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Operational exposition on offline and online AI closed-loop control systems applications

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Abstract

Offline and online operations are the two commonly identified computer operations in practice. These two operations have their advantages and limitations and should be weighed by the user before making a choice. With the current artificial intelligence revolution, critical decision has to be made on its applications in order to obtain the desired objectives. Close-loop control system is amendable for use by artificial intelligence experts, engineers and scientists for problems solving. Such decisions should not be taken without critical analysis of pros and cons of the two types of operations, selecting the best choice based on each scenario or application. This research seeks to explore the possible threats and risks associated in their operations and provide the necessary guides to enable adequate application of the two methods in closed-loop control system engineering. Such results as presented in this work have provided the platform in the utilization of artificial intelligence in closed-loop control system applications. It is hoped that this research will serve engineers in the exploration and application of offline and online computer applications in various artificial intelligence closed-loop control system usage to drive the industries, plants and similar systems suitable for their applications.

Keywords: Artificial Intelligence; Closed-Loop; Offline; Online; Control System; Operations

1. Introduction

AI is the simulation of human intelligence processes by machines especially the computer system. AI programming system hinge on cognitive skills such as learning, reasoning, self-correction and creativity.

AI has four categories- Type 1,Type II, Type III and Type IV. Type 1 AI has no memory and are task specific. It cannot use past experience to perform future tasks. It is reactive in nature. It reacts to the provided data and can only perform limited roles with limited scope. It is also called narrow AI. Type II AI has memory. The memory is however limited. They have a certain understanding of historical events and data. They can use this experience to build their knowledge but cannot fully comprehend the world on a broader perspective. It uses past experience to take future decisions.

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In Type III, the AI is linked with the ability to infer human intentions and predict behaviour. It is a system designed to understand human emotions. The AI thinks beyond its functions. It could broaden its understanding into numerous fields that could be regarded as Artificial general intelligence. Type IV AI is expected to have self-awareness. They are expected to have the understanding of the world. This is far from reality. Such a machine is not in existence and may never exist.

The introduction of AI in closed-loop control system has been proposed by researchers in recent times [1][2]. This is due to the immense benefits expected to be obtained from this technology.[2] has shown the application of offline AI in checking surface roughness of parts on assembly line. Figure 1 and Figure 2 show the results obtained from the research work.

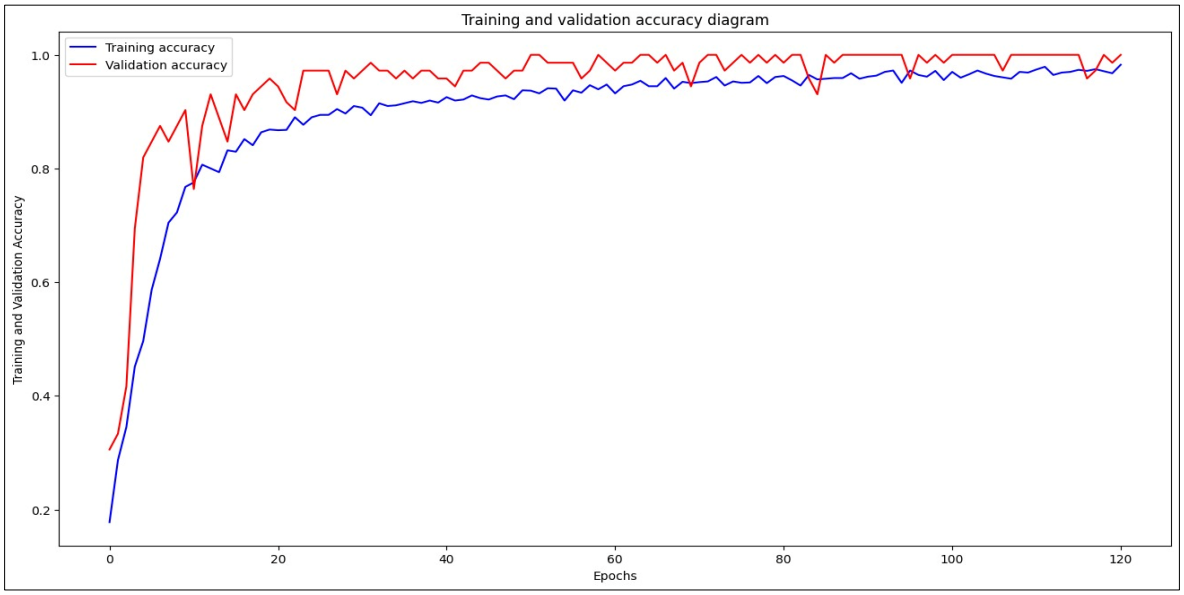

Figure 1 Precision Against Epoch [2]

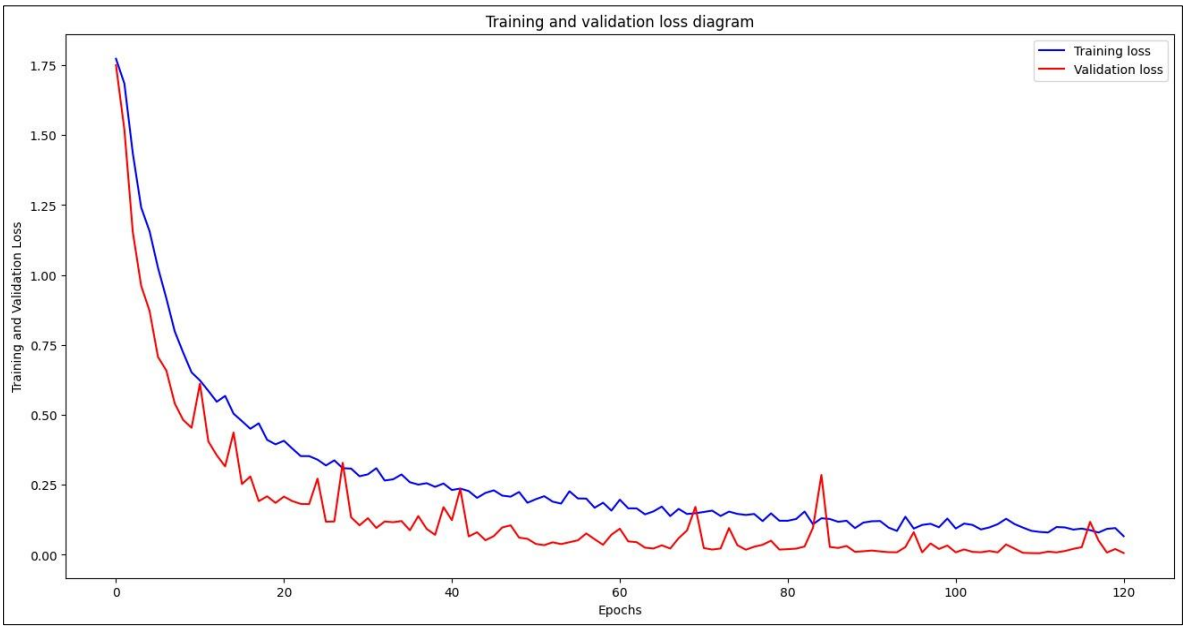

Figure 2 Deviation Against Epoch [2]

Table 1 shows the system accuracy and losses during training and validation of 150 Epochs.

Table 1 Accuracy and Losses during training and validation of 150 Epochs

Model Epoch (Iteration)	Model Accuracy	Model Losses	Accuracy during Validation	Losses during Validation	Implication
1/150	0.1603	1.7797	0.1667	1.7713	Increased
2/150	0.2119	1.7457	0.3056	1.6982	Increased
3/150	0.3139	1.5992	0.3889	1.3885	Increased
4/150	0.3824	1.3815	0.6111	1.1440	Increased
5/150	0.4568	1.2480	0.6528	1.0781	Increased
6/150	0.5420	1.1024	0.6667	0.9732	Increased
7/150	0.5714	1.0227	0.7500	0.7730	Increased
8/150	0.6327	0.9455	0.8056	0.6975	Increased
9/150	0.6627	0.8606	0.8333	0.5891	Increased
10/150	0.6807	0.8279	0.8194	0.5571	No increase from 0.8333
11/150	0.7197	0.7537	0.83333	0.5422	No increase from 0.8333
12/150	0.7407	0.7111	0.8611	0.5101	Increased
13/150	0.7491	0.6814	0.7639	0.5678	No increase from 0.8611
14/150	0.7695	0.6344	0.8889	0.3593	Increased
15/150	0.7785	0.5976	0.8750	0.4560	No increase from 0.8889
16/150	0.8049	0.5711	0.7778	0.5837	No increase from 0.8889
17/150	0.8109	0.5418	0.9028	0.3360	Increased
18/150	0.8115	0.5427	0.9306	0.2724	Increased
19/150	0.8427	0.4764	0.9306	0.2691	No increase from 0.93056
20/150	0.8403	0.4612	0.9306	0.2738	No increase from 0.93056
21/150	0.8427	0.4478	0.9028	0.3022	No increase from 0.93056
22/150	0.8325	0.4715	0.9444	0.2247	Increased
23/150	0.8505	0.4203	0.9583	0.1903	Increased
24/150	0.8391	0.4673	0.8750	0.3550	No increase from 0.9583
25/150	0.8691	0.3997	0.9167	0.2524	No increase from 0.9583
26/150	0.8697	0.3840	0.9028	0.3192	No increase from 0.9583
27/150	0.8764	0.3781	0.9444	0.1779	No increase from 0.9583

28/150	0.8902	0.3372	0.9167	0.1944	No increase from 0.9583
29/150	0.8836	0.3382	0.9306	0.1613	No increase from 0.9583
30/150	0.8673	0.3686	0.9167	0.2057	No increase from 0.9583
31/150	0.8547	0.4029	0.9444	0.1619	No increase from 0.9583
32/150		0.3425	0.9444	0.1428	No improvement from 0.9583
33/150	0.8908	0.3410	0.9306	0.2084	No increase from 0.9583
34/150	0.8884	0.3323	0.9306	0.1607	No increase from 0.9583
35/150	0.9028	0.2854	0.9306	0.1737	No increase from 0.9583
36/150	0.8992	0.2958	0.9028	0.2488	No increase from 0.9583
37/150	0.8998	0.3020	0.9306	0.1696	No increase from 0.9583
38/150	0.9064	0.2789	0.9583	0.1535	No increase from 0.9583
39/150	0.9034	0.2840	0.9583	0.1278	No increase from 0.9583
40/150	0.9076	0.2825	0.9444	0.1141	No increase from 0.9583
41/150	0.8980	0.2959	0.9306	0.1510	No increase from 0.9583
42/150	0.9118	0.2582	0.9583	0.0974	No increase from 0.9583
43/150	0.9004	0.2784	0.9306	0.1259	No increase from 0.9583
44/150	0.9154	0.2461	0.9444	0.1954	No increase from 0.9583
45/150	0.9112	0.2545	0.9444	0.1336	No increase from 0.9583
46/150	0.9202	0.2594	0.9583	0.1410	No increase from 0.9583
47/150	0.9112	0.2466	0.9583	0.0961	No increase from 0.9583
48/150	0.9160	0.2341	0.9444	0.1977	No increase from 0.9583
49/150	0.9250	0.2422	0.9306	0.2139	No increase from 0.9583
50/150	0.9214	0.2248	0.9722	0.0894	Increased
140/150	0.9712	0.0873	1.0000	0.0085	Increased

141/150	0.9730	0.0844	1.0000	0.0152	Increased
142/150	0.9784	0.0729	0.9306	0.3097	No increase from 1.000
143/150	0.9790	0.0725	1.0000	0.0080	Increased
144/150	0.9706	0.0853	0.9722	0.1111	No increase from 1.000
145/150	0.9694	0.0958	1.0000	0.0071	Increased
146/150	0.9610	0.1065	0.9722	0.1268	No increase from 1.000
147/150	0.9778	0.0692	0.9583	0.1252	No increase from 0.9722
148/150	0.9574	0.1291	0.9306	0.1992	Increased
149/150	0.9760	0.0827	0.9861	0.0412	Increased
150/150	0.9670	0.0932	0.9861	0.0502	Same

[2]

Table 2 shows the system structure applied.

Table 2 System Structure

Phase name	**Dimensions (Result)**	**Parameters**
Convolution	(Nill, 200, 200, 32)	2432
Convolution Iteration 1	(Nill, 200, 200, 32)	9248
Maximum pooling	(Nill, 100, 100, 32)	0
Convolution Iteration 2	(Nill, 100, 100, 64)	18496
Convolution Iteration 3	(Nill, 100, 100, 64)	36928
Maximum pooling Iteration 1	(Nill, 50, 50, 64)	0
Convolution Iteration 4	(Nill, 50, 50, 128)	73856
Convolution Iteration 5	(Nill, 50, 50, 128)	147584
Maximum pooling Iteration 2	(Nill, 25, 25, 128)	0
Dropout	(Nill, 25, 25, 128)	0
Flattening	(Nill, 80000)	0
Dense	(Nill, 256)	20480256
Dropout Iteration 1	(Nill, 256)	0
Dense Iteration 1	(Nill, 128)	32896
Dropout Iteration 2	(Nill, 128)	0
Dense Iteration 2	(Nill, 6)	774

Summation of parameters: 20,802,470
Learnable parameters: 20,802,470
Untrained parameters: 0
[2]

There are two possible ways of application of AI in closed-loop control system, namely offline and online application.

An offline process describes any operation or data processing that is done without a direct connection to the internet network. The process or operation is performed locally without real-time interaction or reliance on remote systems. In a typical offline process, the operation is performed on a single computer without interaction with external servers or databases. Offline operations are independent of network connection. It includes data storage on a local hard drive, editing files on a computer or calculations without assistance on online services. It is completely localized.

It is useful where sensitive data is needed to be processed locally for security reasons and in situations where real-time access is not needed or internet connectivity is unreliable.

Online process computers connected to servers to send or be available through a system and especially a computer or telecommunication system. The systems are linked or connected to communicate in real-time. Online process or processing is typically for data processing that handles a large number of concurrent transactions. It is characterized by the need for fast response time and ability to handle large volume of data and deliver very quickly to its destination. The systems are expected to respond to user requests and process them in real time. It possesses many advantages including increased speed, convenience, cost-effectiveness and security. It promotes businesses by reaching a wider audience, improves efficiency and give a competitive advantage to the user.

Online systems process transaction faster than offline operations. It leads to customer's satisfaction. It allows customers to make transactions anywhere in the world and breaking geographical and time-based limitation. It reduces paper work, automate task and reducing physical contacts and cost. There is improved customer's experience. It provides options for personalized operations and 24 hours and 7 days availability-providing security payment gateways and encrypted transaction environment for payments, thereby reducing risks of fraud.

It offers better data control. Data management, tracking and enable analysis to be made to improve operation. It allows organizations to access global market and expanding their businesses. It allows flexibility with changing needs and scaled to promote growth.

It however houses the following disadvantages: Technical problem, pass word threats, cost due to fraud, security concern, illiterates opened to threats, limitation to operation, possible disputes, loss of smart cards and allows for false identity.

1.1. Offline Artificial Intelligence

This refers to the ability of Artificial intelligence to function or operate without an internet connectivity, depending only on locally stored data and pre-trained models. It allows the AI to function in areas with limited or no internet connection. The benefits are increased privacy and control. It provides privacy as sharing of data with third party is reduced or non-existent. It prevents sensitive information or data from being transmitted to external server. It is cost effective compared to cloud computing. It reduces latency times due to local process which is faster. It is flexible and provides customized solution. Such applications are found in offline image recognition, speech recognition and smart assistant and statistical analysis.

1.2. Online Artificial Intelligence

Online AI is Artificial intelligence technologies and applications that are accessed and used over the internet. Such are found in natural languages, processing, machine learning, computer vision, etc.

They have the following characteristics:

- Accessibility- It is accessible to anyone with internet connection.
- Remote Operation-Hosted on servers, AI models and algorithms are accessible from anywhere around the globe.
- Diverse Application-It offers diverse online services. Search engines. Virtual assistant, shopping and in this case control system element control in closed-loop system.
- Scalability- It is scalable for different types of purpose and data
- Constant Learning- It applies machine learning for continuous improvement and can adapt to new data and user interaction

Practical Implications

Artificial intelligence has found applications in closed-loop control system. Its potentials and enormous benefits have been identified for further exploration. Artificial intelligence can be applied both in offline and online processes, indicating its versatility in control system engineering. Right decisions should be made on its applications of the two available options offered with good balance of judgment. The pros and cons on each decision should be clearly weighed and clear-cut choice made on a particular scale of application. In that case, analysis must be made to determine if offline or online application is desired for any case weighing security, cost, ease of operation and efficiency. It is only by thorough and objective analysis that such choices can be made. It is on this premise that this research is built and anchored to provide engineering decisions.

1.3. Background to the Problem

Artificial intelligence has provided a platform to improve on the performance of closed-loop control systems. In making such choices several factors have to be considered to select the two available options-offline and online process for a particular operation. Such guidance in decision making must be backup with analysis to arrive at a good engineering decision. What are the necessary factors to be considered? What are the challenges? These questions must be assessed properly before taking a decision on the process type. It is only when these are done that the desired objectives of Artificial intelligence can be successfully applied in control system engineering.

2. Signal Processing in Offline Artificial Intelligence operation

Signal processing in offline Artificial intelligence requires no connection with the internet in its operations. It allows engineers to analyze, optimize and correct signals into useable form such as audio streams, images and video or scientific data without web interaction. It means the processing of data into useful form without linkage with the internet, cloud or web. The connections can be between many computers but not any of those computers connected to the web.

The signal processed in this form is within the control system and the AI loop without extension to the internet. Data from sensors and inputs can be filtered, analyzed and acted upon to ensure precise control [2].

Modulation and demodulation are complementary processes to extracts the original information carrier waves; these practices are useful in control systems to transmit and receive data across networks and are pivotal in telecommunication [3].

Sampling and quantization are important. They ensure signals are converted into digital form for engineering applications. The dual process, enable the analog-to-digital conversion for the digital signal processing that facilitates the modern control systems [4].

2.1. Signal processing in online AI control loop system

The configuration in Online AI looped system is slightly different. In this case, the control system is connected to the internet, cloud or wed. There is direct communication between the AI loop with the internet and invariably with the control loop system. Data processing is online and vulnerable to intrusion and possible to cyber -attacks. This is where the risk exists for systems not well secured or protected against such attacks. Imagine an attacker, an enemy penetrating the nuclear plant linked to AI online control system. If the security of the system fails, it can turn out t be a simply route for military attacks. It can also open a dangerous window for ventures or fame seekers to attack plants or industries of developed and developing countries.

With this, the 5G signal processing can be deployed to commit such havocs. The expansion of 5G will further enhance the capabilities and applications of online signal processing in control systems [8-11].

Expert System: is a computer program created to simulate human judgment. The computer programme applies AI techniques to solve problems in a particular field that requires human knowledge [12]. The applications area include: robotics, fuzzy logic, neural networks [13-20]].

The neural network can be single layer feed forward, multilayer feed forward or recurrent networks. [13] showed how AI based control-loop control system design can be implemented. Figure 3 presents a block diagram for this function.

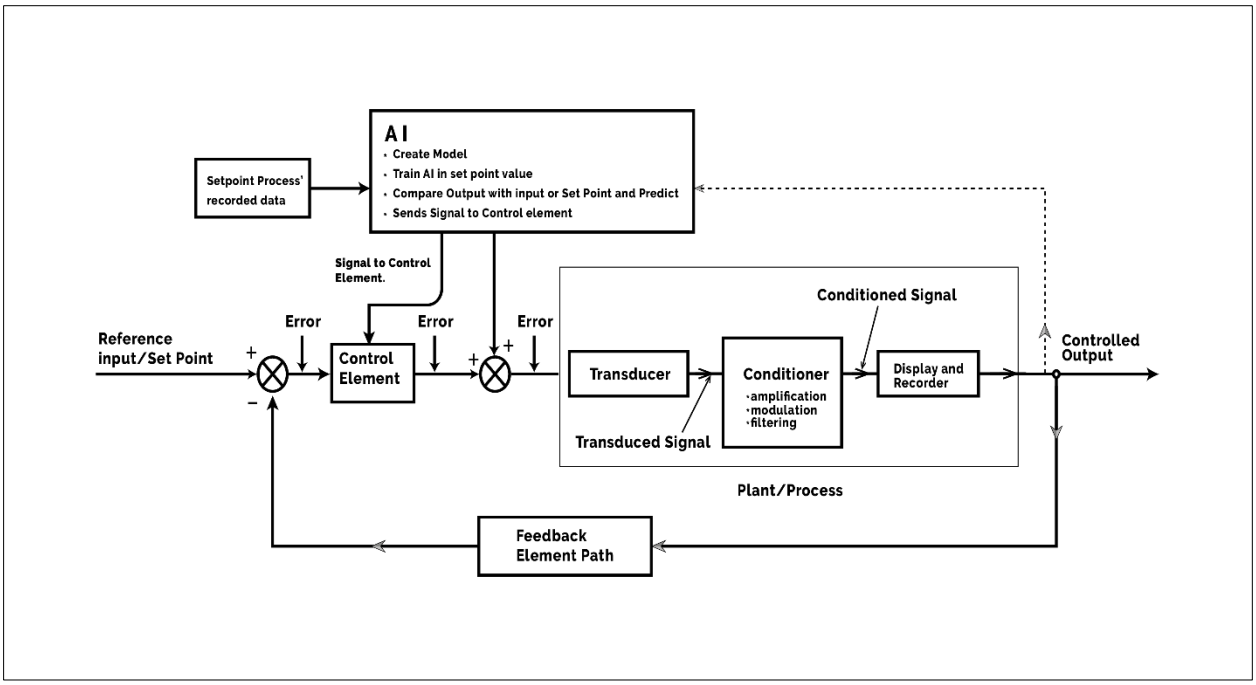

Figure 3 Offline AI-Based Closed-Loop Signal Processing Path [13]

Figure 4 shows a representation for online AI application.

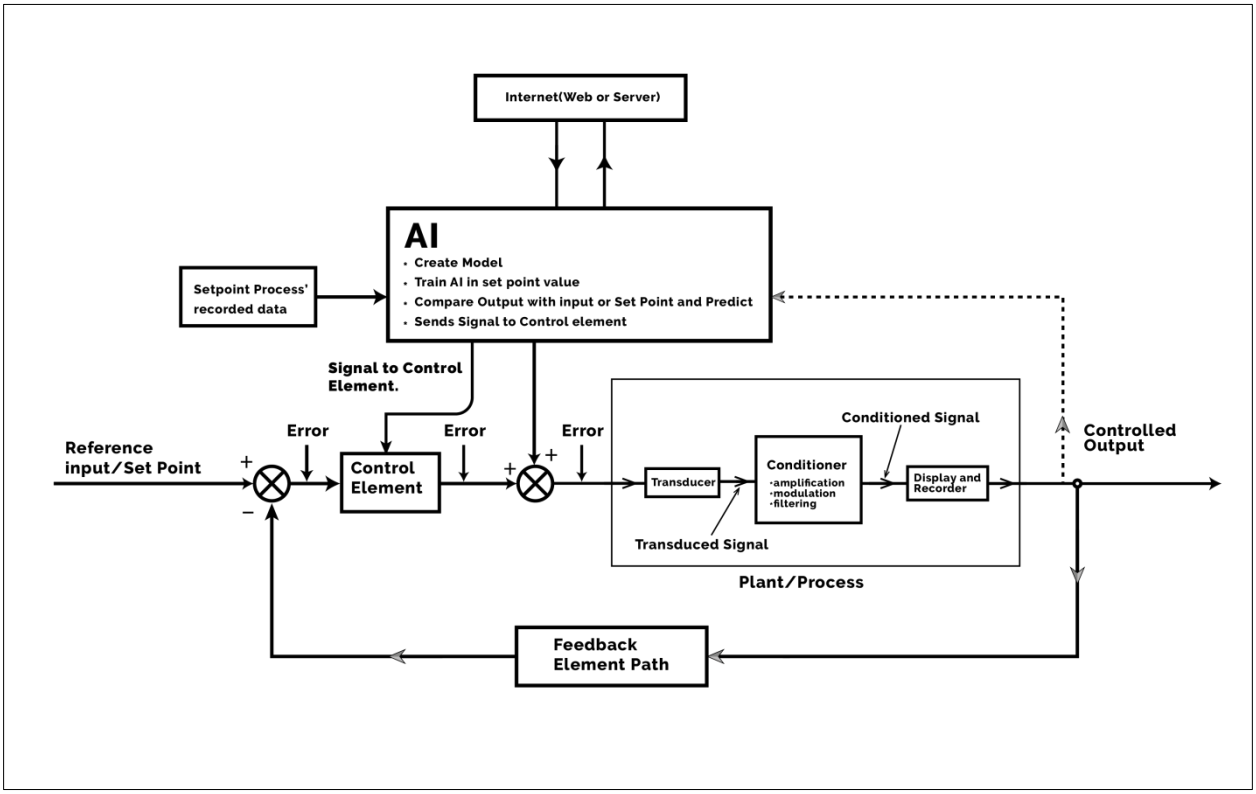

Figure 4 Online AI-Based Closed-Loop Signal Processing Path

3. Conclusion

Offline and online artificial intelligence closed-loop system applications are capable to improve operations in industries. A clear-cut analysis is needed to be carried before making a choice of the type of method to be adopted. Privacy and

security are important as well as versatility, ease, speed, cost and high performance. A pair wise comparative analysis can provide the lee-way for Engineers and Scientists to decide on appropriate method at all times for different situations. A mid-train can be obtained; where operation can be shifted from offline to online and vice versa depending on the needs.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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