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Human Adaptive Mechatronics for Gait Rehabilitation using EMG-Based Neuromuscular Control

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ABSTRACT: Human gait impairments caused by neurological disorders, injuries, or aging significantly reduce mobility and quality of life. This paper presents a Human Adaptive Mechatronics (HAM) system designed to assist gait using real-time electromyography (EMG) signals. The system captures muscle activity, processes it through feature extraction, and predicts intended motion using a Support Vector Neural Network (SVNN). Based on predictions, a neuromuscular controller generates control signals to actuate an exoskeleton system. A cybernetic feedback loop ensures adaptive and real-time assistance. Experimental results demonstrate improved gait synchronization and responsiveness, making the system suitable for rehabilitation and assistive applications.

KEYWORDS: Human adaptive mechatronics, gait rehabilitation, EMG signals, neuromuscular control, assistive robotics, prosthetics, exoskeleton systems, biomedical engineering, motion analysis, rehabilitation systems

I. INTRODUCTION

Walking is something we do every day. It is an important thing that we can do. When we walk, our muscles and joints and the systems in our brain all work together.. When people get older or have problems like a stroke or Parkinsons disease it can be very hard to walk.

The number of people in the world is getting bigger very fast. Soon there will be a lot of people who're over 65 years old. When people get older they often have problems with their muscles and balance. It is hard for them to walk.

The old way of helping people walk again is not very good. It is usually done by people. It does not change to help each person individually. Each person walks a little differently. The old systems do not understand this.

Human Adaptive Mechatronics or Human Adaptive Mechatronics is an idea. It combines what people can do with what machines can do. Human Adaptive Mechatronics helps machines understand what people want to do. Then the machines can help. This is very good for people who need help walking again.

This project is about making a system that uses Human Adaptive Mechatronics to help people walk. The system will use sensors to understand what the person wants to do and then it will help them walk using a smart control system. The Human Adaptive Mechatronics system will be very good, at helping people walk again.

The system uses something called EMG signals to predict what movement a person wants to make. Then it helps them make that movement, with the exoskeleton. This is all part of Human Adaptive Mechatronics. It is a really important area of research.

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II. PROBLEM STATEMENT

Gait disorders can really affect peoples independence. Make them rely more on caregivers. There are some problems with the rehabilitation systems we have now.
These include:

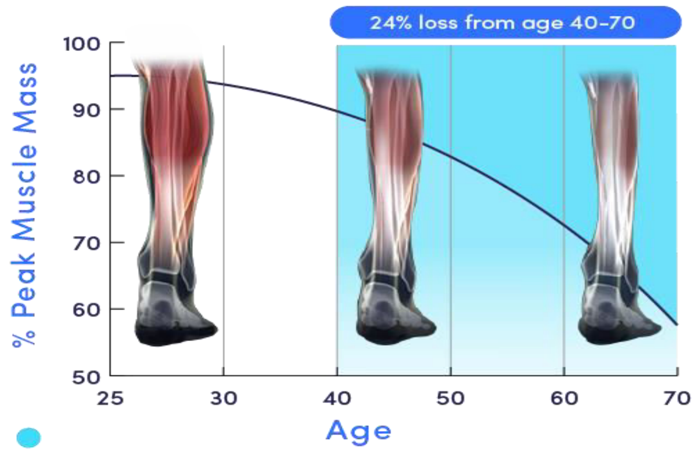
1. They cannot adapt to what's happening at the moment
2. They are not very good at predicting what will happen
3. It takes them a time to respond
4. They do not take into account what people think and feel

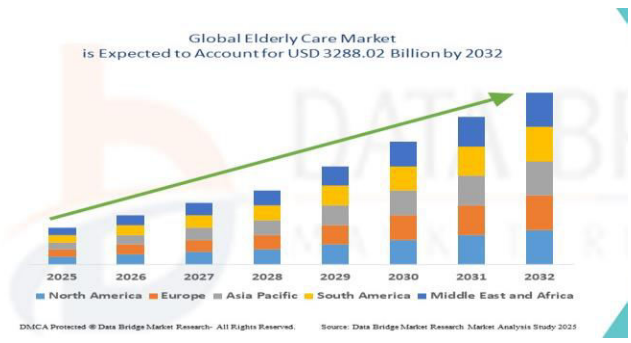
Older people often have muscles and trouble, with coordination, which makes them more likely to fall.
The exoskeleton systems we have now can help people. They do not change what they are doing based on

what the person wants.
So we need a system that's smart and can:

1. Figure out what the person wants to do with their body
2. Change what it is doing away
3. Make it easy for people and machines to work together smoothly

Gait disorders and these systems are a problem and we need to make them better.





III. PROPOSED SYSTEM ARCHITECT

The proposed HAM system is made up of different parts that work together.
These parts are like a team that helps the HAM system do its job.

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3.1 EMG Signal Acquisition
To get the signals from the muscles we put sensors on the skin.These sensors go on muscles like the quadriceps and hamstrings.They catch the electrical signals that the muscles make when they move.

3.2 Signal Processing
The signals we get from the muscles are not very clear. They have a lot of noise that we need to get rid of.
To make them clearer we do a thing to the signals:

a. We use a filter to block out signals that are too high or too low
b. We make all the signals positive so they are easier to work with
c. We make sure all the signals are at the level so they are comparable

3.3 Feature Extraction
Now that we have clean signals we need to find the important parts.We use tools to find these important parts:

a. We calculate the size of the signal
b. We calculate the strength of the signal
c. We calculate how often the signal crosses zero
d. We use a math tool to look at the signal in a different way

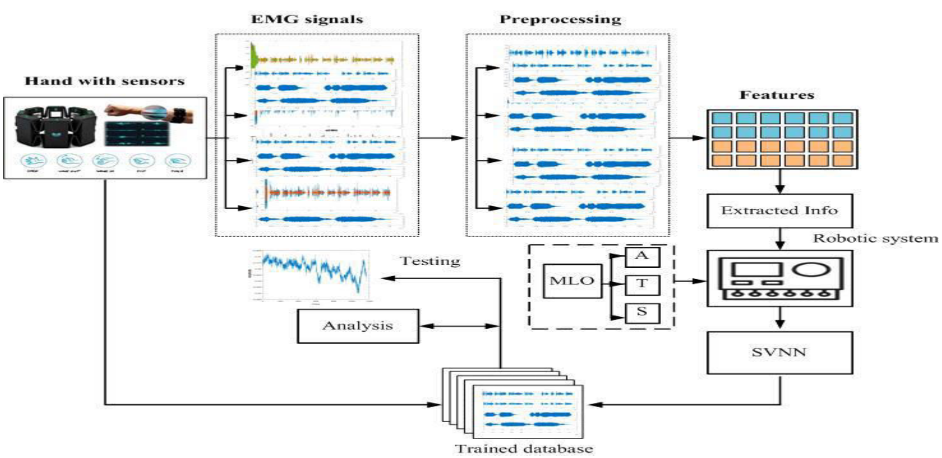
These important parts tell us a lot about what the muscles are doing.

3.4 SVNN-Based Prediction
To figure out what the muscles will do next we use a special kind of computer program.
This program is called a Support Vector Neural Network or SVNN for short.
It is good at figuring out what will happen next. It can adapt to new situations.

3.5 Neuromuscular Controller
The controller is like the brain of the HAM system.
It sends signals to the muscles based on what it thinks they will do next.
It can also change its mind if something unexpected happens.

3.6 Exoskeleton System
The exoskeleton is like a suit that helps people move.
It helps at the hip and the knee, which are joints for walking.

3.7 Cybernetic Feedback Loop
The HAM system is always paying attention to what's happening.
It uses this information to make sure it is doing the thing.
This helps it adapt to situations and do its job better.
The HAM system is always. Getting better thanks, to this feedback loop.



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IV. METHODOLOGY

The system does things in an order.
The system follows an approach to get the job done.

4.1 Data Acquisition
The system collects EMG signals when a person is walking. The EMG signals are collected during parts of the walk like when the heel hits the ground when the foot is in the middle of the step and when the toe leaves the ground.
These parts are:
a. Heel strike
b. stance
c. Toe-off

4.2 Signal Preprocessing
The system removes noise from the signals.It uses filters to clean up the signals and make them smoother and more even. The signal is. Normalized so it is easier to work with.

4.3 Feature Extraction
The system uses tools to get important information from the signals.It looks at the signals in two ways: by time and by frequency. The system uses wavelet transforms to get time-domain and frequency-domain features, from the EMG signals.

4.4 Model Training
The system uses the SVNN model to learn from the labelled EMG data The SVNN model is trained using labelled EMG data so it can make predictions. The more the SVNN model trains, the better it gets at predicting things.

4.5 Control Strategy
The system takes the predicted motion. Turns it into signals that the machine can understand. It uses a controller to convert the predicted motion into actuator signals.

4.6 Real-Time Implementation
The system works in time which means it does things right away. The system operates in time using a cybernetic feedback loop, which helps it make good decisions quickly.

The systems performance is evaluated based on:
a. Accuracy
Our system gets around 95 to 96 percent accuracy in predicting motion.
b. Response Time

The response time is under 100 milliseconds, which allows for real-time help.
System Performance
Smooth working together between the user and the exoskeleton
Better stability while walking
delay

Advantages
a. The system adapts to users
b. It has accuracy
c. It works in time

Limitations
a. Noise, in EMG signals
b. Needs calibration
c. Complex hardware

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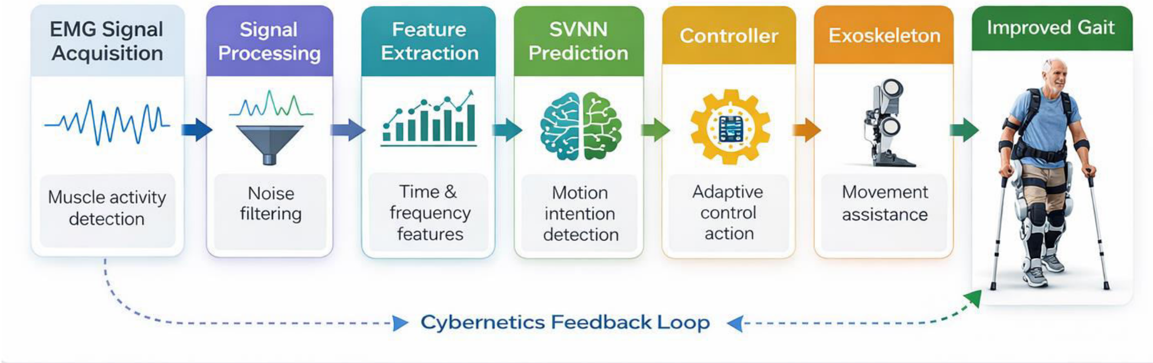

V. CONCLUSION

This paper is about a Human Adaptive Mechatronics system that helps people walk. It uses EMG signals and SVNN to do this. The system puts together signal processing and machine learning to give people the help they need when they need it.

The results show that this system is really good at what it does. It is very accurate. It works in real time. This means that people can use it and it will help them away. The Human Adaptive Mechatronics system is also very good at working with people. This is important, for people who need help walking. The Human Adaptive Mechatronics system can be used to help people get better. It can also be used to help people who need assistance.

REFERENCES

1. Carlo J. De Luca, “The Use of Surface Electromyography in Biomechanics,” *Journal of Applied Biomechanics*, 1997.
2. Kevin Englehart and Bernard Hudgins, “A Robust, Real-Time Control Scheme for Multifunction Myoelectric Control,” *IEEE Transactions on Biomedical Engineering*, 2003.
3. Bernard Hudgins, “Electromyogram Pattern Recognition for Control of Powered Prostheses,” *IEEE Transactions on Biomedical Engineering*, 1993.
4. Kazuo Kiguchi, “Development of a Wearable Exoskeleton for Gait Assistance,” *IEEE International Conference on Robotics and Automation*, 2007.
5. Vladimir Vapnik, *The Nature of Statistical Learning Theory*, Springer, 1995.
6. Hogan Neville, “Impedance Control: An Approach to Manipulation,” *ASME Journal of Dynamic Systems*, 1985.
7. Dario Farina, “Machine Learning for Neural Signal Processing,” *IEEE Reviews in Biomedical Engineering*, 2014.
8. C.Nagarajan and M.Madheswaran - ‘Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques’- Taylor &Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011. DOI: 10.1080/15325008.2010.541746
9. C.Nagarajan and M.Madheswaran - ‘Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter’ - Journal of Electrical Engineering, Vol.63 (6), pp.365-372, Dec.2012. DOI: 10.2478/v10187-012-0054-2
10. C.Nagarajan and M.Madheswaran - ‘Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis’- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011. DOI 10.1007/s00202-011-0203-9
11. S.Tamilselvi, R.Prakash, C.Nagarajan,“Solar System Integrated Smart Grid Utilizing Hybrid Coot-Genetic Algorithm Optimized ANN Controller” Iranian Journal Of Science And Technology-Transactions Of Electrical Engineering, DOI10.1007/s40998-025-00917-z,2025
12. S.Tamilselvi, R.Prakash, C.Nagarajan,“ Adaptive sliding mode control of multilevel grid-connected inverters using reinforcement learning for enhanced LVRT performance” Electric Power Systems Research 253 (2026) 112428, doi.org/10.1016/j.epsr.2025.112428
13. S.Thirunavukkarasu, C. Nagarajan, 2024, “Performance Investigation on OCF and SCF study in BLDC machine using FTANN Controller," Journal of Electrical Engineering And Technology, Volume 20, pages 2675–2688, (2025), doi.org/10.1007/s42835-024-02126-w

14. C. Nagarajan, M.Madheswaran and D.Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- *Acta Electrotechnica et Informatica Journal ,* Vol.13 (2), pp.18-31,April-June.2013, DOI: 10.2478/aeei-2013-0025.

15. C.Nagarajan and M.Madheswaran - 'DSP Based Fuzzy Controller for Series Parallel Resonant converter'- *Springer, Frontiers of Electrical and Electronic Engineering*, Vol. 7(4), pp. 438-446, Dec.12. DOI 10.1007/s11460-012-0212-0.

16. C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- *Iranian Journal of Electrical & Electronic Engineering*, Vol.8 (3), pp.259-267, September 2012.

17. C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007

18. Suganthi Mullainathan, Ramesh Natarajan, "An SPSS and CNN modelling based quality assessment using ceramic materials and membrane filtration techniques", Revista Materia (Rio J.) Vol. 30, 2025, DOI: https://doi.org/10.1590/1517-7076-RMAT-2024-0721

19. M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022

20. T. Lenzi, "Powered Hip Exoskeletons for Walking Assistance," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2013.

21. H. Hermens, "Development of Recommendations for SEMG Sensors and Placement," *Journal of Electromyography and Kinesiology*, 2000.

22. R. Merletti, *Surface Electromyography: Physiology, Engineering and Applications*, Wiley-IEEE Press, 2004.

23. S. Pons, "Wearable Robots: Biomechatronic Exoskeletons," Wiley, 2008.

24. A. Dollar and Hugh Herr, "Lower Extremity Exoskeletons and Active Orthoses," *IEEE Transactions on Robotics*, 2008.

25. N. Hogan, "Adaptive Control of Mechanical Impedance," *MIT Press*, 1984.

26. G. Cybenko, "Approximation by Superpositions of Sigmoidal Functions," *Mathematics of Control*, 1989.

27. L. Hargrove, "Real-Time Pattern Recognition Control Using EMG," *IEEE Transactions on Biomedical Engineering*, 2007.

28. J. Perry, *Gait Analysis: Normal and Pathological Function*, SLACK Incorporated, 1992.

29. ∟S. Winter, *Biomechanics and Motor Control of Human Movement*, Wiley, 2009.

30. IEEE, "IEEE Standard for EMG Signal Processing," 2018.

31. Springer, *Robotics in Neurorehabilitation*, 2016.

32. Elsevier, "Wearable Robotic Systems for Rehabilitation," *Robotics and Autonomous Systems*, 2017.

33. **Kiran, A., Rubini, P., & Kumar, S. S. (2025).** Comprehensive review of privacy, utility and fairness offered by synthetic data. *IEEE Access.*

34. **Gopinathan, V. R. (2024).** Real-Time Financial Risk Intelligence Using Secure-by-Design AI in SAP-Enabled Cloud Digital Banking. *International Journal of Computer Technology and Electronics Communication, 7(6), 9837-9845.*

35. **Udayakumar, R., Elankavi, R., Vimal, R., & Sugumar, R. (2023).** Improved Particle Swarm Optimization with Deep Learning-Based Municipal Solid Waste Management in Smart Cities. *Environmental & Social Management Journal, 17(4).*

36. **Anand, L. (2023).** An Intelligent AI and ML–Driven Cloud Security Framework for Financial Workflows and Wastewater Analytics. *International Journal of Humanities and Information Technology, 5(02), 87-94.*

37. **Soundappan, S. J. (2020).** Big Data Analytics in Healthcare: Applications for Pandemic Forecasting. *International Journal of Advanced Research in Computer Science & Technology, 3(1), 2248-2253.*

38. **Rajasekar, M. (2024).** Real-Time Predictive DevOps Intelligence for Risk-Aware Digital Business Processes in Cloud and SAP Ecosystems. *International Journal of Advanced Research in Computer Science & Technology, 7(4), 10713-10718.*

39. **Poornima, G., & Anand, L. (2024, May). Novel AI Multimodal Approach for Combating Against Pulmonary Carcinoma. In 2024 5th International Conference for Emerging Technology (INCET) (pp. 1-6). IEEE.**

40. **Prabha, P. S., & Rengarajan, A. (2025).** Adaptive Cloud Resource Allocation Using Attention-Driven Deep Reinforcement Learning. *Engineering, Technology & Applied Science Research, 15(6), 29334-29340.*

41. **Jagadeesh, S., & Sugumar, R. (2017).** A Comparative study on Artificial Bee Colony with modified ABC algorithm. *European Journal of Applied Sciences, 9(5), 243-248.*

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42. **Varma, K. K., & Anand, L. (2025, March). Deep Learning Driven Proactive Auto Scaler for High-Quality Cloud Services. In International Conference on Computing and Communication Systems for Industrial Applications (pp. 329-338). Singapore: Springer Nature Singapore.**
43. **Kumar, S. A., & Anand, L. (2025). A Novel EEG-Based Deep Learning Framework for Enhancing Communication in Locked-In Syndrome Using P300 Speller and Attention Mechanisms. KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS, 19(11), 3841-3855.**
44. **Poornima, G., & Anand, L. (2025). Medical image fusion model using CT and MRI images based on dual scale weighted fusion based residual attention network with encoder-decoder architecture. Biomedical Signal Processing and Control, 108, 107932.**
45. **Archana, R., & Anand, L. (2025). Residual u-net with Self-Attention based deep convolutional adaptive capsule network for liver cancer segmentation and classification. Biomedical Signal Processing and Control, 105, 107665.Kumar, S. A., & Anand, L. (2025).** A Novel EEG-Based Deep Learning Framework for Enhancing Communication in Locked-In Syndrome Using P300 Speller and Attention Mechanisms. *KSII Transactions on Internet and Information Systems, 19(11), 3841-3855.*
46. **Rengarajan, A. (2025).** Cloud-Based AI-Driven Threat Detection Framework for Smart Grid Cybersecurity. *International Journal of Future Innovative Science and Technology, 8(6), 16065.*
47. **Murugeshwari, B., Sudharson, K., Panimalar, S. P., Shanmugapriya, M., & Abinaya, M. (2020).** SAFE–Secure Authentication in Federated Environment using CEG Key code.
48. **Raj A. A., & Sugumar, R. (2023).** Early Detection of COVID-19 with Impact on Cardiovascular Complications using CNN Utilising Pre-Processed Chest X-Ray Images. *2023 International Conference on Applied Intelligence and Sustainable Computing (ICAISC), IEEE.*
49. **Jagadeesh, S., & Sugumar, R. (2017). A Comparative study on Artificial Bee Colony with modified ABC algorithm. European Journal of Applied Sciences, 9(5), 243-248.**
50. **Selvi, G. V., Anbarasan, A. B., Murthy, B. A., & Prabavathy, S. (2023).** An Application Oriented Integrated Unequal Clustering Algorithm for Wireless Sensor Network. In *Underwater Vehicle Control and Communication Systems Based on Machine Learning Techniques* (pp. 140-154). CRC Press.
51. **Sruthi, R. S., Ananya, S., & Murugeshwari, B. (2010).** Web Based Virtual Control System Laboratory and On-Line Temperature Control of Electrophoresis Equipment using LabVIEW. *International Journal of Computer Applications, 975, 8887.*
52. **Vimal Raja, G. (2021).** Mining Customer Sentiments from Financial Feedback and Reviews using Data Mining Algorithms. *International Journal of Innovative Research in Computer and Communication Engineering, 9(12), 14705-14710.*
53. MATHEW, A. R. (2025). Neurosecurity and Brain-Computer Interfaces.
54. Soundappan, S. J. (2024). AI-Driven Customer Intelligence in Enterprise Lakehouse Systems Sentiment Mining Governance-Aware Analytics and Real-Time Data Synchronization. International Journal of Advanced Engineering Science and Information Technology (IJAESIT), 7(5), 14905.
55. Mathew, A. (2025). Human–AI Collaboration in Security Operations: Measuring Alert Trust, Automation Bias, and Analyst Upskilling in AI-Augmented SOC Environments. International Journal of Computer Technology and Electronics Communication, 8(5), 11375-11380.
56. Soundappan, S. J. (2022). AI-Based Fault Detection and Isolation for Reliability in Modern Power Systems. International Journal of Research Publications in Engineering, Technology and Management (IJRPETM), 5(4), 7106-7110.
57. **Poornima, G., & Anand, L. (2024, April). Effective Machine Learning Methods for the Detection of Pulmonary Carcinoma. In 2024 Ninth International Conference on Science Technology Engineering and Mathematics (ICONSTEM) (pp. 1-7). IEEE.Garg, V. K., Soundappan, S. J., & Kaur, E. M. (2020).** Enhancement in intrusion detection system for WLAN using genetic algorithms. *South Asian Research Journal of Engineering and Technology, 2(6), 62–64.*
58. Rengarajan, A., Jayakumar, C., & Sugumar, R. (2012). Optimization Of Recent Attacks Using Internet Protocol. National Journal of System and Information Technology, 5(1), 8.
59. Mathew, A. (2024). AI TRiSM: Trust, Risk, and Security Management in Cybersecurity. Cybersecurity, 4(3), 84-90.
60. Mathew, A. (2025). Deep seek vs. ChatGPT: A deep dive into AI Language mastery. Int J Multidisciplinary Res, 7(1), 1-5.