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Enhancing EV Charging Safety: Web-Integrated Real-Time Monitoring and Robotic Arm Solutions

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Abstract: This research paper introduces an innovative system designed to enhance the efficiency and safety of Electric Vehicle (EV) charging processes. The system integrates real-time monitoring capabilities with a robotic arm, offering a comprehensive solution to address the evolving demands of EV charging infrastructure. Battery data is securely stored in Firebase's Fire store database, facilitating instant access to crucial insights via a user-friendly interface. The robotic arm, operated through an Arduino Nano board and an Android application, mitigates safety concerns associated with manual cable handling during the charging process. By bridging the gap between users and operators, this unified system not only promotes sustainable EV usage but also significantly improves safety and charging efficiency.

Keywords: Electric Vehicle(EV);Real-time Monitoring; Web Integration; Charging Slot Management; Robotic Arm; Safety Measures; Charging Infrastructure.

1. Introduction

The current scenario witnesses a significant surge in the adoption of Electric Vehicles (EVs), marking a critical moment in the transportation sector. This surge underscores the immediate need for transformative advancements in charging infrastructure to meet the evolving demands of the EV landscape. As EV technology rapidly progresses, the focal points of charging efficiency and operational safety emerge as critical considerations. Recognizing these imperatives, this paper introduces an approach that combines real-time monitoring technology with a precisely engineered robotic arm system. The primary objective is to revolutionize safety standards, operational efficiency, and user experience within the realm of EV charging infrastructure.

The web-based component of this system of fersanintuitive interface for real-time monitoring of EV battery status. This design draws inspirationfrom[1], which focuses on electrical safety in large-scale EVcharging stations. This work utilizes insights from[2], a comparative case study on metamodel-based electric vehicle power train design. By doing so, the monitoring interface, providing EV owners with valuable information about their vehicle's healt hand charging capacity are enhanced.

The system designed in this paper integrates insights from various research studies to enhance its functionality and effectiveness in managing EV charging processes. In [3], a study on holistic web application security visualization, which serves as a foundation for ensuring secure and reliable monitoring for EV owners is considered. The authors in [4] provided valuable insights into electric drive technology trends and challenges, inspiring the integration of dynamic slot management for charging station operators. [5] contributes to the clear understanding of battery parameter monitoring and control systems for electric vehicles, influencing the management approach adopted in the system.

Furthermore, [6] focus on real-time State-of-Charge (SoC) estimation for light electric vehicles, offering advancements in range estimation and battery management. Also, the methodologies to estimate the state of charge of a battery, providing foundational knowledge for battery management systems is presented in [7].

[8] presents the in-depth analysis of SoC estimation methods for Lithium-ion batteries used in EVs. Precise SoC calculation is crucial for battery safety, performance optimization, and overall lifespan. The review covers both direct and indirect SoC estimation approaches, focused on their advantages and limitations. Understanding degradation factors that impact battery life span is essential. Therefore, modelling Lithium-ion Batteries, predicting their State of Health (SoH) and Remaining Useful life (RUL) are studied from [9].

ThefocusonchargingDecember infrastructureforCommercialElectricVehicles(CEVs) is explained in [10].AsCEVsgainprominence,addressingchargingchallengesbecomescritical.Two major chargingstrategies are reviewed (i) thereturn-to-basemodel, (ii) on-routecharging.Challengesrelatedtopublicchargingstations,temperaturefluctuations,andcharging efficiencyare also analyzed. The study also exploredthepotential of Vehicle-to-Grid technology for CEVs. In[11-12], Android application development for controlling mobile robots via Bluetooth is discussed. Their work show cases the integration of MIT App Inventor, enabling manual and automaticcontrolofa4-wheel-drive mobile robot. This innovative approach bridges robotics and mobile app development, offering practical solutions forreal-worldapplications. Dynamicmodel-basedselectioncriteriaforroboticarms are explored in [13] and [14]demonstrated Arduino-controlled roboticarms. These studies contribute to the field of robotics, emphasizing the importance of precisecontrol mechanisms for various applications.In [15], a study on the design of a controlled robotic arm was focused on optimizing mechanical components, kinematics, and actuations ystems. By addressing design challenges, such as pay load capacity, workspace ,and joint flexibility,the authors contribute to the development of efficient and reliable robotic arms.

Avariablestructuremodelforarticulatedroboticarms is proposed in [16] whichadaptstovaryingoperatingconditions,ensuringstabilityandrobustness.Byincorporatingvariablestructurecontrol,theauthorsenhancethearm'sperformanceacrossdifferenttasksandenvironments.[17] discussed mathematicalmodelingtechniquesforflexiblerobotarms.Theirfiniteelementmethod-basedapproachaccountsforarmflexibility,materialproperties,anddynamicbehavior.Suchmodelingenablesaccuratesimulationsandpredictions,aidinginarmdesignandcontrol. The brain-controlledrobotarmsusingembeddeddeeplearningfromSurfaceElectromyography(SEMG)sensors is discussed in [18].Bydecodingneuralsignals,thisinnovativeapproachallowsuserstomanipulateprostheticarmsintuitively.Thestudybridgesneuroscience,machinelearning,androbotics,offeringnewpossibilities forassistivedevices.In [19],alow-cost6-Degree-of-Freedom(6-DoF)roboticarmwithagripper is designed.Theirworkemphasizesaffordabilityandaccessibility,makingroboticarmsmoreattainable foreducationalinstitutions,researchlabs,andsmall-scaleapplications.Thestudycontributes to democratizingroboticstechnology. Mathematicalmodelingtechniquesforflexiblerobotarms are discussed in [19].Theirworkemploysthefiniteelementmethodtoanalyzearmbehaviorundervaryingloadsandconditions.By understandingflexibility and dynamic responses, designers can optimize armperformance forspecific tasks is discussed in[20].In [21], anInternet ofThings (IoT)-enabled robot-assistedsurgerysystem is proposed.ByintegratingIoTdevices,surgicalrobotsgainreal-timedataexchangecapabilities,enhancingprecision,safety,andremotecollaboration.Thisinterdisciplinaryapproachbridgesrobotics,healthcare,andcommunicationtechnologies.

Avoice-controlledroboticarmforvisuallyimpaireddisabledveterans is developed in [22].Byintegratingvoicecommands,thisassistivetechnologyallowsuserstograspobjectsintuitively.Smartphone-basedcontrolfor roboticarmsusingRaspberryPiandAndroid is explored in [23].By utilizing smartphones that are widely available and commonly used, this interdisciplinary approach streamlines user interaction and broadens the accessibility of robotic arms.In [24] worked on making a robotic arm for medical surgery. They focused on making it very precise, safe, and easy to control. By adding Bluetooth communication, surgeons can use the arm to do surgery more carefully and accurately. In [25], worked on creating a robotic arm that can be controlled wirelessly to pick and place items. An automatic robotic arm that uses Bluetooth to regulate its actions is proposed in [26]. This system helps in making industrial processes smoother by allowing for seamless control and automation. Their study contributes to Industry 4.0 technologies, where having good connectivity and adaptability is very important.

In [27] addressed the problem of obstacle avoidance in the path planning of robotic arms. They used artificial potential fields and the A* algorithm to improve safety and efficiency. Their study showed practical implications for agricultural automation, specifically in scenarios like apple picking.

In summary, the proposed system contributes to the existing literature introducing an innovative system that enhances the safety, efficiency, and user experience of electric vehicle charging processes. By integrating real-time monitoring, dynamic slot management, and robotic arm safety measures, the system addresses critical challenges in EV charging infrastructure while paving the way for future advancements in the field. The remaining sections in this paper are organized as description of the system in section 2, discussion of the results in section 3 and finally, Section 4 presents the conclusion.

2. Model of the proposed system

The description of the system beganwithanexactanalysisoftherequisiteswithintheElectricVehicle(EV)charginginfrastructure.Anin-depthassessmentisconductedtodiscernthefundamentalneedsencompassingsafety,efficiency,anduserexperience.Thisphaseculminatedinthestrategicdesignofacomprehensivesystemarchitecture,exactlyoutliningthehardware,softwarecomponents,andcommunicationprotocolsvitalfortheintegrationofreal-timemonitoringandroboticarm safetymeasures.

Figure 1 shows theblockdiagram whichoutlinesthekeycomponentsandtheirinteractionswithintheproposed system.ThislayoutdepictstheEVmodel,withbranchesleadingtothereal-timemonitoringhardware,webinterface,andAndroidapp.TheAndroidappinteractswiththereal-timemonitoringhardwareandthe roboticarmsystem, whiletheroboticarmsystemitselfisconnectedtoFirebase'sFirestoreDatabase.Theuserfeedbackloop encompassesallcomponents,indicatinganiterativeprocessofimprovementbasedonuserinput.

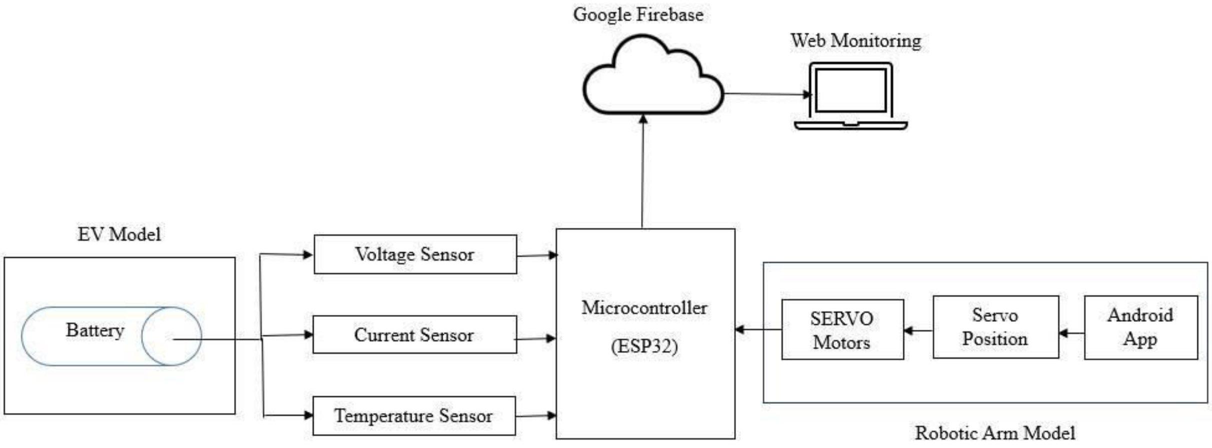


Figure1: Blockdiagram ofweb-integrated real-timemonitoringandrobotarm safetymeasuresforelectricvehiclecharging.

The following elements mainly constitute the description of the proposed system.

1. EVPrototypeModel:Theelectricvehicleprototypemodelsserveastheprimarydatasource,providingessentialbatteryparameterslikecurrent,voltage,temperature,andinformation forthe system.

2. Real-TimeMonitoringHardware:ThiscomponentinterfacesdirectlywiththeEVmodels,equippedwithsensorsandnecessaryhardwaretocollectcrucialbatteryparameterssuchascurrent, voltageandtemperature securely.
3. Firebase'sFirestoreDatabase:Actsasthecentralizeddatabaseforsecurelystoringthereal-time batterydatacollectedfrom theEVmodels viathe monitoring hardware.
4. WebInterface:Providesauser-friendlyplatformaccessibleviawebbrowsers.ItallowsEV ownersand charging station operators to accessreal-timebatterystatus(percentageofa battery) updates and other relevantinformationfrom theFirestoredatabase.
5. AndroidApp:DevelopedusingMITAppInventor,theAndroidapplicationservesasabridgebetweenusersandthesystem.Itallowsuserstointeractwithboththereal-timemonitoring hardwareandthe robotic armsystem.
6. RoboticArmSystem:ComprisedofservomotorsconnectedtoanArduinoNanoboard,this system is designed tohandle the physicalaspect of chargingcableconnections duringEVchargingoperations.ItreceivescommandsfromtheAndroidappviaBluetoothforpreciseand safeoperation.
7. UserFeedbackLoop:Thisrepresentstheiterative processof collectingfeedbackfromEVownersandchargingstationoperators.Thisfeedbackisutilizedtorefineandenhancethesystem'susabilityandefficiencyovertime.

The flowstartsfromtheEVmodels,whichprovidedatatothemonitoringhardware.ThisdataissecurelystoredinFirebase'sFirestoreDatabase.Thewebinterfaceallowsuserstoaccessthisstoreddata.Simultaneously,theAndroidappinteractswithboththereal-timemonitoringhardwareandtheroboticarmsystem,enablingusercontrolandfeedbackcollection.Theroboticarmsystem,controlledbytheapp,handlesthephysicalchargingcableconnections.Thefeedbackloopcontinuallyrefinesthesystembasedonuserinput,ensuringongoingimprovementsinusabilityandefficiency. Table 1 showstheComponentsusedinthedesignoftheElectricVehicleprototypeandcomponents specifications.

Table 1: Components Used forthe EV PrototypeModel.

Components Used	VoltageRating	CurrentRating	Temperature Rating
Lithium-IonBattery	12 volts	1.5 Ah	-
DC Motor	12 volts	25 mA	-
VoltageSensor	25 volts	-	-
Current Sensor	-	30 A	-
DHTSensor	3.5 -5.5 volts	0.3 mA	0 – 50º C

2.1 Determination of State ofCharge(SoC) of a Battery

TheCoulombcountingmethod,alsoknownastheAmpere-HourIntegralmethod,isawidelyusedtechniqueforestimatingtheSoCofabattery.Thismethodisbasedonintegratingthecurrentflowingintooroutofthebatteryovertime,essentiallykeepingtrackofthetotalelectricchargethathasbeentransferred.ThecurrentsensorofabatteryofanEVprototypesensesthecurrent flowing into or out of the battery ofan EVprototype.

CoulombcountinggivesarelativechangeinSoCandnotanabsoluteSoC.IfyoumeasurethecurrentoveragiventimestepyouhaveameasureofthenumberofAhthathaveleftorbeenreceived by the battery.TheStateof Chargeis thencalculated using thefollowing expression:

$$SoC(t) = SoC(t - 1) + (I(t)/Qn)\,\Delta t$$

Where SoC(t)= estimated Stateof Chargeattime, t,
SoC(t-1) = previous Stateof Chargeat timet-1,
I(t) =charging ordischarging current at time t,
Q_n= batterycell capacity and
Δt =time stepbetweent-1 and t.

TheSoCofabatterycellisrequiredtomaintainitssafeoperationandlifetimeduringcharge,discharge,andstorage.However,SoCcannotbemeasureddirectlyandisestimatedfromothermeasurementsandknownparameters.ThisleadstoerrorsintheestimatedSoCandthat means it is not possible to fullyexploit thefull capability of thecell.

2.2 Design of Real-Time Monitoring System

The functional representation of the real time monitoring system for EV with web integration is shown in figure2. It involvesacomprehensivesystemdesignedtocollect,process,andpresentreal-timedatafromvarioussources,accessiblethroughawebinterface.ThissystemisespeciallypertinentindomainslikeElectricVehicle(EV)charging stations, industrial monitoring, healthcare,andmore.

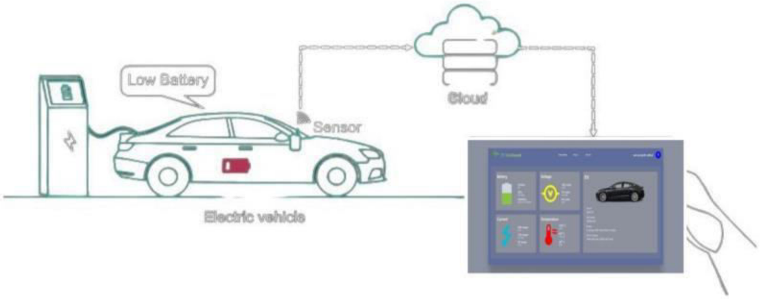


Figure2:FunctionalRepresentation of real-timemonitoring system forEVwith webintegration.

The various steps involved in the design of the real time monitoring system are outlined as follows:

i. DataCollection:Thesystemtypicallyincorporatesspecializedhardwareequippedwithsensorsorinterfacescapableofgatheringreal-timedata.InthecontextofEVcharging,thiscouldinvolvecollectingbatteryparameters,chargingstatus,orenergyconsumptiondatadirectly from the EVmodels or charging stations.

ii. DataProcessingandStorage:Oncecollected,thedataisprocessedandsecurelystoredinadatabase.TechnologieslikeFirebase'sFirestoreDatabaseorsimilarplatformsfacilitatesecureand scalablestorage, enablingefficient data managementfor immediate access andfuture analysis.

iii. WebIntegration:The datacollectedandstoredismade accessiblethroughauser-friendlywebinterface.Thisinterfaceprovidesavisualrepresentationofthereal-timedata,ofteninttheformofdashboards,graphs,orcharts.Users,suchasEVownersorchargingstationoperators,canaccessthisinterfacefromanyweb-enableddevice,gaininginstantinsightsinto systemstatus and performance.

iv. UserInteraction:Thewebinterfaceallowsuserstointeractwiththesysteminreal-time,facilitatinginformeddecision-making.Forinstance,inanEVchargingscenario,userscanmonitorthechargingstatus,batterylevels,andpotentiallyevencontrolchargingparametersremotely through this interface.

AReal-TimeMonitoringSystemwithwebintegrationamalgamatesdatacollection,processing,storage,andpresentationintoaseamlessanduser-friendlyinterface.Itoffersreal-timeinsights,promotesinformeddecision-making,andplaysapivotalroleinenhancingoperationalefficiencyanduserexperience across diversedomains.

2.3 Robotic Arm

A Robotic Arm is a versatile mechanical system designed to mimic the functions of a human arm. These systems find applications across various industries, from manufacturing and assembly lines to healthcare and space exploration. Figure 3 shows the robotic arm components and structure. The base of a robotic arm serves as the foundational support for the entire robotic arm. It often incorporates a motorized turntable for rotational movement. The Shoulder enables the vertical movement, allowing the arm to reach different heights. The elbow facilitates the horizontal movement, extending or retracting the arm. The wrist adds rotational flexibility, allowing the end effector to adjust its orientation and the gripper is an end effector responsible for grasping and manipulating objects.

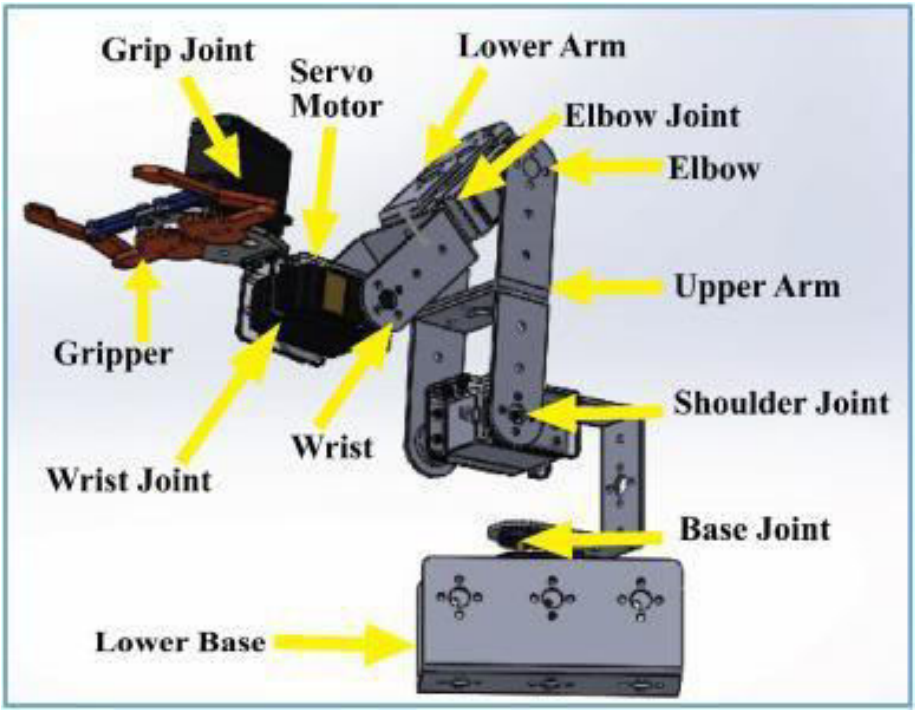


Figure 3: Robotic Arm Components and Structure

A typical robotic arm consists of a series of interconnected segments or links, usually resembling a human arm with joints and appendages. The structure enables multi-axis movement, allowing for precise and controlled motion. Each joint or segment of the robotic arm is powered by actuators, often electric motors, or servo motors. These motors facilitate movement, providing the necessary torque and precision for each articulation of the arm. At the extremity of the arm, there's an end effector, which can be a gripper, tool, sensor, or any device designed for specific tasks. The end effector enables the arm to interact with objects, perform actions, or complete tasks within its operational domain. Robotic arms are controlled by sophisticated control systems, which could be as simple as pre-programmed instructions or as complex as adaptive algorithms based on sensors and feedback mechanisms. These control systems dictate the arm's movements, precision, and response to external stimulation.

3. Results and Discussion

Thepapershowcasesa new idea for real time monitoring of EV with web integration.Thisintegrationnotonlyharmonizeshardwareandwebcomponentsbutalsodeliversvital real-timedataonEVbatteryparameters.Byconvergingtheseelements,this paper givesacomprehensivemonitoringsolution,bestowingEVownersandchargingstationoperatorswith immediateinsightsintothehealthandperformanceofEVbatteries.Additionally,theimplementation of anexactlydesignedroboticarmsystemaimed atimproving EV chargingsafety and demonstrated promising outcomesacross various parameters.

Electric Vehicle Prototype

Thehardware EV prototype as shown in figure 4, successfullyincorporatedthesensorstomonitorcrucialbatteryparameters,namelyvoltage,current,t emperature,andpercentage.This datawasefficientlyprocessedandtransferredto Firebase Firestore'sdatabase.

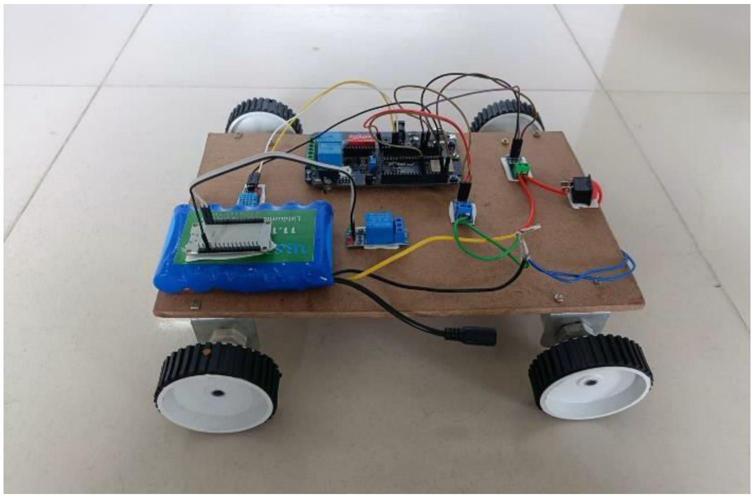
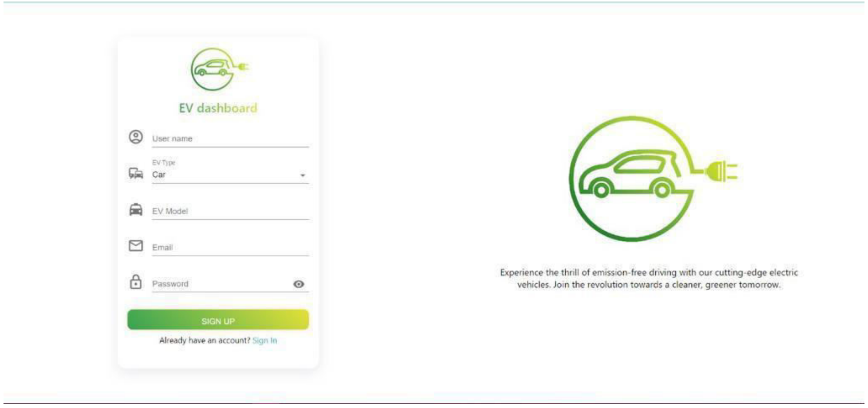


Figure4: Prototypeof Electric Vehicle.

Thisinnovativeintegrationencompassesbatteries,ESP32microcontrollers,currentsensors,voltagesensors,andtemperaturesensors,collectivelyformingthebackboneofthesystem.Thebatteries,servingastheprimarypowersource,arecomplementedbyESP32microcontrollersfunctioningascentralprocessingunits,facilitatingcontinuousdatacollection,processing,andtransmission.Concurrently,currentsensorsmonitorelectriccurrentflow,whilevoltagesensorstrackpotentialdifferencesacrosscomponents.Temperaturesensorsplayapivotalroleindetectingandmonitoringtemperaturefluctuationswithinthesystem.Beyonditsimmediatefunctionality,thisintegratedsystemforms the baseforfurtherresearchanddevelopmentpropellinginnovationaimedatrefiningEV performance, safety,andefficiency.

3.1 User-friendly Webpage

ThewebcomponentofthesystemprovidedanintuitiveuserinterfaceforbothEVownersandchargingstationoperators.Itenables the EV ownerstomonitortheirvehicle'sbatterystatus,i.e.,stateofcharge,voltagelevels,existingconsumption,andbatterytemperatureatanytimeduringtheday.SuchinformationenablesEVownerstomakeinformeddecisionsontheirvehicle'suseandmaintenance.Atthesametime,ithasprovedtobeofextraordinaryvalueforstationmanagerswhohavebeenabletotrackelectricvehiclebatteryperformanceviathewebsite.Thereal-timeinformationenabledchargingstationoperatorstoeffectivelyallocatechargepointsaccordingtothecurrentbatteryconditions,optimizeutilizationofresources,andensurethatelectricvehiclesarecharged efficiently.



EV Type: Car

Experience the thrill of emission-free driving with our cutting-edge electric vehicles. Join the revolution towards a cleaner, greener tomorrow.

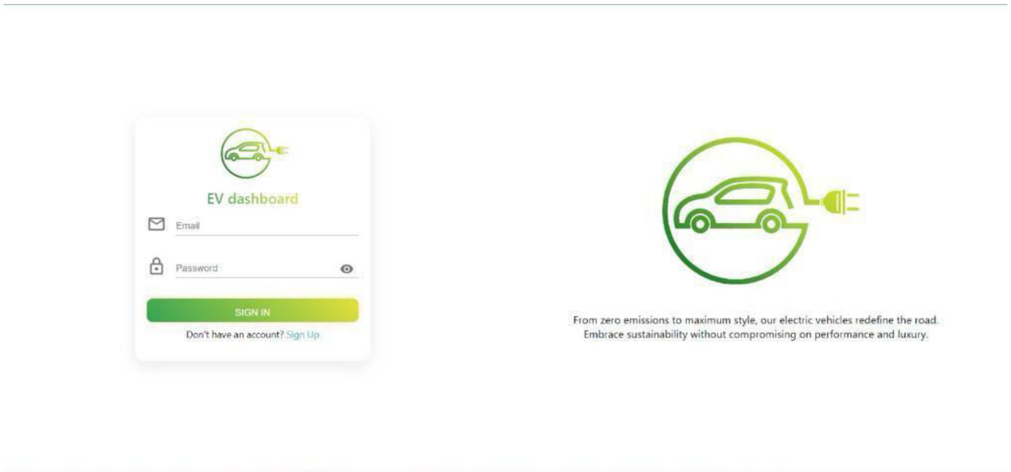
Figure5: Sign Up pagefor Dashboard.

Figure5depictstheuser-friendlySignuppage,whereuserscancreateanaccountwithease.Thestraightforwardprocessinvolvesenteringadesiredpasswordandselectingwhethertheyownatwo-orfour-wheeldriveelectricvehicle.Thispersonalizationoptionenhancestheregistrationexperience andallows for more tailoredservices.

TheSignuppageisdesignedwithsimplicityandconvenienceinmind.Usersareguidedthroughtheprocesswithclearinstructionsandintuitiveprompts.Theoptiontospecifyvehicletype,whethertwo-or four-wheeldrive, demonstrates theplatform'sattentionto detailandcommitmenttoprovidingapersonalizedexperience.Tocreateanaccount,userssimplyenter theiremailaddress,name,andphonenumber.Theythenchooseastrongpasswordandselecttheirvehicletype. Onceallfieldsarecomplete, userscanclick the"Sign Up" button to finalize the process.

Figure6showsthesecuregatewaytoaccesstheEVDashboard,theSignInpage.Thiscrucialelementservesastheentrypointforauthorizeduserstoaccesstheir EVdataandmanagetheirchargingexperience. Thesecuregatewayensuresthatonlylegitimateuserscangainaccess,safeguardingsensitiveinformationand upholding the platform'sintegrity.

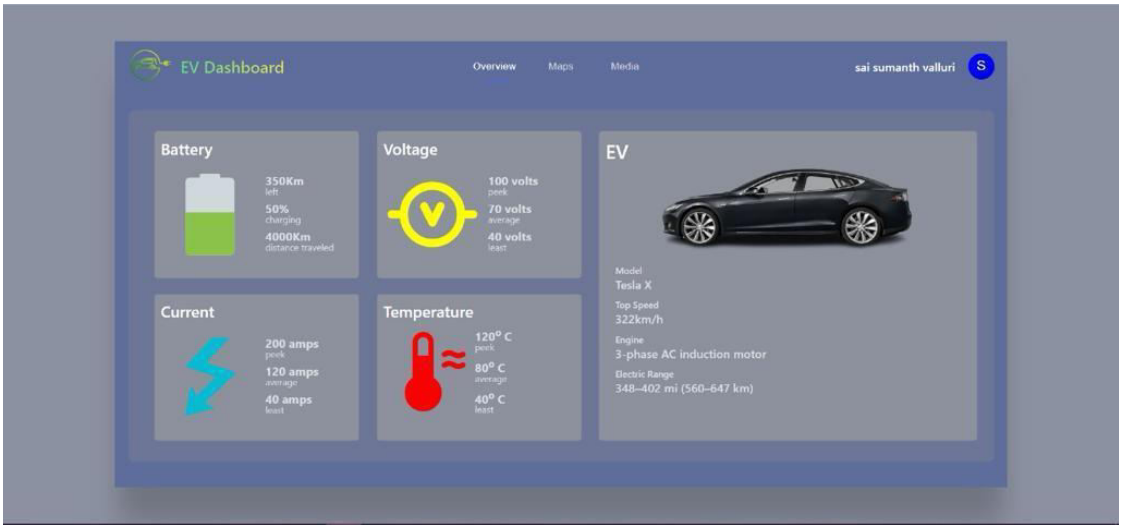
TheSign Inpage is designed with securityat its core.Users arepromptedtoentertheir registeredemailaddressandpassword,employingrobustencryptionmethodstoprotecttheircredentials.



From zero emissions to maximum style, our electric vehicles redefine the road.
Embrace sustainability without compromising on performance and luxury.

Figure6: SignInpagefor Dashboard

Uponsuccessfulauthentication,usersaregrantedaccesstotheirpersonalizedEVDashboard,wheretheycangothroughreal-timedataandmanagetheirchargingneedswithconfidence.TheemphasisonsecurityextendsbeyondtheSignInpage,permeatingtheentireplatform.Datatransmissionisencryptedusingindustry-standardprotocols,andaccesscontrolsareenforcedtopreventunauthorizedaccess.Thisunwaveringcommitmenttosecurityinstilstrustinusers,ensuringthattheir privateinformationremainsprotected whiletheyreapthebenefitsoftheplatform.



350Km left
50% charging
4000Km distance traveled

100 volts peek
70 volts average
40 volts least

200 amps peek
120 amps average
40 amps least

120° C peek
80° C average
40° C least

Model
Tesla X
Top Speed
322km/h
Engine
3-phase AC induction motor
Electric Range
348–402 mi (560–647 km)

Figure7: Dashboard of EV monitoringsystem.

Figure7presentstheDynamicWebPageoftheEVDashboard,acomprehensiveportalthatempowersuserstostayinformedabouttheirvehicle'sbatterystatusandoptimizetheirEVownershipexperience.Thisintuitivedashboardprovidesreal-timeinsightsintocriticalbatteryparameters,includingthecurrentstateofcharge,voltagelevel,consumptionrate,andtemperature.Additionally,userscanaccessvitalvehicleandmodelinformation,fosteringinformeddecision-making andenhancedconvenience.

TheEVDashboardservesasacornerstoneforEVowners,enablingthemtomakeinformedchoicesregardingtheirvehicle'susageandmaintenance.Real-timemonitoringofbatterycharginglevelsempowersuserstooptimizetheirchargingroutine,minimizingrangeanxietyandmaximizingefficiency.Voltageandcurrentreadingsprovidevaluableinsightsintobatteryhealth,allowinguserstoproactivelyaddresspotentialissuesbeforetheyarise.Temperaturecontrolmonitoringsafeguardsbatteriesfromoverheating,ensuringoptimalperformanceandextendingtheir lifespan.

Beyondbatteryhealth,theEVDashboardalsocontributessignificantlytooveralluserexperience,promotingsafetyandefficiencyinelectricvehicleownership.Convenientaccesstovehiclemodelinformationandpersonaldatasimplifiestheprocessof EVmonitoringandmanagement.Thisintegratedapproachstreamlinestheuserexperience,makingtheEVDashboardanindispensabletool forEV owners.

Inessence,theEVDashboardempowersuserstotakecontroloftheirEVownershipexperience,ensuringthattheirvehiclesareoperatingatpeakperformance,maximizingefficiency,andextendinglifespan.Thedashboard'scomprehensivedata,intuitiveinterface,andintegratedapproachmakeitthego-toresourceforallaspectsofelectricvehicleownershipandmaintenance.

3.2 Charging Slot Management atCharging Station

Chargingstationoperators,alsoknownasadministrators,haveprivilegedaccesstocrucialdataforefficientslotmanagement.Thismeansthat,usingthisaccess,theycanassignchargingslotsbasedonthecurrentbatterylevelineachEVmodel.Thisinnovativeapproachtoslotmanagementhassignificantlyimprovedtheefficiencyofthecharginginfrastructure,preventingbothoverchargingand underutilization.

EffectivelyutilizingchargingresourcesbenefitsbothEVownerconvenienceandstationrevenue.Bylimitingovercharging,thesystemhasbeeninstrumentalinextendingthelifespanandhealthofelectricvehiclebatteries.Simultaneously,avoidingunderutilizationhasfosteredasustainableanduser-friendlyecosystem for electric vehicles.

3.3 Robotic Arm for EV Charging

Integrationoftheroboticarmsystemmarkedlyreducedsafetyrisksassociatedwithhigh-voltagemanualcable handling, promoting a saferchargingenvironment.

Theroboticarmexhibitedexceptionalprecisionandcontrolduringitsoperations,flawlesslymanagingtheconnectionanddisconnectionofEVchargingcableswithoutencounteringanyuntowardincidents.Rigorousreal-worldsimulationsandtestingconductedacrossdiverseEVmodelshighlightedtheremarkableadaptabilityandversatilityoftheroboticarmsystem.Thiscomprehensivetestingvalidatedthesystem’scapabilitytoseamlesslyadapttovaryingvehicleconfigurations,effectivelymeetingtheproject’sprimaryobjectiveofaccommodatingtheintricaciespresentedbydifferentEVmodels.Thesesuccessfuldemonstrationsunderscoredthe reliabilityandefficacyoftheroboticarminhandlingchargingprocessesacrossaspectrumofscenarios,affirmingitsrobustnessandsuitabilitywithintheevolvinglandscapeofelectricvehicletechnologies.

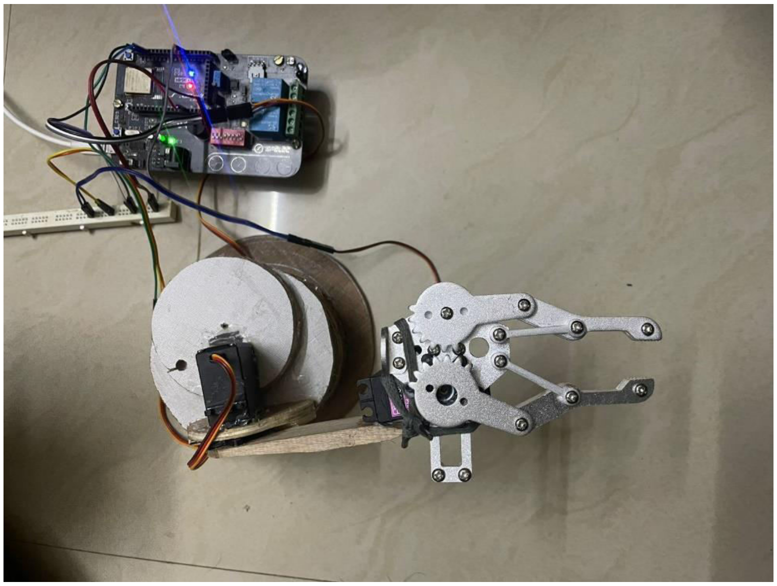


Figure8: Robotic Arm for EVCharging

3.4 User-friendly Mobile Application

Thesuccessofanynewtechnologyreliesheavilyonitsuserinterface(UI).Theroboticarmsystem'sUI wassignedtobeintuitive,user-friendly,andinformative,ensuringaseamlessexperience for EV ownersthroughout the chargingprocess.

Figure9: Mobile Applicationfor Robotic Arm.

TheUIprovidesEVownerswithclearandconcisefeedbackonthechargingprogress,keepingtheminformedeverystepofthe way. Real-time updateson charging status, estimatedcompletiontime,andpotentialerrormessagesaredisplayedprominentlyonthescreen.This transparencyfostersuserconfidenceandtrustintheautomatedchargingprocess.TheUIgoesbeyondsimplydisplayingchargingstatus;italsoservesasavigilantsentinel,detectingandnotifyingusersofany potentialerrorsthatmayarise.Clearerrormessages,accompaniedbyappropriateiconsandvisualcues , promptly informusers of anyissues,enabling them to take correctiveactions if necessary.

TheintuitiveandinformativeUIplaysacrucialroleinenhancinguserconfidenceintheroboticarmsyst em.Byprovidingclearfeedback,visualcues,andtimelyerrornotifications,theUIempowersuserstounderstandandmanagethechargingprocess,alleviatinganyconcernsoranxieties they may haveabout using the automatedsystem.

TheUIdesignedfortheroboticarmsystemsetsanewstandardforuserinteractionwithautomatedchargingtechnology.Itsintuitivedesign,clearfeedbackmechanisms,anderrordetectioncapabilitiesfosteruserconfidenceandcontributetoapositiveuserexperience.Astheadoptionofelectricvehiclescontinuestogrow,suchuser-centricdesignprincipleswillbeincreasinglycrucialforensuring the successfulintegration of automatedchargingsystems intothe EVecosystem.

4. Conclusions

This paper presents a methodology that combines a real time monitoring system with a smart robotic arm that gives the safety measures for Electric Vehicles charging. Thisintegratedsystemnotonlyexcelsincollectingandprocessingreal-timebatterydatabutalsoempowersusersthroughauser-friendlyinterface,ensuringimmediateinformationintochargingdynamics. TheprecisionandadaptabilitydemonstratedbytheroboticarminhandlingchargingprocessesacrossvariousEVmodelsshowcaseitsversatility. Overall, this paper sets the stage for safer, easier, and more user-friendly ways to charge electric cars. It shows a promising future where EV adoption is not only convenient but also sustainable and accessible to all.

References

[1]Wang,Bo,etal.“Electricalsafetyconsiderationsinlarge-scaleelectricvehiclechargingstations.”IEEETransactionsonIndustryApplications,vol.55,no.6,2019,pp.6603–6612,https://doi.org/10.1109/tia.2019.2936474.

[2]Helbing,Maximilian,etal."ComparativeCaseStudyofaMetamodel-BasedElectric VehiclePowertrainDesign."*IEEEAccess*9 (2021): 160823-160835.

[3]Sönmez,FerdaÖzdemir,andBanuGünelKiliç."Holisticwebapplicationsecurityvisualizationfor multi-projectandmulti-phasedynamicapplicationsecuritytestresults."*IEEEAccess*9 (2021): 25858-25884.

[4]Husain,Iqbal,etal.“ElectricDriveTechnologyTrends,challenges,andopportunitiesforfutureelectricvehicles.”ProceedingsoftheIEEE,vol.109,no.6,2021,pp.1039–1059, https://doi.org/10.1109/jproc.2020.3046112.

[5]S,GopiyaNaik,etal.“Batteryparametermonitoringandcontrolsystemforelectricvehicles.”InternationalJournalofElectricalandElectronicsEngineering,vol.9,no.3,2022,pp.1–6,https://doi.org/10.14445/23488379/ijeee-v9i3p101.

[6]Pasetti,Marco,etal.“Real-timestateofchargeestimationoflightelectricvehiclesbasedonactivepowerconsumption.”IEEEAccess,vol.11,2023,pp.110995–111010,https://doi.org/10.1109/access.2023.3322651.

[7]Chiasson, J., and B.Vairamohan. “Estimating theStateof chargeof abattery.”Proceedings of the 2003American Control Conference, 2003., https://doi.org/10.1109/acc.2003.1243757.

[8]Geevarghese,PriyaA.,L.PadmaSuresh,andAneeshP.Thankachan."MethodsforEstimatingSOCofLiBsinElectricVehicles: AReview."*2023InternationalConferenceonCircuitPowerand*

Computing Technologies (ICCPCT). IEEE, 2023.

[9]Elmahallawy,Mohamed,etal."AComprehensiveReviewofLithium-IonBatteriesModeling,and Stateof HealthandRemainingUseful Lifetime Prediction."*IEEEAccess*(2022).

[10]Al-Hanahi,Bassam,etal."Charginginfrastructureforcommercialelectricvehicles:Challengesand futureworks."*IEEEAccess*9 (2021): 121476-121492.

[11]Kavitha,R.,etal."AReviewonChargeControlTechniquesforBatteriesinElectricVehicles."*2022SecondInternationalConferenceonAdvancesinElectrical,Computing,CommunicationandSustainableTechnologies(ICAECT)*. IEEE, 2022.

[12]Ahmet,T.O.P.,andMuammerGÖKBULUT."AndroidApplicationDesignwithMITAppInventorfor Bluetooth Based Mobile Robot Control." (2021).

[13]Bhangale,PrasadkumarP.,S.K.Saha,andV.P.Agrawal."Adynamicmodelbasedrobotarmselection criterion."Multibody System Dynamics 12 (2004): 95-115.

[14]Bhargava,Ankur,andAnjaniKumar."Arduinocontrolledroboticarm."2017InternationalconferenceofElectronics,CommunicationandAerospaceTechnology(ICECA).Vol.2.IEEE,2017.

[15]Chen,Chien-Wei,Rui-MingHong,andHung-YuWang."Designofacontrolledroboticarm."20163rdInternationalConferenceonGreenTechnologyandSustainableDevelopment(GTSD).IEEE ComputerSociety,2016.

[16]deJesusRubio,Jose,etal."Variablestructuremodelofanarticulatedroboticarm."IEEELatinAmerica Transactions 13.12 (2015): 3794-3802.

[17]Chichester,F. D., and G. A.Downes."Extension of aRigidLink Model of aRobot Armto aFlexibleLink Model." 1990 American Control Conference.IEEE, 1990.

[18]Güleçi,Mehmetcan,andMuratOrhun."AndroidbasedWI-FIcontrolledrobotusingRaspberryPi."2017InternationalConferenceonComputerScienceandEngineering(UBMK).IEEE, 2017.

[19]Hsieh,Yi-Zeng,Fu-XiongXu,andShih-SyunLin."DeepConvolutionalGenerativeAdversarialNetworkforInverseKinematicsofSelf-AssemblyRoboticArmBasedontheDepthSensor."IEEESensors Journal 23.1 (2022): 758-765.

[20]Hussein,M.,M.Robaiy,andM.Shjary."MathematicalModelingofFlexibleRobotArmUsing FiniteElement Method." College of Engineering 18.2 (2010): 704-712.

[21]Ishak,MohamadKhairi,andNgMunKit."DesignandimplementationofrobotassistedsurgerybasedonInternetofThings(IoT)."2017Internationalconferenceonadvancedcomputingandapplications (ACOMP). IEEE,2017.

[22]Marnell,Alex, Mahmood Shafiee,andAmirHoseinSakhaei. "Designing andmanufacturinganAndroid-controlledroboticarmusingrapidprototyping."202227thInternationalConferenceon Automation and Computing (ICAC).IEEE, 2022.

[23]Mohanavel,V.,etal."Aneffectivedesignofwirelessandroidbasedroboticoperationcontrolusing8051microcontroller."2022InternationalConferenceonAdvancesinComputing,Communication

and Applied Informatics(ACCAI).IEEE, 2022.

[24]Sahoo,AshwinKumar,BarnaliBrahma,andAsutoshPattanaik."Design&developmentofroboticarmformedicalsurgery."20192ndInternationalconferenceonpowerandembeddeddrivecontrol(ICPEDC).IEEE,2019.

[25]Sain,Arka,Janardan Dattani,andDharaM. Mehta. "DesignandImplementationofWirelessControlofPickandPlaceRoboticArm."InternationalJournalofAdvancedResearchinEngineeringand Technology 9.3 (2018).

[26]Sathyamoorthy,B.,SnekhalathaUmapathy,andT.Rajalakshmi."AutomaticRoboticArmBasedonBluetoothRegulatedforProgressedSurgicalTask."2022InternationalConferenceonIndustry 4.0 Technology(I4Tech).IEEE, 2022.

[27]Zhuang, Min, GeLi,andKexin Ding."ObstacleAvoidance Path Planning forApplePickingRobotic ArmIncorporatingArtificial Potential Fieldand A* Algorithm."IEEEAccess(2023).