithms	• Rise time • Settling time • Steady state error • Integral error • Peak overshoot • Stability

Figure 4. Outline of parameters associated with the electric motor used in medical devices

The DC motors (BLDC and PMDC) as micromotors are widely used in different medical applications and is tabulated in Table 2. The usage of miniaturized motors in medical applications is unlimited (this information has been referred from the manufacturer of micro and mini motors for medical applications).

Table 2. DC motors in medical devices

Medical devices	Applications
Positive Airway pressure	For treatment of sleep apnea, respiratory disorders.
Medical Analyzer	Laboratory automation
Radiation therapy and image-guided therapy	reduce chances of patient collateral tissue damage.
Biopsy hand-held device	To attain tissue samples
Medical Pipettes	accurate delivery of samples and reagents, thereby reducing the risk of repetitive strain injury.
Mesotherapy Gun Motors	multiple micro-injections therapies
Wearable robots and Robots	Exoskeleton applications and surgical robots.
Dental hand-held tools	rotary endodontics, root canal obturator, prosthodontics screwdriver and other surgical instruments.
Medical Infusion system	Insulin pumps, home and hospital infusion pumps, ambulatory eternal feeding pumps.

6. Discussion and Conclusion

Current advances in computing are prominently incorporated in medical equipment and health care applications. Among all devices, the focus on infusion pumps is true. Most therapies require drug infusion, fluids, and nutrients through infusion pumps. The review shows that once the infusion flow rate is known, the minimum lag time will be computed. The information on the lag time steady-state error is needed. These values should be minimum and to handle the pumping mechanism. The research survey concentrated in this paper is limited to the infusion pump control based on the pumping mechanism. The infusion pumping mechanism is implemented in Induction and maintenance phase. The initial injection of a certain quantity of drugs (bolus) for a short time, followed by a phase without adding drug before switching to a manual control corresponding to the maintenance phase. To emulate this, a quick induction phase is needed with minimum time for the infusion pumping mechanism. With quick rise time and fast settling of the electric motor will be the requirement of the smart infusion pump. The actuation of the pump is majorly based on the precise position, speed, and torque control of electric motors employed in the pumping mechanism. Based on this, the required optimal control strategy should be implemented with less error. From the literature, it is inferred that the focus on the DC motors transient response analysis with different control strategies such as PID controller, ANN, fuzzy controller, optimal controller, optimization techniques should be incorporated independently or in different combination to achieve quick settling time, rise time and minimized percentage overshoot, steady-state, integral error. These are essential to ensure the optimum and precise flow of fluid and drug to the patients. Apart from drug delivery, the review in the current research enables minimized error and helps the patients. The survey enables the researchers to focus on the physiological control system of medical devices, which is an important concept to be addressed to handle the medical devices accurately so that the patients who are part of the society will be benefited.

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