SEMS

Queen Mary University of London

EMS715P - Extended Research Project - 2024/25

CW1: Directed Learning Assignment 1 (DLA1)

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2024 Nov.

MSc EMS715 Extended Research Project

Directed Learning Assignment 1 (DLA1) Article 1 of 3

Student Name:	***Cao Zichong***	**Student ID:**	***240022835***
Full Title of MSc Degree Programme:	***Robotics and AI***		
MSc Project Area of Interest:	***VR for soft robotic exoskeletons***		

Part A	
Article Title:	Soft robotic glove for kinesthetic haptic feedback in virtual reality environments
Source Details:	**Authors:** Saurabh Jadhav, Vikas Kannanda, Bocheng Kang, Michael T. Tolley, Jurgen P. Schulze **Year:** 2017 **Conference/Publication:** IS&T International Symposium on Electronic Imaging 2017: The Engineering Reality of Virtual Reality **Pages:** 19th–24th(6) **Publisher:** Society for Imaging Science and Technology
DOI:	*https://doi.org/10.2352/ISSN.2470-1173.2017.3.ERVR-102*
Relevance of article to MSc Extended Research Project:	This paper develops a low-cost soft robotic haptic glove for kinesthetic force feedback. It delves into how haptic feedback can improve immersion in virtual reality environments and explores how interaction design can be improved. The article demonstrates user evaluation methods and technological solutions (e.g. McKibben muscles and fluid control systems), which can support research in virtual reality systems, wearable technology or user experience optimisation. My MSc research topic was in the areas of virtual reality, human-computer interaction or haptic feedback systems, and this thesis is highly relevant to my research in these areas.

Part B	
Article's Background and Rationale:	This article is based on the limitations of current virtual reality systems, which rely primarily on audio and visual feedback for immersion. It mentions that existing haptic systems are limited to tactile stimuli such as vibration and cannot provide kinesthetic feedback. The authors argue that integrating kinesthetic force feedback can significantly enhance user immersion and interactivity in VR environments.
Article's Aim(s):	The main objective of this article is to develop a wearable soft robotic glove that provides kinesthetic haptic feedback in VR environments to improve immersive experiences.
Article's Objective(s):	The aim of the article is to design a soft, low-cost, mass-manufacturable haptic glove using McKibben muscle actuation. It will provide realistic force feedback when the user interacts with virtual objects such as piano keys in a VR environment. Informal user studies were also conducted to evaluate the effectiveness of the glove in enhancing immersion and to ensure that the hand size is compatible with the majority of users.
Article's Method(s):	The article uses a data collection-system design-virtual testing-user testing approach for the project content. The authors used anthropometric data to design a soft exoskeleton that fits most hand types. The device combines VR hardware with a custom fluid control board and Unity for VR simulation. In the virtual testing phase, the article designed a virtual piano playing environment, and in the user testing phase an informal pilot study with 15 participants was conducted to assess immersion and usability.
Article's Finding(s):	The gloves designed for the study greatly enhanced the user's immersive experience, as demonstrated by the fact that 11 out of 15 participants felt that the gloves accurately

	mimicked keystrokes. Users described the experience as ‘mesmerising’ and ‘amazing’. The gloves are commercially viable, costing about $65 to produce and users are willing to pay between $40 and $200. Users also noted some limitations, including a slight lag in the fluid control panel and a slightly longer time required to wear the gloves.
Article’s Conclusion(s):	The study concludes that this soft robotic glove design effectively enhances immersion in VR environments by providing realistic haptic feedback. The design is low-cost, adaptable to different hand sizes, and compatible with existing VR systems, and is expected to be widely adopted in VR applications. Future improvements include miniaturisation of the control panel, reduction of lag and introduction of more degrees of freedom for complex interactions.

Part C	
Citation #1 citation (author, year & title) and explain its importance to the article:	**Content:***"Synthetic haptic user interfaces greatly increase the degree of immersion in virtual environments"[5]* **Source Citation:**Mihelj, M., & Podobnik, J. (2012). Haptics for Virtual Reality and Teleportation. Springer, Intelligent Systems, Control and Automation, Volume 64. **Contribution:**This citation provides foundational support for the importance of haptic feedback in VR environments and establishes a theoretical basis for the research. By highlighting the role of haptics in enhancing immersion, it demonstrates the importance of developing kinesthetic feedback gloves as a means of overcoming the limitations of current VR interfaces.
Citation #2 citation (author, year & title) and explain its importance to the article:	**Content:***"Haptic rendering of 3D objects using ultrasound provides tactile feedback but lacks compelling kinesthetic force feedback"[13]* **Source Citation:**Yasuaki Onai et al., "Adding Texture to Aerial Images Using Ultrasounds," Asia Haptics 2014. **Contribution:**The citation highlights the limitations of existing haptic technologies, particularly haptic-only approaches like ultrasound-based rendering. It emphasises the need for the proposed gloves to provide kinesthetic feedback, which alone cannot replicate the fully immersive senses required for a realistic VR experience. This further justifies the focus of research on kinesthetic force feedback.

Part D	
How could the article inform future work state how and why?	**How:** The article highlights the potential of soft robotics to create user-friendly haptic feedback systems. Future research could explore extending the degrees of freedom of gloves to enable complex hand movements such as grasping and manipulating objects in VR environments. Next research could attempt to combine haptic feedback with motion feedback to improve realism. **Why:** The results of the study demonstrate the critical role of haptics in enhancing virtual reality immersion. This research can address identified limitations and reduce system lag and component miniaturisation. It can also refine haptic systems, paving the way for more realistic interactive experiences and commercially viable VR interactions.
Briefly summarise how the article could inform your extended research area – *how and why*?	**How:** My Masters research focuses on virtual reality systems, wearable technology and human-computer interaction. This article provided me with a low-cost, adaptable design solution for immersive feedback. It provides a framework for integrating sensory technologies into virtual reality systems to improve the user experience. **Why:** With an emphasis on integrating soft robotics with VR, this article provides inspiration for developing innovative user-friendly interfaces. Its practical approach from prototyping to user evaluation provided valuable guidance for implementing and evaluating similar systems in my research.

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Directed Learning Assignment 1 (DLA1)   Article 2 of 3

Student Name:	***Cao Zichong***	**Student ID:**	***24022835***
Full Title of MSc Degree Programme:	***Robotics and AI***		
MSc Project Area of Interest:	***VR for soft robotic exoskeletons***		

Part A	
Article Title:	Breaking the Tracking: Enabling Weight Perception using Perceivable Tracking Offsets
Source Details:	**Authors:** Michael Rietzler, Florian Geiselhart, Jan Gugenheimer, Enrico Rukzio **Year:** 2018 **Conference/Proceedings:** CHI Conference on Human Factors in Computing Systems (CHI '18) **Pages:** Paper No. 128, 1–12 **Publisher:** Association for Computing Machinery (ACM) **Location:** Montreal, QC, Canada
DOI:	*https://dl.acm.org/doi/10.1145/3173574.3173702*
Relevance of article to MSc Extended Research Project:	The article introduces a new approach to pseudo-haptic weight feedback that uses perceptible tracking offsets to simulate weight perception in VR. The article also employs a force-based model that simulates gravity and the effort required to lift an object through visual cues. This pseudo-haptic technique can complement the physical feedback provided by soft robotic systems to enhance the realism of weight simulation. This is highly relevant to my research.

Part B	
Article's Background and Rationale:	**Background:** Current virtual reality systems typically lack effective weighted haptic feedback and rely only on visual or tactile cues, which limits immersion. This paper builds on this by utilising a pseudo-haptic technique to attempt perceptual compensation. **Rationale:** Weight perception is a key component of realistic virtual reality interaction. By introducing perceptible tracking offsets, this research provides a lightweight, scalable solution that enhances the user's experience in VR without the need for a complex hardware setup.
Article's Aim(s):	Developing a pseudo-haptic feedback mechanism for weight perception in VR using perceptible tracking offsets to simulate the sensation of lifting different weight objects.
Article's Objective(s):	Explore how visual manipulation can create the illusion of weight in VR, bridge the gap between traditional haptic feedback systems and lightweight, hardware-independent solutions, and validate the effectiveness of this approach in enhancing user immersion and interaction with virtual objects.
Article's Method(s):	The article devises a force model in which tracking offsets represent the perceived weight of an object. The offsets can be used to simulate gravitational pull and lift forces. The article also devised two visual offset manipulation techniques, including obvious offsets and subtle cues. Finally these methods are implemented in a VR gaming application and tested and evaluated to measure user perception and engagement.
Article's Finding(s):	Pseudo-haptics did have an effect, with users successfully perceiving weight differences when lifting virtual objects, confirming that visual tracking offsets can simulate weight. This method was well received, with participants reporting improved immersion and convincing perception of object weight. However, prolonged interactions or overly exaggerated offsets can cause discomfort as well as reduce the accuracy of weight perception.
Article's Conclusion(s):	Pseudo-haptics by tracking offsets is a feasible and effective way to simulate weight in virtual

	reality. This method can replace mechanical systems, reducing complexity and cost. Future attempts could be made to combine pseudo-haptics with physical systems to further enhance realism. Hybrid feedback mechanisms can also be created to blend visual manipulation with physical resistance for more immersive VR interactions.

Part C	
Citation #1 citation (author, year & title) and explain its importance to the article:	**Content:**"*Lécuyer et al. contributed that participants perceive friction, gravity, or viscosity when a virtual object was slowed down using a 2D and 3D mouse."[18]* **Source Citation:**Lécuyer, A., Burkhardt, J.M., & Etienne, L. (2004). Feeling bumps and holes without a haptic interface: The perception of pseudo-haptic textures. **Contribution:**It strengthens the theoretical framework of pseudo-haptics technology by demonstrating that tactile sensations such as gravity and friction can be effectively modelled by visual feedback. It supports the authors' argument that pseudo-haptic techniques are not only feasible but can be extended to VR systems, i.e., weight perception in this study.
Citation #2 citation (author, year & title) and explain its importance to the article:	**Content:**"*Dominjon et al. (2005) used a pseudo-haptic approach to simulate weight. Participants compared the weight of virtual balls seen on a computer screen while lifting a real ball. When the visually sensed motion of the object was amplified, they observed that the weight was perceived as less."[7]* **Source Citation:**Dominjon, L., Lécuyer, A., Burkhardt, J.M., Richard, P., & Richir, S. (2005). Influence of control/display ratio on the perception of mass of manipulated objects in virtual environments. **Contribution:**This study provides basic concepts of pseudo-haptics, demonstrating how altering visual feedback can affect weight perception. The cited study serves as a rationale for the authors' use of tracking offsets to create the weight illusion, highlighting the potential of visual manipulation in immersive VR applications.

Part D	
How could the article inform future work state how and why?	**How:** Expand the combined feedback system and explore combining these visual techniques with physical systems such as soft robotic exoskeletons to achieve more realistic and nuanced feedback in VR. The concept could also be applied to complex VR tasks to enhance the realism of interacting with virtual tools or objects. **Why:** This research provides a low-cost, hardware-light approach to weight simulation. Combining pseudo-haptics with physical systems can produce hybrid solutions for scalability and immersion, addressing the limitations of current standalone haptic systems.
Briefly summarise how the article could inform your extended research area – *how and why*?	**How:** By combining perceptible tracking offsets with a soft exoskeleton system, explore how visual manipulation can dynamically simulate large-scale weight differences and how finer, more tactile weight feedback can be provided by soft robotic gloves. **Why:** To reduce reliance on purely mechanical or pneumatic systems, which can be bulkier and more costly. Provide a scalable solution to feel the difference in weight of different objects in various VR scenarios.

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Directed Learning Assignment 1 (DLA1)   Article 3 of 3

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Full Title of MSc Degree Programme:	***Robotics and AI***		
MSc Project Area of Interest:	***VR for soft robotic exoskeletons***		

Part A	
Article Title:	Triggermuscle: Exploring Weight Perception for Virtual Reality Through Adaptive Trigger Resistance in a Haptic VR Controller
Source Details:	**Authors:** Carolin Stellmacher, Michael Bonfert, Ernst Kruijff, Johannes Schöning **Year:** 2022 **Journal:** Frontiers in Virtual Reality **Volume:** 2 **Article Number:** 754511 **Publisher:** Frontiers Media S.A.
DOI:	https://dl.acm.org/doi/10.1145/3173574.3173702
Relevance of article to MSc Extended Research Project:	This paper explores a novel haptic mechanism for weight perception in VR through adaptive triggered resistance, which is implemented using the HTC Vive controller. It makes an important contribution to understanding how haptic feedback can enhance weight perception in VR environments, and has greatly assisted my research.

Part B	
Article's Background and Rationale:	**Background:** Weight perception in VR remains a challenge due to the limitations of consumer-grade VR controllers and existing haptic technologies. Traditional pseudo-haptic techniques rely on visual manipulation but lack the haptic cues required for realistic weight feedback. **Rationale:** In VR applications, accurate weight feedback enhances immersion and interactivity. The system can simulate the level of effort involved in manipulating virtual objects of different weights by dynamically adjusting the trigger resistance. This provides a practical and scalable alternative to exoskeletons or external force feedback devices.
Article's Aim(s):	Design and evaluation of a haptic VR controller, Triggermuscle, which uses adaptive triggered resistance to simulate weight perception of virtual objects.
Article's Objective(s):	To allow users to experience different virtual object weights by adjusting the resistance of the controller triggering mechanism. Evaluate the effectiveness of this approach in enhancing weight discrimination and user immersion, and explore the user's sensitivity to changes in resistance and how these can be linked to changes in weight.
Article's Method(s):	The study integrated the Triggermuscle into the HTC Vive controller, using spring-loaded machine braking to continuously and dynamically adjust the trigger resistance to simulate the effort required to lift a virtual object. This was followed by two user studies in a testing session to assess the actual experience of weight perception.
Article's Finding(s):	The adaptive trigger mechanism effectively created a novel form of haptic feedback without the need for additional complex hardware. Some participants were able to distinguish weight differences based on trigger resistance, associating objects with greater resistance with heavier objects. However, sensitivity varied greatly between users and not all users were able to notice resistance differences. Individuals also vary in their sensitivity to haptic feedback.
Article's Conclusion(s):	The Triggermuscle system demonstrates the potential of adaptive resistance to simulate VR

	controller weight perception in a lightweight and cost-effective manner. In the future, this triggered resistance mechanism could be combined with other haptic technologies to improve weight recognition and realism in VR interactions.

Part C	
Citation #1 citation (author, year & title) and explain its importance to the article:	**Content:***"Suchoski et al. (2018) explored how scaling inertial forces can alter weight perception in VR. Their approach involved dynamically adjusting force feedback to simulate weight differences."* **Source Citation:**Suchoski, J. M., Martinez, S., & Okamura, A. M. (2018). Scaling inertial forces to alter weight perception in virtual reality. Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), pp. 484 – 489. **Contribution:**This research provides foundational work for modelling weight perception using force scaling. It provides support for Triggermuscle's methodology by illustrating how small changes in feedback can significantly affect perceived object weight.
Citation #2 citation (author, year & title) and explain its importance to the article:	**Content:***"Westling and Johansson (1984) studied how precision grip force is controlled during lifting tasks, providing insights into human sensorimotor responses to weight variations."* **Source Citation:**Westling, G., & Johansson, R. S. (1984). Factors influencing the force control during precision grip. Experimental Brain Research, 53, pp. 277 – 284. **Contribution:**It emphasises the biological basis of weight perception and the role of resistance in grasping and lifting tasks.The Triggermuscle system builds on these principles, replicating similar force variations through adaptive resistance mechanisms, enhancing the realism of the virtual interaction.

Part D	
How could the article inform future work state how and why?	**How:** Adaptive trigger resistance mechanisms can be combined with wearable haptic devices such as soft robotic exoskeletons to provide haptic and kinesthetic feedback. Tailoring the resistance profile to an individual's sensorimotor capabilities, or combining it with visual cues from a hybrid feedback system, could increase the user's sensitivity to changes in resistance. **Why:** This research provides a scalable, hardware-efficient solution for weight perception. Its adaptive resistance mechanism lays the foundation for more immersive VR systems, bridging the gap between pseudo-haptic and physical feedback approaches.
Briefly summarise how the article could inform your extended research area – *how and why*?	**How:** Adaptive Trigger Resistance complements the force feedback of soft robotic gloves, providing localised resistance for finer control and weight recognition to enhance the realism of lifting and manipulating virtual objects. **Why:** Adaptive triggering mechanisms meet the goal of accurate weight simulation, providing a lightweight, cost-effective complement to exoskeleton systems. Combining this mechanism with the physical feedback of a soft exoskeleton improves the user experience in applications such as rehabilitation, training, and immersive VR scenarios.