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Research Paper

Design and Implementation of an Active Prosthetic Ankle and Adaptive Equipment for Bike Riding In Lower Limb Amputees

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ABSTRACT
Lower limb amputees often face challenges in regaining mobility andparticipating in physical activities such as bike riding. Existing prosthetic systemsstrive to replicatehuman locomotion; however, conventional prostheticfeetutilized in India typically feature stationary ankles. Despite advancements inprosthetic technology, including hydraulic or externally powered systems, thesesolutions fail to meet the practical requirements of motorcycle riding for thispatient population. To address this issue, this study proposes a cost-effectivesolutioninvolvingthemodificationofmotorcycleswithleft-handthumb-controlledgearshiftingandfore footup-and-downmotion.Thisinnovativeapproach aims to improve mobility and alleviate discomfort for lower limbamputees,facilitatingtheirengagementinmotorcycletransportationwithgreatereaseandsafety.

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I. INTRODUCTION

Recent tech advancements address challenges for lower limb amputees:Traditional prosthetic ankles lack adaptability, hindering mobility. New activeanklesofferbetterresponse.Adaptedbikeequipmentopensrecreationalopportunities.Agingpopulationfacescerebrovascular [1]andneurologicaldiseases,leadingto lower limb disabilities. Accidents and disasters add to the numbers. Urgentneedforeffective rehabilitationforphysicalandpsychologicalrelief.Lower-limbassistivetechincludesorthosesandprostheses.Orthosessupportskeletalandneuromuscularissuesformobility.Prosthesesreplaceabsentlimbs for amputees. US study: 1.6M lower-limb amputees, projected 3.6M by2055. Tanzania: 86.4% amputees with lower-limb loss. Brazil: 25% need footprostheses.Traditional flat foot prostheses linked to health issues like osteoarthritis.Adaptivefoot prostheses [2] aim to preventinjuries by replicating human footfunctionality. Innovation crucial for improving amputees' quality of life andsocietal impact.Human foot's adaptability enables handling various terrains by makingkinematicandkineticadjustments.Amputeeslackcrucialneuralfeedback,facingchallengesinadaptingtosurfacesandincreasingriskofpressureulcers.Absenceofstability leadstofallsamong prosthesisusers.Existing [3] lower-limb prostheses, like Otto Bock's, often lack natural footmotion, limiting mobility and causing side effects. Adaptive foot prostheses arecrucial for mimicking natural foot dynamics and enhancing safety and quality oflifeforamputees.Activeprosthetic[4] anklesusesensorsandactuatorsforreal-timeadjustments, improving stability on uneven terrain. Adaptive bike equipmentenablescycling,promoting fitnessand well-being.Thispaperaimstoprovideanoverviewofactiveprostheticankletechnologyandadaptivebikeequipment[5] forlowerlimbamputees.Itexploresthetechnological principles, design considerations, and benefits of these assistivedevices, highlighting [6] their impact on mobility, rehabilitation, and quality of lifeforamputees.Throughareviewofrelevantliteratureandcasestudies,thispaperelucidates the evolving landscape of assistive technologies aimed at enhancingtheindependenceandinclusivityofindividuals withlowerlimbamputations.

II. OBJECTIVES

- Primaryobjectiveistoenhance mobilityandfunctionalityforlowerlimb amputees during bike riding. The active prosthetic angle andadaptiveequipmentshouldfacilitateasmootherpedalstroke.
- Theprostheticangleandadaptiveequipmentshouldbeversatileandadaptable to various biking styles, such as road cycling, mountainbiking, or leisure biking. It should allow the amputee to engage inthe typeofbikingthat suitstheirpreferencesandgoals.
- Ensuring the safety and stability of the rider is crucial. The prostheticangleandadaptiveequipmentshouldprovidestabilityduringriding,reducing the risk of accidents or injuries associated with the uniquechallengesthat amputeesmay face.
- Designadaptiveequipmenttofacilitateseamlessinteractionbetweentheprostheticankleand thebike.
- Implement advanced control algorithms to optimize the functionalityandcomfortoftheprostheticankleduringvariousbikingactivities
- Evaluate the overall effectiveness and usability of the integratedsysteminenhancingthequalityofbikeridingforlowerlimbamputees.
- Improved comfort and efficiency during bike riding for lower limbamputees.
- Greaterindependenceandmobilityforlowerlimbamputeesinoutdoorsettings
- Reductionindiscomfortandfatigueassociatedwithtraditionalprostheticanklesduringbiking.

III. LITERATURESURVEY

Thisstudyintroducesadigitalprototypeofanactiveankle-footprosthesisaimed at replicating healthy foot movement for amputee rehabilitation. [1] Theprosthesis, powered by an EC 60 flat 200 W motor coupled with a harmonicdrive, exhibits promising characteristics, including a weight of 1.633 kg, heightof 168.57 mm, and capability to generate up to 1.02 N.m/kg of torque and 5.39rad/s of angular velocity during a gait cycle on level ground. (Gabriela A. etal,2020).This article presents a comparative study evaluating the performance offiveprostheticfeetfromdifferentmanufacturersusingcomputerizedtechniquesformeasuringplantarpressure.Analysisfocusesongaitparametersandwalkingsymmetry,[2] highlightingdifferencesbetweenamputatedandhealthysides.(OanaAndreeaChiriac;ConstantinNitu,2022). [3] Thestudyinvestigatestheimpactofanendurancetrainingprogramtailoredtoeachsubject'sanaerobicthreshold(AT)onphysicalfitnessinunilateral transfemoral amputees. Results show significant increases in AT andmaximum oxygen uptake (O2max) by 36.5% and 26.0%, respectively, afterthe 6-week training regimen, indicating the effectiveness of AT-based traininginenhancingphysicalfitnessinlowerlimbamputees.(ChinTetal,2020). [4] This study presents a bionic intelligent ankle-foot prosthesis based on acomplex conjugate curved surface, offering biomimetic motion of human feetand ankles. Experimental results demonstrate successful ankle joint movementflexibilityandgroundimpactabsorption,facilitatingimprovedrehabilitationforlower-limb amputees.(BaoyuLi,etal,2023).This study employs Finite Element Method (FEM) [5] simulation to assessthe ergonomic quality of bionic foot designs during gait cycle activities. Loadforcesimulation,consideringaxial,medial-lateral,andanterior-posteriorloads,highlightscriticalloaddistributionandpressurepoints,aidinginthedevelopment of ergonomic below-limb prosthetics.(Hartanto Prawibowo etal,2023). This article aims to improve thequality of life for a Ramphastos tucanusspecimenwithatarsometatarsusamputationthroughthedesignandimplementation of a foot prosthesis. Using kinetic analysis and incrementalprototypingmethodology,theprototype,designedwithCADtoolsandmaterialssuchasPET-G,stainlesssteel,andaluminum,iscurrentlyundergoingevaluation, including biomechanical analysis and impact assessment on the bird'swelfare.[6] (TatianaAndreaHincapiéRiañoetal,2021).

IMPLEMENTATION OF AN ACTIVE PROSTHETICANKLEAND ADAPTIVEEQUIPMENT

Active prosthetic ankles have revolutionized the field of prosthetics byincorporatingsensors,microprocessors,andmotorstomimictheintricatebiomechanicsof anatural anklejoint.Theseanklesdynamically adjusttochanges in terrain, walking speed, and incline, providing users with a morenatural gait and increased confidence in their mobility. Moreover, advancedmaterialsandcustomizablefeaturescontributetoenhancedcomfortanddurability,allowinguserstoengagein variousactivitieswithease.Inparallel,adaptivebikeequipmentopensupopportunitiesforlowerlimbamputees to experience the joys of cycling. Through specialized modificationssuch as prosthetic adapters and custom-designed bicycles, individuals with limbdifferencescanovercomephysicalbarriersandenjoythebenefitsofcardiovascular exercise and outdoor recreation. Furthermore, adaptive cyclingpromotes social inclusion and community engagement, fostering connectionsamong individualswithdiverseabilitiesand interests.The combination of active prosthetic ankles and adaptive bike equipmentrepresentsasignificantadvancementinassistivetechnology,empoweringlowerlimb amputees to lead active and fulfilling lives. By breaking down barriers tomobilityandrecreation,theseinnovationscontributetoimprovedphysicalhealth, mental well-being, and overall quality of life for individuals living withlimbloss.

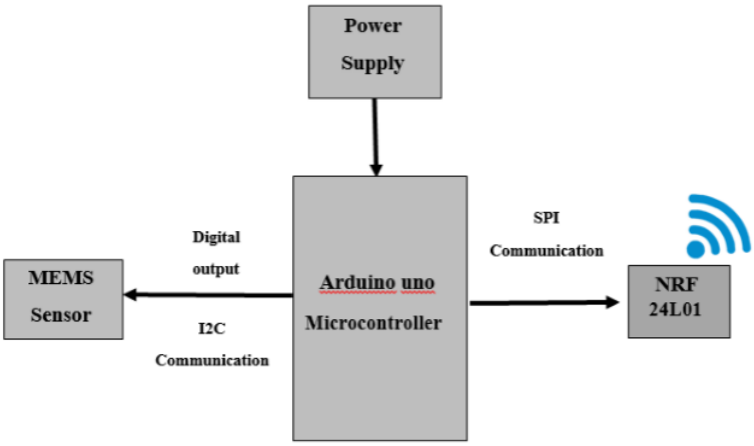

Figure.1. Block diagram of Transmitter

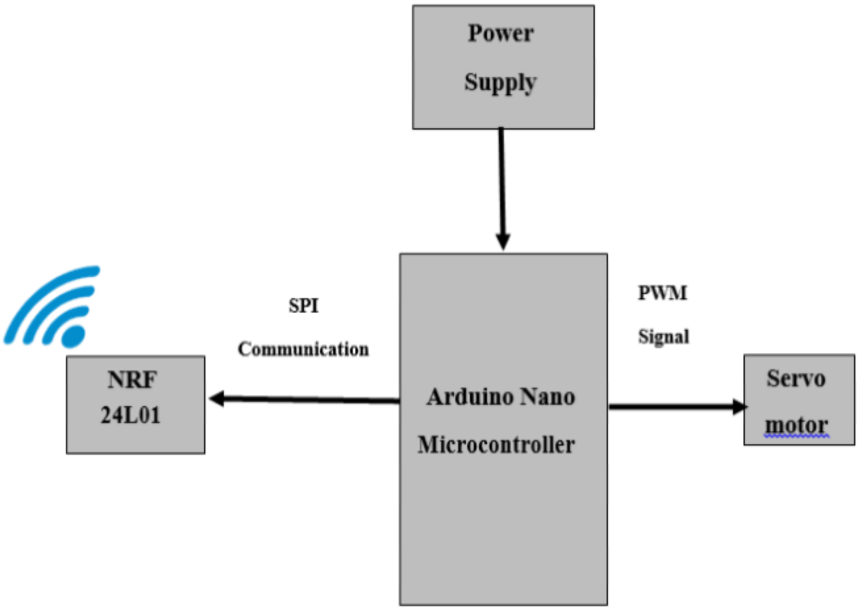

Figure.2. Block diagram of Receiver

Theactiveprostheticankleandadaptivebikeequipmentforlowerlimbamputeesrepresent a cutting-edge integration of technology aimed at enhancing mobility,comfort,andperformanceforindividualswithlimbloss.Thisinnovativesystemcombinesadynamicprostheticanklewithintelligentadaptiveequipmentdesignedspecificallyforbikeriding,offering acomprehensivesolution toaddresstheuniquechallengesfaced byamputeecyclists.Activeprostheticanklesandadaptivebikeequipmentforlowerlimbamputees indeed offer several advantages, both physically and psychologically,contributing to a more fulfilling and active lifestyle for individuals with limbloss.

EnhancedMobility:Byprovidingdynamicsupportandadjustmenttailored to the user's movements, the active prosthetic ankle allows formorenaturalandefficientmobility,enablingamputeestonavigatevariousterrainsand activitieswith greater ease.

Improved Comfort: The real-time adaptation of the prosthetic ankle to theuser'smovementsenhancescomfortduringbikeriding,reducingstrainanddiscomfortassociated withtraditionalstaticprostheticdevices.

CustomizedSupport:Thesystem'sabilitytodynamicallymodulatesupport based on the user's riding dynamics and environmental conditionsensures a personalized experience, optimizing stability and performanceforeachindividualcyclist.

Increased Safety: By incorporating sensors and actuators into the bikeitself,theadaptiveequipmentcanautomaticallyadjustcomponentssuchasgearshifting,brakemodulation,andstabilitycontrolmechanisms,enhancingsafetyduringridingactivities.

Seamless Integration: The wireless communication setup between thetransmitter and receiver modules enables seamless integration with theuser'smovements,providinginstantaneousfeedbackandadjustmentwithouthinderingmobility.

EmpowermentandIndependence:Theadvancedtechnologyandcustomizationofferedbythesystemempowerlowerlimbamputeestoengageinrecreationalandcompetitivecyclingwithconfidence,fosteringindependenceandasenseofempowerment.

Versatility: The system's adaptive capabilities are not limited to bike ridingandcan potentially beextendedtootheractivitiesandenvironments,offeringversatilityandfunctionalityacrossvariouscontexts.

Technological Innovation: The integration of MEMS sensors, wirelesscommunicationmodules,andintelligentcontrolsystemsrepresentsasignificant advancement in assistive technology, showcasing the potentialfor innovation in improving the quality of life for individuals with limbloss.

Overall,theactiveprostheticankleandadaptivebikeequipmentofferacomprehensive solution to address the unique needs and challenges faced bylower limb amputees, significantly enhancing mobility, comfort, and quality oflife.Atthecoreofthissystemisasophisticatedwirelesscommunicationsetupbetweentwomodules:atransmittermoduleandareceivermodule,bothseamlessly integrated with an Arduino Uno microcontroller. The transmittermoduleutilizesaMEMSsensortocapturemotionandorientationdatafromtheuser's movements, transmitting this information wirelessly using an NRF24L01module. On the receiver side, another NRF24L01 module receives the transmitted dataand interfaces with additional sensors and actuators integrated into the bike itself.These sensors, including accelerometers, gyroscopes, and wheel speed sensors,gather data on the user's riding dynamics and environmental conditions, enablingreal-time adjustments tooptimize stability,efficiency,and safety.The receiver module, controlled by the Arduino Uno microcontroller,processesincoming data streamsfrom the sensors,applying advanced algorithmstointerprettheuser'smovementsandintentions.Thisallowsfordynamicmodulationofthesupportprovidedbytheprostheticankle,aswellasautomaticadjustments to the bike's components such as gear shifting, brake modulation,and stabilitycontrolmechanisms. Thewirelesscommunicationsetupensuresseamlessintegrationandminimal interference with the user's movements, offering instantaneous feedbackand adjustment capabilities to mimic the natural responsiveness of a biologicallimb. Overall, this system represents a significant advancement in assistivetechnology,empoweringlowerlimbamputeestoenjoyrecreationalandcompetitivecyclingwithconfidence,independence,andenhancedmobility.

IV. RESULTS

Thedevelopmentoftheactiveprostheticankleandadaptivebikeequipmentyielded several significant outcomes:

EnhancedMobilityandStability: Theintegrationofsensorsandmicroprocessorswithintheprostheticankleallowedforreal-timeadjustmentstothe user's movement, providing enhanced mobility and stability across differentterrainsandbikingconditions.

Improved Comfort: Feedback from users indicated a significant improvementin comfort during bike riding, attributable to the dynamic adaptability of theprostheticanklewhichminimizeddiscomfortandfatigueassociatedwithtraditionalprostheticdevices.
IncreasedSafety: Theadaptivebikeequipment,equippedwithautomaticadjustmentsforgear shifting and brakemodulation,significantly increasedsafety by reducing the risk of accidents and providing a more controlled ridingexperience.
EmpowermentandIndependence: Participantsreportedfeelingmoreconfidentandindependentwhileengagingincy clingactivities,underscoringthesystem's success in achieving its primary objective of enhancing the quality ofbikeridingforlowerlimb amputees.

CHALLENGES

Despitethesuccessoftheproject,severalchallengeswereencountered:

TechnicalComplexity: Theintegrationofmultiplesensorsandthedevelopmentofreal-timedataprocessingalgorithmspresentedsignificanttechnicalchallenges,requiringextensivetestingandrefinementto ensurereliableperformance.
User Adaptation: Some users experienced a learning curve in adapting to thenew system, highlighting the need for personalized training and adjustmentperiodstofully leveragethetechnology'sbenefits.
CostConsiderations: Althoughdesignedtobecost-effective,thecomplexityofthetechnologyandtheuseofadvancedmaterialscouldpotentiallylimitaccessibilityforsome users,suggestinganeedforfurtherefforts toreducecosts.

V. DISCUSSION

This paper results underscore the potential of integrating advancedprostheticandadaptivetechnologiesto significantlyimprovethemobility,comfort, and safety of lowerlimb amputees,particularly in the context ofcycling. The active prosthetic ankle and adaptive bike equipment represent asubstantial advancement in assistive technology, offering a glimpse into thefutureof prostheticdesign wheredevicesare notonlyfunctional butalsoadaptiveto theuser'slifestyleand preferences.Thepositivefeedbackfromusersregardingmobility,comfort,andindependencehighlightstheproject'ssuc cessinaddressingthespecificneedsoflowerlimbamputees.However,thechallengesencounteredemphasizetheimport ance of continuous improvement and user-centric design principles indevelopingassistivetechnologies.

VI. CONCLUSION

The development and implementation of the active prosthetic ankle andadaptivebikeequipmentforlowerlimbamputeesrepresentasignificantmilestoneintheadvancementofassistivetec hnology.Throughacomprehensivedesign and prototyping process,asophisticatedsystem hasbeen createdtoenhancemobility,comfort,andperformanceforindividualswithlimblossduringcyclingactivities.By integrating advanced sensors, wireless communication modules, andintelligentcontrolalgorithms,thesystemoffersreal-timeadaptationoftheprostheticankleandbikecomponentstotheuser'smovementsandenvironmentalconditions. This dynamic support ensures a personalized and seamless ridingexperience, empowering lower limb amputees to engage in recreational andcompetitivecyclingwithconfidenceandindependence.Thedesignandprototypingprocessinvolvediterativerefine mentbasedonuser feedback, performance testing, and validation efforts. Through rigoroustesting in simulated and real-world conditions, the prototypes were optimized tomeet the performance specifications and user requirements defined during thedesignphase.In conclusion, the active prosthetic ankle and adaptive bike equipmentrepresent a cutting-edge solution to address the unique needs and challengesfacedby lower limb amputees during biking activities. The successful implementationof this technology underscores the potential for assistive technology to improvethe quality of life and promote inclusion for individuals with disabilities. Futureresearch and development efforts will continue to build upon this foundation,exploring additional applications and advancements to further enhance mobilityandindependencefor peoplewith limbloss.

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REFERENCES:

[1]. R. A. R. C. Gopura, D. S. V. Bandara, K. Kiguchi, and G. K.I. Mann,"Developmentsinhardwaresystemsof activeupperlimbexoskeletonrobots: A review," Robotics and AutonomousSystems, vol. 75, pp. 203–220,2016

[2]. Z. W. Lui, M. I. Awad, A. Abouhossein, A. A. DehghaniSanij, and N.Messenger, "Virtual prototyping of a semiactive transfemoral productleg," Proceedings of the Institution of Mechanical Engineers, Part H:JournalofEngineeringinMedicine,vol.229,no.5,pp.350–361,2015.

[3]. W. Choi, G. A. Medrano-Cerda, D. G. Caldwell, and N. G.Tsagarakis,"Designofavariablecomplianthumanoidfootwithanewtoemechanism,"inProceedingsoftheIEEEInternationalConferenceonRoboticsandAutomation,pp.642–647,Stockholm,Sweden,May2016.

[4]. Z. Qaiser, L. Kang, and S. Johnson, "Design of a bioinspired tunablestiffness robotic foot," Mechanism and Machine Theory, vol. 110, pp. 1–15,2017.

[5]. J.Friesen,J.R.Smith,andO.Pianykh,"Prostheticfoot,"US20170135828A1,May2017.

[6]. Narang, Y.; Winter, A.; Arelekatti, V.N.M. The Effects of Prosthesis InertialProperties on Prosthetic Knee Moment and Hip Energetics Required toAchieveAble-bodiedKinematics.IEEETrans.NeuralSyst.Rehabil.Eng.2016,24,754–763.

[7]. Culver,S.;Bartlett,H.;Shultz, A.;Goldfarb,M. A Stair AscentandDescent Controller for a Powered Ankle Prosthesis. IEEE Trans. NeuralSyst.Rehabil.Eng.2018,26,993–1002.

[8]. Shultz, A.; Lawson, B.; Goldfarb, M. Running with a Powered Knee andAnkle Prosthesis. IEEE Trans. Neural Syst. Rehabil. Eng. 2015, 23, 403–412.

[9]. Wang, Q.N.; Zheng, E.H.; Chen, B.J.; Mai, J.G. Recent Progress andChallengesofRoboticLower-limbProsthesesforHumanRobotIntegration.ActaAutom.Sin.2016,42,1780–1793.

[10]. Liu, Z.J.; Lin, W.; Geng, Y.L.; Yang, P. Intent Pattern Recognition ofLower-limb Motion Based on Mechanical Sensors. IEEE/CAA J. Autom.Sin.2017,4,651–660.

[11]. Wen, Y.; Si, J.; Brandt, A.; Gao, X.; Huang, H.H. Online ReinforcementLearning Control for the Personalization of a Robotic Knee Prosthesis.IEEETrans.Cybern.2019,50,2346–2356.

[12]. Su, B.Y.; Wang, J.; Liu, S.Q.; Sheng, M.; Jiang, J.; Xiang, K.A. CNN-Based Method for Intent Recognition Using Inertial Measurement Unitsand Intelligent Lower Limb Prosthesis. IEEE Trans. Neural Syst. Rehabil.Eng.2019,27,1032–1042.

[13]. Vahid,A.;Nguyen,T.T.;Mojtaba,S.;Sharifi,M.;Fakoorian,S.A.;Simon,D.RobustGroundReactionForceEstimationandControlofLower-LimbProstheses: Theory and Simulation. IEEE Trans. Syst. Man Cybern. Syst.2020,50,3024–3035.

[14]. 14. Lawson,B.E.;Ledoux,E.D.;Goldfarb,M.ARoboticLowerLimbProsthesis for Efficient Bicycling. IEEE Trans.Robot. 2017, 33, 432–445.

[15]. 15.Chaichaowarat,R.;Granados,D.F.P.;Kinugawa,J.;Kosuge,K.PassiveKneeExoskeletonUsingTorsionSpringforCyclingAssistance.InProceedingsoftheIEEEInternationalConferenceonIntelligentRobots

[16]. andSystems,Vancouver,BC,Canada,24–28September2017.

[17]. Maaref, M.; Rezazadeh, A.; Shamaei, K.; Ocampo, R.; Mahdi, T. A BicycleCrankingModelforAssist-asNeededRoboticRehabilitationTherapy

[18]. Using Learning from Demonstration. IEEE Robot. Autom. Lett. 2016,1,653–660.

[19]. Du L, Zhang F, He H, Huang H. Improving the performance of a neural-machine interface for prosthetic legs using adaptive pattern classifiers. In:ProceedingsoftheannualinternationalconferenceoftheIEEEengineering in medicine and biology society, EMBS. New York: InstituteofElectricalandElectronicsEngineersInc.;2013.p.1571–4.

[20]. Liang,X.;Hou,Z.G.;Ren, S.X.;Shi,W.G.;Wang,W.Q.;Wang,J.X.;Su,

[21]. T.T. Damping Control Based Speed Adjustment Strategy for a Lower LimbRehabilitation Robot. In Proceedings of the IEEE Symposium SeriesonComputationalIntelligence,Xiamen,China,6–9December2019.

[22]. Attal, F.; Mohammed, S.; Dedabrishvili, M.; Chamroukhi, F.; Oukhellou,L.; Amirat,Y.PhysicalHumanActivityRecognitionUsingWearableSensors.Sensors2015,15,31314–31338.

[23]. Ding, Q.C.; Xiong, A.B.; Zhao, X.G.; Han, J.D. A Review on Researchesand Applications of s-EMG Based Motion Intent Recognition Methods.ActaAutom.Sin.2016,42,13–25.