Integration of IoT in mechatronic systems : Enhancing Efficiency and Automation

Master's thesis in
Mechatronics Engineering

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Abstract: This synthesis article explores the impact of integrating IoT (Internet of Things) in mechatronic systems to augment automation and efficiency. The paper delves on the relation between iot and mechanical aspect of mechatronics and the facing challenges, also examines the major impact done by IIOT (industrial internet of things) so far by not only introducing theoretical aspect but different practical industry implementations and examples. The article explores of iot in mechatronic systems, outlining how these innovations enhance connectivity and communication between devices. It particularly highlights the integration of IoT for predictive maintenance strategies, illustrating how wireless communication and real time monitoring can give preemptive problems solving. Through a systematic collected analysis of IIot's impact, the article emphasises the idea of more adoption of these technologies into the industry globally and mechatronic systems particularly.

Key-Words: IoT,IIoT, Mechatronics,Data processing ,Real-time monitoring,Wireless communication .

Contents

1. Introduction

The integration of IoT in mechatronic devices is transforming industrial processes by connecting and making machines and devices intelligent, this integration process offers new possibilities for improving efficiency[1], monitoring, and automating industrial processes , By connecting smart devices and sensors enhance data acquisition , enabling real-time insights when combined with mechatronic systems that integrate mechanical , electronic , and control engineering principles , this connectivity can empowers industries to gather and analyze data to optimize decision-making processes ,enhance predictive maintenance strategies, and improve overall operational efficiency , The paper focuses on the relationship between IoT and mechatronics systems, future challenges, and how to improve the efficiency and productivity of IoT and mechatronics systems in industry. Despite the promising of enhanced efficiency and automation , integrating IoT and mechatronics into industry process can face complex challenges like : safety , cyber threats and the harmony of workforce between both mechanical and digital fields , these are all obstacles that require to be managed carefully in this article we aim to provide insights into the future of combining IoT and mechatronic systems and how we can manage the potential risks in order to get a more efficient and automated processes .

2. Data processing

In data processing we recognise different ways to gather and transform data depending on the industry sector, as an example IIoT have been applied in batteries for energy sectors that data processing and gathering can take a major role in designing a platform to plan an IoT application . As an example, an IoT platform that has been designed for controlling cooling, heating, and air conditioning (HVAC) in a place needs to use appropriate communication technology and related environmental sensor , the showing figure1 represents the cycle of data gathering, transfer, and processing [2] .

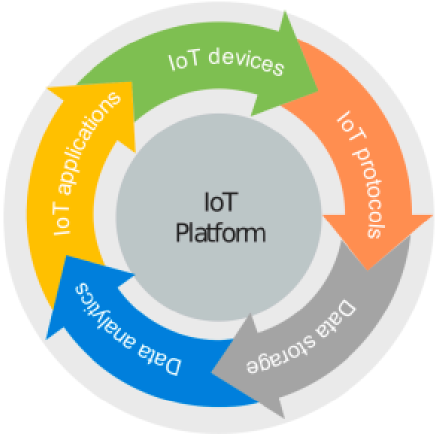

Figure 1: The IoT platform constituents.

as we can see here [3] in an experimental setup of IoT node installed at a Diesel Generator (DG) unit , The main objective of this experimental work is to identify and analyze various DG parameters for optimizing efficiency , one of the main steps of the experiment is to do real-time data collection using IoT nodes and smart fuel sensors for the analysis of diesel consumption , Coolant Temperature (CT), Engine Speed (ES), Fuel Level (FL), Oil Pressure (OP), Battery Voltage (BV), Voltage (V), Current (I) generated and Frequency (F), etc. are acquired from the DG using the GPRS TraDe unit such as its shown in 2.

Table 2 Real-time DG parameters acquired using IoT Device.

Sl. No.	CT (°C)	ES (RPM)	BV (Volt)	FL (Liter)	V (Volt)	I (Amp.)	F (Hz)	P (Pa)	DG Status
1.	30	1498	12.6	273.093	409	2.1	46.67	51	ON
2.	33	1503	12.5	271.44	414	2.2	50	51	ON
3.	36	1499	12.5	271.411	414	3.1	49.9	50.3	ON
4.	32	0	12.8	271.411	0	0	0	0	OFF
5.	32	0	12.8	271.411	0	0	0	0	OFF
6.	31	0	12.9	271.411	0	0	0	0	OFF
7.	30	1498	12.6	269.12	409	3.6	49.9	51	ON
8.	34	1503	12.5	269.062	414	3.8	49.8	51	ON
9.	39	1499	12.5	269.004	414	3.7	50	50.3	ON

Figure 2: Table of Real-time DG parameters acquired using IoT Device..

The data can be processed by intelligent algorithms, thus making it possible to make quick and precise decisions regarding the maturity of the fruits. Harvesting machines can be programmed to specifically target ripe fruit, thus improving the overall efficiency of the harvesting process. In addition, IoT will facilitate communication between the different components of the agricultural system, enabling more efficient coordination of logistics, inventory management, and crop planning.[4]
This global integration will contribute to a more intelligent and sustainable management of the entire agricultural process.In summary, the future use of IoT in selective fruit harvesting promises to bring significant improvements, both in terms of operational efficiency and quality of harvested products[5]

3. the intersection between the mechanical components of Mechatronics and IIoT

One of the primary challenges confronted by mechanical systems is the unpredictability of component failures adding a layer of complexity,Internet of Things—The future or end of mechatronics"[4] argues that many intelligent components related to the Internet of Things will be mechatronic in nature and will be built according to the traditional model of layered interaction with the physical world. This model takes into account controllers for mechatronic components that pass through sensors and actuators with controlled physical units. However, in order to integrate traditional mechatronic components into an IoT-based industrial environment, a software layer above them is needed to interface their traditional Convert to an IoT-compliant interface. also in a mechanical perspective the sensors, actuators and harsh environments can also be a considerable obstacle but with implementing advanced sensor technologies and choosing a robust design and material, also because most modern industrial machines use both mechanical and electronic systems to operate. As a result, regular maintenance of large industrial devices is essential to avoid concerns such as decreased productivity [3] .as a practical example enhancing fuzzy details based on digital image processing of monitoring screen of mechanical manufacturing equipment will appear fuzzy problems ,which will affect the monitoring of equipment manufacturing process , therefor in this design digital image processing technology is adopted to enhance the fuzzy details of the monitoring image , set up the Plc control module to sharpen the fuzzy outline of the image , according to the shape of the image ,this process combines the Toggle operator and the Top-hat operator to achieve sharpening on the basis of ensuring the fuzzy details are not ignored , the figure 3 bellow showing the image after sharpening.

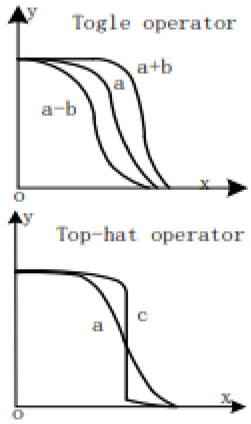

Figure 3: Schematic diagram of sharpening treatement

4. Impacts and Advantages of IIoT in Mechatronics

The major impact of IIoT(Industrial internet of things) is that simply smart machines are better than humans at accurately, consistently capturing and communicating data. Further, these data can be used for empowering organizations to complete the task in lesser time, solve the problems, save money and support business intelligence efforts [6]. The concept behind IIoT is to enhance maintenance convenience and reliability through the utilization of cost-effective Condition Monitoring Systems (CMS) and Industry 4.0 technologies. This approach encompasses three main components: the creation of an experimental setup, the development of an IIoT-based Condition Monitoring Application (CMA), and the evaluation of Machine Learning (ML) models . this research found that there are three major dimensions of IIot in the manufacturing activities the first one is visibility into the field operations and shop floor, visibility in the supply chain of manufacturing unit. The third dimension is visibility into the outsourced and remote operations .

5. IOT applications in mechatronic devices

Addressing machine failures is one of the aspects of iot in mechatronic devices, as its exemplified in Laxmi Prasanna's work where the author address to the issue of catching machine failure before occurrence, so The work utilized the LabVIEW software to monitor the condition of PV solar cells. An array of four PV solar panels interfaced with a bespoke LabVIEW application, which communicated to a web server through a raspberry Pi, acting as a gateway. The general parameters this system monitored included maximum power, voltage, current, efficiency, irradiance, temperature and so forth. Like the alerting mechanism in the current project [7]. The identification of industrial faulted situations and defects accurately mechatronic devices needs data processing of the sub-system and extracting features from measurements across the kinematic linkage. Through a dynamic model, it integrates data from internal and external sensors, considering factors like resolution and processing time.[6].

Another solution have been study made in Algeria adopted an appropriate approach to the specificity of the product, stale bread, the area, and the country. The solution framework is based on wireless sensor nodes connected to the intelligent bins manager with a monitoring station by sending the bins filling level status for analysis and control of waste. This solution involves the following features:

-Optimal fill level setting
- Check bin status
- Notifications
- Reports

encouraging the recycling of stale bread to minimize the cost of importing soft wheat and valorize it for farmers[8]

Figure 4: Architecture of the proposed system. [8]

Several applications can be used for the visualization and manipulation of the data of an IoT application. For the online platform, we use Grafana Cloud, an open-source platform for querying, visualizing, and alerting metrics and logs, wherever they live. The navigation of the website is intuitive and easy for the user to use. The platform also allows setting the framing and the start and end time to show the later graphics. [9]

In industrial automation IoT networks and mechatronic systems are managed and monitored through various interfaces, including human-machine interface (HMI) panels industrial, which are physical interfaces

typically located in industrial environments. They offer operators a user-friendly and tactile way to interact

with and control electromechanical systems. These panels typically feature displays, buttons, and other

controls for seamless navigation. [10]

6. integration architecture

For the integration of this mechatronic system into the IoT-based industrial automation environment, a software layer is essential. This layer acts as an intermediary over the mechatronic system, converting its conventional interface into an IoT-compliant interface. This intermediate layer, called IoTwrapper, plays a crucial role in facilitating communication and interaction between the mechatronic component and the wider IoT ecosystem. By offering this compatibility, IoTwrapper enables seamless integration, allowing the mechatronic component to contribute to the connected, data-driven industrial automation environment[11] une autre architecture proposé pour les robots [12] y compris les composants de l'architecture sont:

1.Un annuaire pour les robots et les objetsconnectés qui va permettre la recherche par nomou identifiant.

2.Un annuaire des services proposésavec ledétail des contraintes etdesconditions initiales.

3.Un langage de communication commun.

4.Un système multi-protocole pourl'acheminement de l'informationentres lesdifférents objets.

5.Un annuaire des problèmes et leurs solutions par IAD et systèmes experts.

7. iot and predective maintenance

IoT plays a crucial role in predictive maintenance by continuously monitoring equipment and machinery, As we mentioned before that [3] discussed the implementation of iot in conditioning monitoring also the concept of predictive maintenance for the Diesel Generator as we can see in the dataset shown in figure 6 contains a small set of entire real-time parameters considered in the proposed analysis technique. The DG status implies the running condition of the generator at a particular instance. These data points are helpful to establish individual mathematics models for the estimation of performance parameters such as the Rate of fuel consumption (liter/min), Rate of decrease of coolant temperature (C/min), Rate of decrease of battery voltage (V/min) and Rate of change of oil pressure (Pa/min). The results and analysis of the proposed predictive maintenance model are discussed in the subsequent section of the article. This paper's findings contribute to the advancement of maintenance strategies, offering insights for effective management and performance.

Table 1 Additional significant DG parameters and sensing principles.

Sl. No.	Other Important Parameters	Type of Principle for Sensing
1.	Particulate Matter (PM)	Quantitative chemical analysis (Gravimetric method)
2.	Sulphur Dioxide (SO_2)	Electrochemical principle (Barium Perchlorate/Thorin titration indicator)
3.	Oxides of Nitrogen (NO_x)	Non-Dispersive IR (NDIR), Non-Dispersive UV (NDUV), Chemiluminescence (high-temperature device for continuous measurement)
4.	Carbon Monoxide (CO)	NDIR
5.	Oxygen (O_2)	Paramagnetic measurement (Electrochemical principle)
6.	Non-Methane Hydro-Carbon (NMHC)	Gas Chromatograph type measurement (Flame Ionisation Detector – FID)
7.	Engine Vibration	Vibration sensor (Piezoelectric type devices, or Accelerometers)
8.	Noise level	Micro Electro Mechanical System (MEMS) type microphones
9.	Engine temperature	Temperature sensors (Resistive, or Optical type principle)

Figure 5: Table of Additional significant DG parameters and sensing principles.

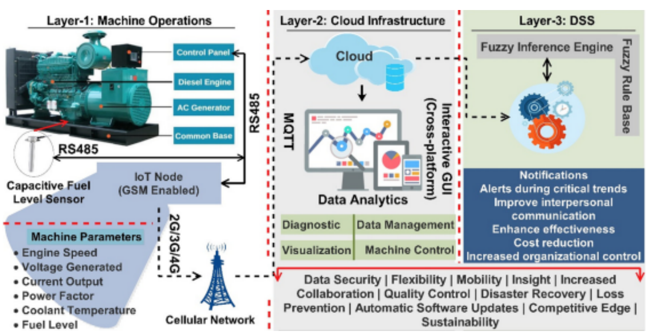

Figure 6: A 3-layer design for the IoT-enabled CMS for DG monitoring and predictive analysis .

8. Real time monitoring and wireless communication between devices

The integration of IoT in mechatronic devices can have a major positive effect on the real time monitoring where these devices can have more enhanced feedback performance, status, and operational metrics. as discussed in this article [2]where the studies have shown promising results to use wireless sensors in an in-vehicle communication system. It can connect around 65,000 devices/cells in the same period, such as monitoring vehicle body fit and communicating with other vehicles. Also the author of this article [6] have introduced another aspect of wireless communication between devices which is logistics and supply chain where he talked about how can products, materials and equipment can be tracked using real-time supply chain information and also can be equipped with position trackers such as GPS and auto identification tags such. All this equipment can play a major role in acquiring information, analyses it and make an optimized decision to achieve more facilitated on-time delivery report to manufacturer, reducing the potential capital expenditure and cost of inventory.

In the analysis of the state-of-the-art of the solved problem, we focused on searching scientific works and existing solutions in the subject field. The found projects showed the possibilities of using augmented or mixed reality for control and monitoring of mechatronic systems within the IoT networks. Another important aspect considered was whether a project was developed using open source code, and whether it was put into practice.

9. integration challenges futures

Integrating IoT into mechatronic systems comes with its set of challenges, including issues such as the absence of a completely wireless setup, larger mechanical dimensions, and limited storage for logs in keys. To tackle these challenges, the ePRO 1.4 system introduces innovative solutions.[13]

like for example Developing MineBot posed several challenges, including integrating teleoperation opensource technologies, designing a robust mechanical structure, implementing an intuitive user interface, ensuring precise navigation control, and integrating environmental monitoring systems with an IoT platform, but the team at Ricardo Palma University's Mechatronics Laboratory adopted a systematic approach. They began by conducting extensive research on existing teleoperation technologies and open-source solutions to identify the most suitable components for MineBot's teleoperation system. They then focused on designing a robust mechanical structure that could withstand the harsh conditions of underground mines while providing the necessary flexibility for exploration.

For the user interface, the team applied user experience design principles to create an intuitive and easy-to-use interface that would allow operators to control MineBot effectively. They also developed a sophisticated navigation control system using advanced algorithms to ensure MineBot could navigate complex underground environments accurately.

Furthermore, the team integrated environmental monitoring systems into MineBot, including sensors for detecting chemical, physical, and biological agents. These sensors were connected to an IoT platform, allowing real-time data storage and analysis to ensure the safety of mine workers.

Overall, through a combination of innovative design, meticulous planning, and collaborative effort, the team successfully overcame the challenges posed by developing MineBot, creating a reliable and efficient robotic solution for underground mine exploration and safety.[14]

10. Conclusions

In conclusion , adding IoT to mechatronic devices can face different challenges such as handling data to connecting wirelessly but as technology continues to advance, finding innovative ways to navigate these challenges will be instrumental in unlocking the full spectrum of benefits that IoT can offer efficiency and connectivity in mechatronic systems.

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