DOI: https://doi.org/10.46632/dmfar/1/1/2

Design, Modelling and Fabrication of Advanced Robots
Vol: 1(1), 2022
REST Publisher; ISBN: 978-81-948459-3-5
Website: http://restpublisher.com/book-series/design-modelling-and-fabrication-of-advanced-robots/

Survey on Artificial Intelligence Based Autonomous Inspection Systems for an Industry 4.0

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Abstract. The main idea of this project is to inspect the manufactured component through machine vision system .Through this project mainly the dimension correctness of the manufactured component is tested .The aim of the project is to improve the quality of the product .The various parts of the automatic inspection machine includes conveyors ,test table ,inspection camera, rejection bin ,image processing unit, monitoring system .Firstly, the specimen to be inspected is taken to the rotating test table by means of a conveyors .Then the inspection camera's detect the specimen under study on the rotating test table and the image of the specimen is captured by the camera and taken for further processing .The image is processed in terms of pixels by the image processing system. The generated image of the specimen is compared with the standard specimen by the image processing system and the result of inspection is projected on the monitoring system. The rejected specimen is automatically taken to the rejection bin by means of nozzle systems. This process is again repeated for every specimen. The overall setup of the machine is bridge type so it could be possible to inspect more than one work piece at a time.

1. Introduction

Quality inspection is one of the key aspects of the product development phase The Artificial Intelligence based inspection machine is used for the automatically inspect the manufactured product and ensure the dimensional correctness of the product. This project is based on various literature studies. The supply of defect-free, high-quality products is an important success factor for the long-term competitiveness of manufacturing companies. Despite the increasing challenges of rising product variety and complexity and the necessity of economic manufacturing, a comprehensive and reliable quality inspection is often indispensable. In consequence, high inspection volumes turn inspection processes into manufacturing bottlenecks. This technology involved in the use of various technologies like machine learning and cloud technologies. A holistic approach was proposed which included the processing the image, image enhancement, target-oriented data acquisition and processing, modelling and model deployment as well as the technological implementation. A real industrial use case in SMT manufacturing is presented to underline the procedure and benefits of the proposed method. The results show that by employing the proposed method, inspection volumes can be reduced significantly and thus economic advantages can be generated. As a result of increasing competitive pressure, the supply of high-quality products continues to evolve as an important competitive factor to secure the long-term success of a company. In order to guarantee the delivery and transfer of zero-defect products, it is essential to ensure a constantly high quality for all products. Additionally, in the ever-growing personalization paradigm, the number of variants and thus the complexity of inspection planning and operation increase tremendously. The design of inspection processes is therefore an extremely important and economically critical procedure, which requires the application of the latest and most sophisticated technologies. In the era of Industry 4.0, appliances are enabled to bring benefits, including personalization, prediction, energy savings, defect reductions, and quality improvement. Industry 4.0 denotes the trend towards automation and data exchange in manufacturing technologies and processes, including Cyber-Physical Systems (CPS), the Internet of Things (IoT), cloud computing, and Artificial Intelligence (AI) CPS constitute a new generation of systems with integrated computational and physical capabilities that enable the interaction with humans through new modalities. The IoT is designated a key enabler for the next generation of advanced manufacturing, describing the technologies of a global infrastructure which allows to connect physical and virtual objects through information and communication technologies (ICT). Non-destructive testing is mostly used in the industry, among them the visual-based approach for fault detection is one of the most common procedures. Images captured by the camera or processed by a neural network, which is trained to detect and localize the defect. Once the visual inspection system is confident about type of problem and its location, it follows the pre-set instructions like sending a notification or executing other operations. In production of juice bottles during production bottles can get damaged which can lead to additional cost, problems whiletransportation which ultimatelycausestrouble for the company. Visual inspection system based on the computer vision model detects this mismatch and notifies us in real time so that the defective piece can be excluded before they reach the final packaging stage. This system is very helpful when it comes to safety of factory worker, it can be used to detect whether the person is wearing its safety measures like gloves, helmet, goggles, shoes. The neural network system is able to analyses this by monitoring cameras and then they notify about the violation. The training of neutral system is a

important aspect in the process of inspection. A trained neural network provides igh inspection accuracy. The network can be trained with many images of different objects. The network of neural system depends on the task image specification objectdetection or semantic segmentation pending on how precisely we would like to detect defect. Define the task and train the network so as to detect any deviations from the standard appearance Not only on the part of inspection but Artificial intelligence based inspection has its applications on road safety inspection as well.Research on damage detection of road surfaces using image processing techniques has been actively conducted, achieving considerably high detection accuracies. Many studies only focus on the detection of the presence or absence of damage. However, in a real-world scenario, when the road managers from a governing body need to repair such damage, they need to clearly understand the type of damage in order to take effective action. In addition, in many of these previous studies, the researchers acquire their own data using different methods. Hence, there is no uniform road damage dataset available openly, leading to the absence of a benchmark for road damage detection. This study makes three contributions to address these issues. First, to the best of our knowledge, for the first time, a large-scale road damage dataset is prepared. This dataset is composed of 9,053 road damage images captured with a smartphone installed on a car, with 15,435 instances of road surface damage included in these road images. In order to generate this dataset, a study with 7 municipalities in Japan and acquired road images for more than 40 hours. These images were captured in a wide variety of weather and illuminance conditions. In each image, an annotation like bounding box representing the location and type of damage. Next, we used a state-of-the-art object detection method using convolutional neural networks to train the damage detection model with our dataset, and compared the accuracy and runtime speed on both, using a GPU server and a smartphone. Finally, a demonstrates the type of damage can be classified into eight types with high accuracy by applying the proposed object detection method. The road damage dataset, our experimental results, and the developed smartphone application used in this study are publicly available.

FIGURE 1. Automated Bottle Inspection Machine

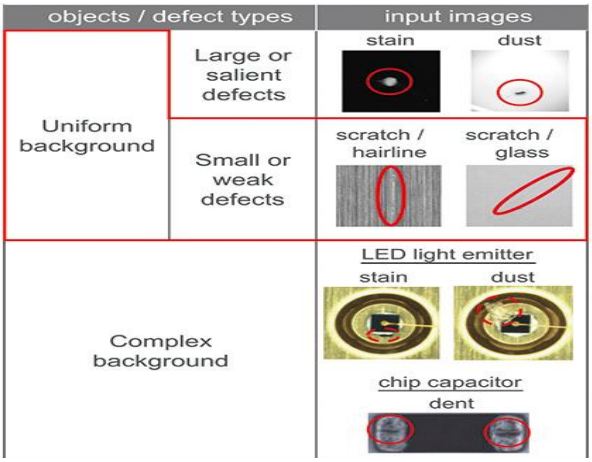

FIGURE 2. Captured image of the manufactured product by machine vision system

2. Literature Reviews

SI.NO	TITLE	AUTHOR'S	YEAR	INFERENCE
1.	Road Damage Inspection	Hiroya Maeda ,YoshihideSekimeto ,Toshikazu Seto ,Takehiro Kashiyama ,Hiroshi Omata .	January 2018	They propose the usage of AI for inspection of roads to ensure the road safety due to various factors. using a state-of-the-art object detection method using convolutional neural networks to train the damage detection model with the dataset, and compared the accuracy and runtime speed on both, using a GPU server and smartphone.
2.	AI Inspection: Computer Vision For Visual Inspection	AmrutaMohite ,Atherva Kulkarni ,RutwikChithis ,Swapnil Mane ,ShubhamAsabe.	January 2021	The review paper explains about computer based visual inspection, comparison between human and computer vison system, its development, improvements and applications.
3.	Inspection machine defect detection based on deep learning	HanzawaYuki,Ikeda YasuyukiKiruta ,Manashi ,Hasiwaga Yuki .	October 2021	This paper explains us about training neural networks with help of images of defects .It uses machine learning and Artificial intelligence that imitates the way humans gain certain knowledge.

4.	Inspection machine based on Machine learning and cloud computing	JochenBoing ,ThorbjornBorggrafe ,GunterBeitinger ,JochenDeuse .	OMRON TECHNICS Vol.51 September 2019.	A pre-training type defect-detection algorithm that could handle a variety of objects and defect types. Through the proposed method, we verified that the algorithm could also handle objects and defects with unknown patterns.
5.	Special purpose Inspection Machine	AB Plastomech, Bangalore.	Advanced Engineering Informatics, 2020	This Artificial Intelligence based inspection machine uses bowl feeder to take the test specimen to rotating test table .The machine vision camera captures the image of specimen and based on the results the defect is automatically rejected.
6.	3D defect detection using photometric stereo illusion	Jong Hyuk Lee , Hyum Min On ,Min Young Kim .	International Conference on Artificial Intelligence 2019	The 3D defect inspection involves the use of laser sensors to ensure 3Dimensional inspection of the work piece and also the use of photometric stereo illusion systems.
7.	Quality control inspection opportunities using deep learning	VladimirsSatrevics ,GundarsKulikovskis ,Oskars Oss.	24th World Multi conference on Systematics Cybernets and Informatics 2020	To meet industry standard quality inspectors in manufacturing firms inspect product quality usually after the product is manufactured in order to reduce time consuming inspection.
8.	Fracture detection using machine vision and neural network	Sarthak J Shetty.	January 2019	They propose the usage of Opens an open source computer vision framework developed by Google.to accomplish the task of detection and prediction of presence of surface defects such as fracture of gears
9.	Machine Vision application in Industrial application	Diego Gonzales.	January 2021	They propose that machine vision is the technology used to provide imaging based automatic inspection and analysis for such application as automatic inspection, process control and robot guidance.
10.	Automatic Inspection System using machine vision	U.S.Khan ,M.A.Khan ,J.Iqbal.	34th Applied Imagery and pattern Recognition Workshop	Machine vision system integrated electronic components with software systems to imitate a variety of human functions. The technique discussed in this paper inspects on basic pixel level image processing.
11.	Bone fracture Detection and Classification using deep learning	D.P. Yadav, Sandeep Rathor	2020 International Conference on Power Electronics &IoT Applications in Renewable Energy and its Control (PARC) Feb. 2020	The fracture in bone mainly occurs due to bad fall. The usage of MRI and X-rays. The purpose of the project is to involving neural network technology to detect and monitor cracks in bones a deep neural network model has been developed to classify the fracture and healthy bone has been proposed.
12.	Bone Fracture detection using ML and Digital Geometry.	Ashosh Sharma, Abisek Mishra, Aashi Bansal	September 2021	The usage of orthopedic X-ray imaging for bone fracture detection and deployment of Machine learning techniques to detect and cure bone fractures.
13.	Intelligent Machine Vision Model for Defective Product Inspection Based on Machine Learning	TajeddineBenbararrad, MarouaneSalhoui,SoukainaBakhatKenitar	J. Sens. Actuator Netw. 2021	The proposed model in exploits all generated data by various integrated technologies in the manufacturing chain, suggesting two types of algorithms and method based identification

14.	AI based sensors for Forest Fires detection and AI based systems for Stopping the Spread	Nidhika Yadav	September 2021	The proposed paper suggests the usage of the machine vision system for the detection of forest fires and extinguishing it by the help of gray scale imaging .
15.	AI-based Automatic Optical Inspection of Glass Bubble Defects	Jing wien , Chiang wang ,Chiehcheng	MSIE April 2020	The work that for the detection of bubble defects in spherical glass, the lighting mechanism, the image acquisition method, as well as the detection algorithm, must be designed together to achieve a high accuracy performance. The initial experimental results validate the feasibility of the proposed AOI method with an accuracy of 95%.
16.	A Large-scale, High-quality Dataset for Object Detection	Shuai shao , Zeming Li , Tianyuan Zhang , Chao peng .	2019 IEEE/CVF International Conference on Computer Vision	In this paper, we present a large-scale, high-quality object detection dataset, Objects365, which establishes a new challenge and benefits the many existing localization sensitive vision tasks. In the future, we plan to investigate bigger models than ResNet-50.
17.	Survey on Deep Learning-Based Marine Object Detection	Ruolan Zhang , Shaoxi Li , Guanfeng Ji, Jing Li	November 2021	This survey covers most of the application scenarios of object detection for maritime surveillance and autonomous ship navigation. In recent years, a large number of marine object detection models based on deep learning have been proposed, but due to the lack of universal evaluation criteria, it is difficult to compare different improved models.
18.	Particle shape analysis of coarse aggregate using digital image processing	A.K.H. Kwan, C.F. Mora, H.C. Chan	October 1998	Although the thickness and volume of the particles are not measured, this DIP method is capable of producing the mean thickness/breadth ratio of the aggregate and shape measurement results in terms of mass fractions. For the purpose of verification, the shape measurement results obtained by the proposed DIP method have been compared to those obtained by traditional mechanical sieving and manual gauging.
19.	Particle Shape Analysis as an Example of Knowledge Extraction by Neural Nets	ReinhardKohlus, Michael Bottlinger	April 1993	In technical problems which are concerned with the extraction of features such as particle shape analysis, neural nets might be an appropriate way to determine the relationship between data and effect. As shown by the example of particle shape analysis, unsupervised learning networks such as self-organizing maps or adaptive resonance theory (ART) networks can be very useful.
20.	Particle shape analysis of tailings using digital image processing	Yonghao yang ,Zuoan Wei , Andy Fourier ,Yulong Chen .	July 2019	The paper suggests the elongation of tailings decreases with the increment of the particle size, which means the shape of tailings tends to be needle-like or columnar with the decreases of particle size. The elongation of sea sand shows a similar pattern of variation law.
21.	R-CNN-Based Large-Scale Object-Defect Inspection System for Laser Cutting in the Automotive Industry	DonggyunIm , JongpilJeong .	November 2021	This paper presents RODIS to perform defect inspection of large objects, such as side-outers. In particular,the lack of FoVs that resulted from the inappropriate combination of camera shutter types and lenses, and the image noise that occurs when multiple cameras are operated simultaneously, should be considered during similar research tasks.

22.	Systematic method for Machine learning and manufacturing system.	Simon , Christoper prince	53rd CIRP Conference on Manufacturing Systems	The SLR at hand analyzed the current state of the art of recent years (2015-2020) with a strong focus on actual implementations and direct naming of used machine learning algorithms in the factory environment for each literature.
23.	Automated Surface Defect Inspection Based on Autoencoders and Fully Convolutional Neural Networks	Cheng Wie, Li Zhang, Ming Tai, Yun Jie .	Appl. Sci. **2021**	The experimental results have revealed the effectiveness of the proposed algorithm for surface inspection. Only normal samples are required for the proposed algorithm. A simple data augmentation scheme is adopted for the generation of defective images for the training of the neural networks. This could facilitate the collection of a training set for the algorithm. In addition, the ability for the self-generation of the template by the AE for an input test image is beneficial for lifting the restriction on the synchronization between the position of the test image and the template.
24.	Analysis of Laser Sensors and Camera Vision in the Shoe Position Inspection System	JaromírKlarák , Ivan Kuric , Ivan Zaja˘cko , VladimírBulej , VladimírTlach and Jerzy Józwik	November 2021	In This paper, there are two methodologies of performing inspection issues for the shoe industry described. In the first case, it was the method of capturing 12 Mpx images by camera vision. These data were used to evaluate the position of the upper on the last. Evaluating was performed by processing image, edge detection, and final DBSCAN clustering, separating white pixels to edges.
25.	Machine learning applied to the design and inspection of reinforced concrete bridges: Resilient methods and emerging applications	Weiying Fan , Yao Chen , Jiaqiang Li , Yue Sun , Jian Feng a, Hany Hassanin	July 2021	This study summarized the applications of machine learning (ML) in reinforced concrete bridges, from design to inspection. It demonstrates that ML has great computing power and image processing capability for dealing with different aspects of reinforced concrete bridges. Once an ML model is trained, the prediction efficiency is significantly high. It surpasses the speed of traditional structural damage recognition and strength prediction methods, realizing nearly real-time performance.
26.	Machine learning based malicious payload identification	Qiumei Cheng , Chunming Wu , Haifeng Zhou , Dezhang Kong , Dong Zhang , Junchi Xing , Wei Ruan .	August 2021	Deep packet inspection (DPI) in software-defined networking (SDN) remains restrictions in the presence of a large volume of data. Despite third-party DPI tools, this paper proposes a novel OpenFlow-enabled deep packet inspection (OFDPI) approach in SDN using machine learning algorithms. OFDPI enables deep packet inspection for both unencrypted traffic and encrypted traffic by training two binary classifiers respectively
27.	Machine vision based control system	Aditya Akundi , Mark Reyna ,	June 2021	Quality control is a critical issue in all industries that MV systems are assisting in. The MV system proposed in this paper offers a simple setup capable of identifying defects in diverse shapes. As shown, the system could identify defects in cubes, cylinders, and sinusoidal objects Furthermore, it is essential that effective MV systems identify minute defects in objects.
28.	Exploring impact and features of machine vision for progressive industry 4.0 culture	MohdJavaid , Abid Haleem , Ravi Pratap Singh , ShanayRab , Rajiv Suman	30th October 2021	MV is the approach of industrial automation and related technology. It can be implemented for automated visual inspection, which can overcome several business problems. The technology of machine vision replaced human quality checks steadily. It offers different precision & durability in the identification of objects. MV is beneficial for Industry 4.0 to improve accuracy, productivity, and overall efficiency to increase traceability of their

				goods. Here industrial equipment uses highly faithful cameras to capture digital environmental pictures or a workpiece to utilise a computer vision system.
29.	Online quality inspection of ultrasonic composite welding by combining artificial intelligence technologies with welding process signatures	Yang Li , Bo Yu, Baicun Wang , Tae Hwa Lee, MihaelaBanu.	20 June 2020	This study investigates the prediction of the failure load and weld quality level (under weld, normal weld, and over weld) in ultrasonic CRFTP welding simultaneously using AI technologies, including ANN and RFmodels. These two models have eight common inputs (the duration and net acoustic wave energy in stages 1, 2, 3, and 4, respectively,) extracted from the process signatures. The findings of this study can contribute to the online quality inspection of ultrasonic composite welding and further aid industrial applications.
30.	Systematic literature review of validation methods for AI systems	LalliMyllyaho∗, MikkoRaatikainen, TomiMännistö, TommiMikkonen, Jukka K. Nurminen	28 July 2021	a systematic literature review on the validation methods of AI systems based on 90 primary studies. The primary studies represent 14 domains carrying out 18 tasks and their impact on malfunction ranges from nuisance to lethal, which demonstrates a wide variety and broad application of AI technologies. As our selection focused on studies with solid empirical evidence, these studies represent relatively mature practical applications rather than immature solution proposals in early-stage research. However, most of these systems applied ML
31.	Survey Paper on Visual Inspection of a Mechanical Part using Machine Learning	Priya Charles , Simrangupta ,NirajBhodhoria	January 2020	A non-contact visual inspection system with minimum manual intervention. Flexible over wide range of products and their defect characteristics. Supervised learning algorithm trains the model which then classifies the input image into given classes. The output can lead to re-machining, rejection or acceptance of machinery part. The automated visual inspection is consistent and precise, leading to an increase in quality assurance factor.
32.	Survey on identifying Artificial intelligence for Field application	Bernd Kuhlencotter	52rd CIRP Conference on Manufacturing Systems	The fact that unsupervised methods are only mentioned twice might be due to the fact, that the actual data preparation and exploration were not described as detailed as the implemented regression or classification task in many publications. The authors are of the opinion that way more implementations make use of unsupervised methods along the whole data analysis pipeline even though they are not mentioned explicitly.
33.	QoS aware Traffic Classification Architecture	Yuxiang Hu ,JiachoXie .	8th International conference on Communication system	In this paper, they propose a SDN flow classification architecture based on DPI and semi-supervised learning of multi-classifier. Subsequently, we test the performance and verify the superiority of the proposed architecture with realistic network traffic data. Architecture can implement efficient traffic classification with high accurate .

34.	Legal aspects of data cleansing in medical AI	Karl Stöger, David Schneebergerb , Peter Kieseberg , Andreas Holzinger	September 2019	In this paper, we motivate, demonstrate, and justify why data cleaning is important for the quality and safety of medical AI systems and should not be underestimated from either a technical or legal perspective. Data cleansing (of training data) is not only a technical issue, but also a legal one. In any case, in the domain of AI and especially Medical AI, the two disciplines of computer science and law need to work more closely together.
35.	Artificial intelligence and machine learning for medical imaging: A technology review	Ana Barrag´an-Montero , UmairJavaid , Gilmer Vald´es , Dan Nguyen	18th April 2021	In medicine, specialties where images are central, like radiology, pathology or oncology, have seized the opportunity and considerable efforts in research and development have been deployed to transfer the potential of AI to clinical applications. With AI becoming a more mainstream tool for typical medical imaging analysis tasks, such as diagnosis, segmentation, or classification, the key for a safe and efficient use of clinical AI applications relies, in part, on informed practitioners.
36.	Artificial intelligence-empowered pipeline for image-based inspection of concrete structures	Jun Kang Chow, Zhaoyu Su, Jimmy Wu, Zhaofeng Li, Pin Siang Tan.	July 2021	In this paper, the feasibility of applying deep learning techniques in the inspection programs of civil infrastructure is reported. An AI-empowered inspection pipeline, which comprises anomaly detection, anomaly extraction and defect classification, is built to alleviate the current assessment practice, which is prone to error, laborious and time-consuming. In this approach, an anomaly map is generated to assist in the extraction of potential defects, and then the suspected defects are categorized into appropriate classes
37.	Artificial intelligence and machine learning for medical imaging: A technology review	Mats Holmstr¨om , Fredrik L¨ofman , Steven Michiels , Kevin Souris , Edmond Sterpin , John A. Lee	18th April 2021	Predictive models are trained based on historic data sets in the cloudand deployed on local edge devices. During the manufacturing process,parameters are recorded and sent to the edge device, on which data processing and model application are handled in near real time. Theprediction results are evaluated and aggregated to a processable levelallowing a dynamic inspection decision.
38.	Implementation of AI-Machine learning for Machine Safety.	Sara Anastasi ,Marianna Madonna, Luigi Monica	International conference on Industry 4,0 and Smart manufacturing.	The implementation of artificial intelligence and machine learning will lead to the intelligent machines. In particular, the analysis identified the EHSRs of the Machinery Directive which will be most influenced by the incorporation of AI/ML applications in the design of the machines, highlighting the changes needed for the Machinery Directive to guarantee safety levels for innovative products at least equivalent to the current ones.
39.	An alert-assisted inspection policy for a production process with imperfect condition signals	Alp Akcay	28th May 2021	the optimal (s, *u)* -policy, a stochastic dynamic programming model is formulated with the objective of minimizing the long-run expected cost rate. The performance improvement achieved by the optimal (s, *u)* -policy is quantified by comparing it to the benchmark policies. The economic value of adding an alert- triggered inspection option to a conventional age-based inspection policy is discussed. Quantifying the performance of the optimal (*s*, *u*) -policy at a given level of imperfectness can be used in practice to obtain the economic value of a certain level of improvement in the predictive model.

40.	AI-assistance for predictive maintenance of renewable energy systems	Won Shin , Jeongyun Han , Wonjong Rhee.	3rd January 2021	Predictive maintenance is a crucial component for the successful operation of renewable energy systems, and adopting the latest AI technology is expected to be inevitable for scaling predictive maintenance to sufficiently frequent and periodic inspections. This work, studied a representative case of bearing fault detection where endoscope images are collected for the inspection. They considered the The results show that all factors, specificity, sensitivity, and time efficiency, can be improved with AI-assistance, for both the generalist group and specialist group.

3. Conclusion

From the literature study the newly proposed AI based system was proposed with enhanced features. The Artificial intelligence based inspection also has applications in weld joints testing, internal defect analysis and even in structural analysis as well.The project has 3 types of machine setup's namely bridge type microscopic setup and the rail type setup. Initially the machine is calibrated and based on the trained cascade file the test specimen is examined and suitable lightning systems are provided to improve the quality of inspection. The proposed CAD model of the project shows the microscopic setup of the Artificial Intelligence based inspection Machine. The future scope of the project involves three dimensional inspections which can be used in automobile part inspection, involving the use of camera 's in all three dimensions and even converting the captured image into 3D models which could be processed and updated based on the requirements of the future.

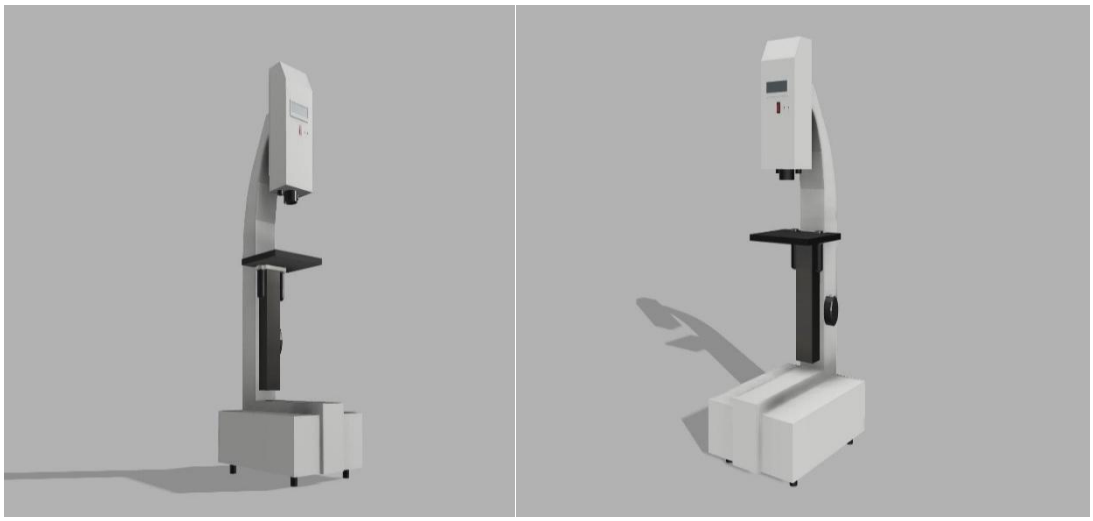

FIGURE 3. Isometric view of the proposed system

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