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Stabilization of a Non-Linear Physiological Control System with Additional Actuating Signal

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Abstract:

In my work, the problem of the desired performance of the control system with nonlinearity is considered. The plan of my paper work proposes to include an Additional Actuating Signal (AAS), besides the standard Actuating signal, to stabilize and control the system for compensating the system to accomplish the standard results. This method may be useful in physiological control system and process control system, where the system input parameters cannot be controlled at all or partially only. The results offer vital information for the design of potential superior control systems and stress the flexibility and effectiveness of AAS as a tool for isolating the system from the influence of nonlinearities and changing system dynamics.

Keywords: Additional Actuating Signal (AAS), Non-linear control system, Physiological control system, Desired response, Adaptive Control System.

1. Introduction

A control system is a group of integrated components, designed to realize a expected response while in the effect of outer disturbances. In open loop mode, the response of the system is determined only by the controlling inputs. In every physical system there is a finite limit on the magnitude of the control that can be provided by the actuator. The actuator may saturate the response. A control system planned to avoid attaining the saturation limit is typically ineffective, since the actuator has a physical capability[1,2] that is not used, like the engine in a heavily overpowered automobile. A well-proportioned control system is one in which the actuator is selected so that its full capabilities are sometimes needed. The actuator should be expected to saturate in extreme tasks. This suggests that well-designed closed-loop system should be ex-pected to be non-linear [3,4], through the saturation of the actuator. If the actuator only saturates rarely, however, it is usually possible to ignore the saturation in the design and to assess its effect only in the performance evaluation. On the other hand, if the authority of the actuator is extremely limited, and it saturates frequently, a design method that explicitly accounts for the saturation, would be more appropriate.

2. Study on research works

A lot of work has been done with Control Systems as to be mentioned. The Torso or Gait stabilization with actuating signal based control systems has found [5,6] use in robotics, mechanical prosthetics and Mechanical suits. The history of control theory can be easily divided into three era. The earliest era, which starts in prehistory and ends in the early 1940s, may be termed the primitive era [7]. This was followed by a classical era, lasting hardly a couple of decades, and finally came the modern era.

The term primitive is used in respect of the initial era, as during this era, ra-ther than the knowledge being organized, the theory consisted of a compilation of analyses of definite processes by appropriate numerical methods, and often invented to deal with the specific problems. During the middle Ages and earlier, although the feedback principles can be seen, but it was not until the later part of 18th and begin-ning of 19th centuries, around the beginning of the industrial revolution, that the deli-berate use of feedback [8,9] to improve the performance of dynamic systems was started.

In the early 20th century, mathematicians Poincare and Liapunov [10,11], made important contributions in respect of the numerical problems involving the stability of feedback control systems. In the first quarter of the 20th century, the gyroscope was developed as a practical navigation instrument [12], used in autopilots of ships and aircrafts.

In fact every new control system invented in that era was a new invention and was indeed patented. Notwithstanding the creativity that these inventions required the diversity of functions that could be achieved with these devices was extremely limited. Thus a numerical theory of the function that a feedback compensator [13] must perform would have been of little practical value, since no way of implementing the function was available.

In the year 1930, Nikolay Mitrofanovich Kryloy and Nikolay Bogoliubov had invented the Describing function method in control system and further developed by Ralph Kochenburger. For finding out the stability of a nonlinear system, Describing function method, out of all the analytical methods developed over the years for nonlinear control [14,15] . systems and is effectively the most useful method for analysis and study of non linear control system, yielding harmonics along with fundamental component of signal at output. This method is basically a rough extension of frequency response methods to non-linear systems.

3. Shortfall in the previous works

The importance of the Control systems is immense in the fields of implementation and much more is desired from exploitation of these systems. It has been pointed out by several authors that big gap existing between theoretical techniques and advanced control system technique applications.

Most control systems are non-linear in nature; although satisfying the basic engineering requirements, many of these ones can be linearized at one of their equili-brium points. Even though these systems can be synthesized and analyzed [16] using methods and theories of linear control system, but there exists some system models which do not fit into, or work as desired when conceptualised by adapting the approximate linearization method.

In other words, a new control theory, which is systematical and non-linear, urgently needs to be introduced to effectively controlling output for the desired out-put. Thus for stabilizing the output of the control system, the Additional Actuating Signal (AAS) is considered for introduction.

4. Introduction of AAS on A non-linear control system

While assessing the performance of any control system, it can be easily concluded that the system is deviate from its planned output, which may be due to many reasons, which may be its environmental parameters, or any unwarranted noise signal etc. Thus, the Additional Actuating Signal (AAS) is planned to be introduced, in addition to the normal feedback signal, for optimizing the stabilizing the control system, so as to achieve its benchmark performance. The real life autonomous and independent process control systems and physiological control systems[17], where the input and other environmental parameters cannot be fully controlled, may find use of this technique.

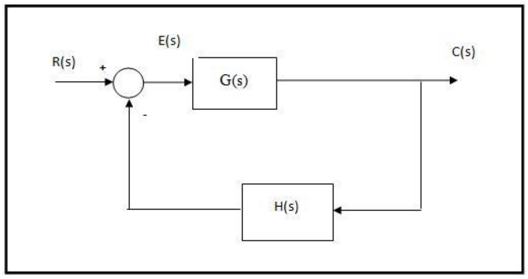

Fig.1 General feedback Control System

A system where there exists a nonlinear relationship between input and output, which does not involve a differential equation is called a static non linearity. On the other hand, the input and output being related through a nonlinear differential equa-tion, is called a dynamic non linearity [18]. The different types of non-linearities can be Saturation, Friction, Dead zone, Relay (ON/OFF controller) and Backlash or others.

Analysis of different nonlinear system is very difficult because of their inherent non-linear behavior. In a closed-loop [19] control system [20] the output C(s) has an effect on control action through a feedback as shown in Fig.1. The control action is actuated by an error signal E(s) which is the difference between the input signal R(s) and feedback of the output signal C(s), having feedback gain H(s). By simple control lay, the response C(s) is given by Eqn. (1) as:

$C(s) = G(s)\, E(s)$

Or $\quad C(s) = G(s)\,[R(s) - C(s)\, H(s)]$

Or $\quad C(s) + G(s)C(s)\, H(s) = G(s)R(s)$

Or $\quad C(s)\big(1 + G(s)H(s)\big) = G(s)R(s)$

Or $\quad C(s) = \frac{(G(s)R(s))}{(1+ G(s)H(s))}$ .... (1)

In this control system, the output signal C(s)is affected due to noise, change in en-vironmental condition or any kind of disturbance. The Additional Actuating Signal R1(s) is applied to system and output response C(s) of system is kept unaltered, de-spite there being any ambient changes in the system itself due to its environmental parameters etc. likely to occur in any actual system as shown in Fig.2.

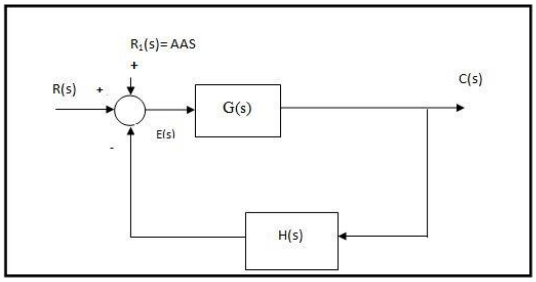

Fig.2 Introduction of AAS in the Control System

Whenever the system response deviates from desired one, due to unwanted noise, system parameter variation with respect to time or else, as being reckoned by the non-linearity in the system, the application of AAS (R1(s))along with the basic input R(s) of the system restores the desired response in the overall control system as depicted in Fig.2. Maintainability of desired response of non-linear control system by different approaches were carried out earlier [21] .

R(s), G(s) and C(s) are the basic input, system gain, output response of system respectively.

R1(s) = Additional Actuating Signal (AAS) to maintain desired response C(s)

Simple response of feedback control system, the desired (i.e. unaltered) response C(s) in presence of AAS may be mathematically represented as

$$C(s) = G(s)\, E(s)$$

where $E(s) = R(s) + R_1(s) - C(s)H(s)$

Or $C(s) = G(s)[R(s) + R_1(s) - C(s)H(s)]$

Or $C(s) = G(s)[R(s) + R_1(s)] - G(s)\, C(s)\, H(s)$

Or $C(s) + G(s)\, C(s)\, H(s) = G(s)[R(s) + R_1(s)]$

Or $C(s)\left(1 + G(s)\, H(s)\right) = G(s)[R(s) + R_1(s)]$

Or $C(s) = G(s)[R(s) + R_1(s)]/\left(1 + G(s)\, H(s)\right)$ ....(2)

Thus the desired response C(s), as shown in Eqn. (2) is kept unaltered by using AAS R1(s) along with basic input R(s).

Table 1: Introduction of Additional Actuating Signal (AAS)

Descriptives								
Sum	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
2.00	1	63.0000	.	.	.	.	63.00	63.00
2.60	1	64.0000	.	.	.	.	64.00	64.00
2.80	4	69.5000	7.18795	3.59398	58.0624	80.9376	63.00	79.00
3.00	3	73.6667	12.85820	7.42369	41.7251	105.6082	59.00	83.00
3.20	12	69.0000	9.31275	2.68836	63.0830	74.9170	54.00	82.00
3.40	13	70.0769	7.25099	2.01106	65.6952	74.4587	58.00	81.00
3.60	9	71.5556	11.21507	3.73836	62.9349	80.1762	57.00	88.00
3.80	8	75.1250	7.90005	2.79309	68.5204	81.7296	63.00	85.00
4.00	14	76.8571	5.93370	1.58585	73.4311	80.2832	67.00	86.00
4.20	10	78.8000	6.66333	2.10713	74.0333	83.5667	71.00	91.00
4.40	9	79.0000	9.52628	3.17543	71.6775	86.3225	66.00	92.00
4.60	8	79.2500	6.94365	2.45495	73.4450	85.0550	68.00	88.00
4.80	6	81.0000	7.92465	3.23522	72.6836	89.3164	68.00	89.00
5.00	2	82.0000	1.41421	1.00000	69.2938	94.7062	81.00	83.00
Total	100	74.6900	8.86566	.88657	72.9309	76.4491	54.00	92.00

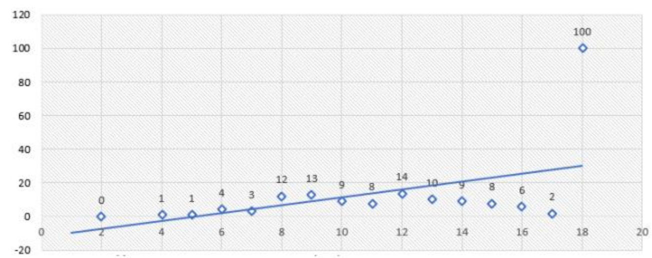

Figure 2: Descriptive 1 of Table 1 Additional Actuating Signal

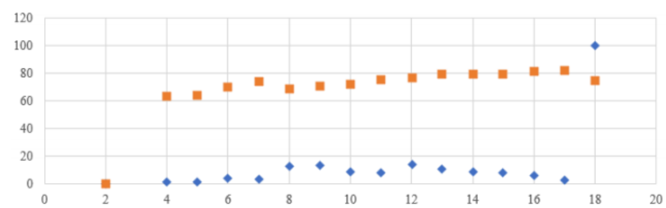

Figure 3: Descriptive 2 of Table 1

For dealing with nonlinear system, as the Laplace operator does not work, the sys-tem transfer function is to be considered in z transformation along with zero order hold (Z.O.H), the analysis and study being carried out in sample domain [22,23]. Thus finally the AAS [24] R1 evaluated in inverse transformation determines the required signal to have the unaltered system response.

5. Conclusions

Our analysis focuses on analyzing the subject's ability to maintain desired response in a control system regardless of there being a variety of change in inputs or in the environment of the system itself. The inclusion of an Additional Actuating Signal (AAS) assists in regulating the control system output, without affecting or relying upon the working of the normal feedback signal and the control systems default working environment.

The method can be of use in any real life process control system, including non-linear ones for sustaining the unaltered output of the system. On interpretation of the outcome of the inclusion of Additional Actuating Signal (AAS) in the control system, it is anticipated that it will be appropriate for control and compensation of non-linear systems also.

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