



Co-funded by the
Erasmus+ Programme
of the European Union

A Multi-Modal Auditory-Visual-Tactile e-Learning Framework

**Filippo Sanfilippo¹, Tomas Blažauskas², Martynas Girdžiūna², Airidas Janonis², Eligijus Kiudys²,
and Gionata Salvietti³**

¹ University of Agder (UiA), Grimstad, Jon Lilletuns vei 9, 4879, Grimstad, Norway.
filippo.sanfilippo@uia.no

² Kaunas University of Technology, Studentu str. 50, LT-51368 Kaunas, Lithuania

³ University of Siena, 53100, Siena, Italy

**This work is supported by the European Union through the Erasmus+ Program under Grant 2020-1-NO01-KA203-076540, project title
“AugmentedWearEdu”,
<https://augmentedwearedu.uia.no/>**

Introduction



Co-funded by the
Erasmus+ Programme
of the European Union

- E-Learning courses have been boosted by the Covid-19 pandemic;
- E-Learning brings several possibilities in terms of interactions for the students;

[1] Sanfilippo, F., Blažauskas, T., Salviati, G., Ramos, I., Vert, S., Radianti, J., Majchrzak, T.A.: Integrating VR/AR with haptics into STEM education. In: Proc. of the 4th International Conference on Intelligent Technologies and Applications (INTAP 2021). Springer (2021), accepted for publication.



Motivation

- Wearable haptic devices that enable a multi contact interaction with virtual objects;
- Opportunity of new e-Learning contents that include tactile experience;
- Necessary to develop systems with a reduced cost by using commercially available off-the-shelf (COTS) components.



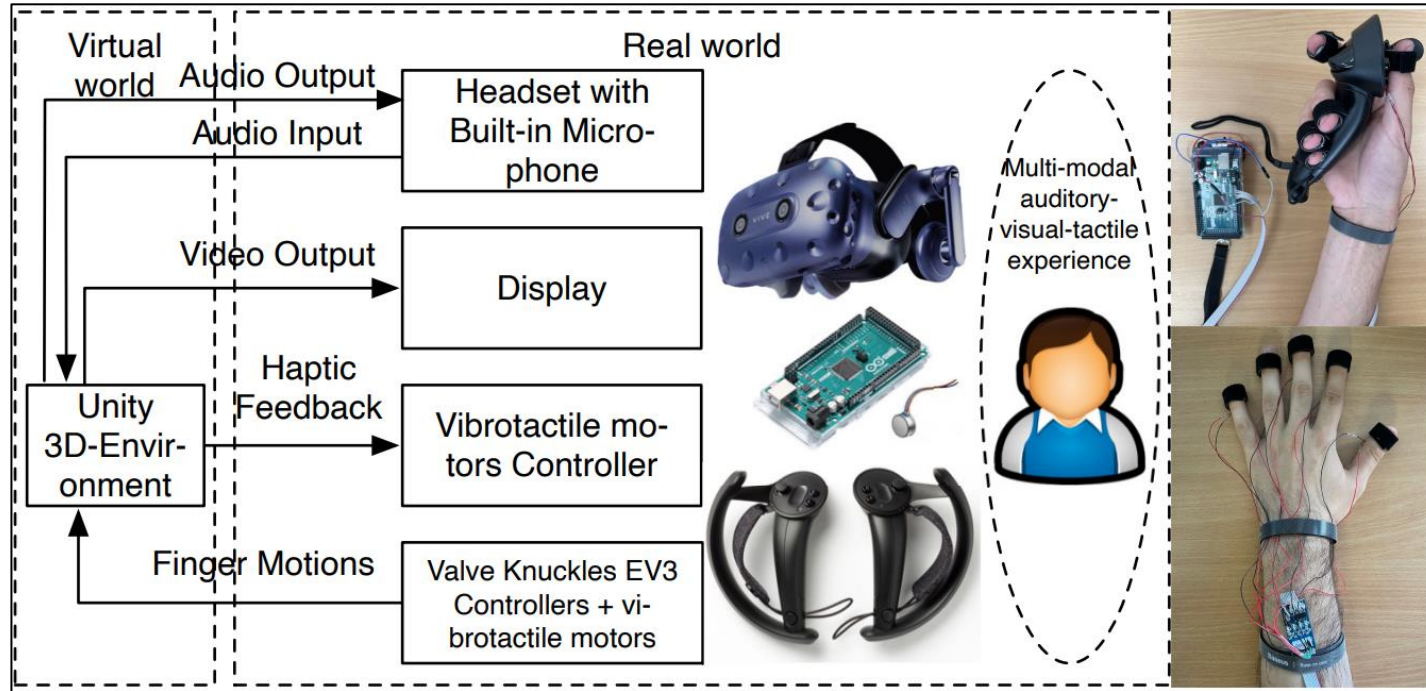
[2] Facebook Technologies, LLC. "Oculus Touch". 2021. url: <https://www.oculus.com/rift/>

[3] Valve Corporation. "Valve Index Controllers". 2021. url: https://store.steampowered.com/app/1059550/Valve_Index_Controllers/

[4] HaptX Inc. "HaptX Gloves". 2021. url: <https://haptx.com/>



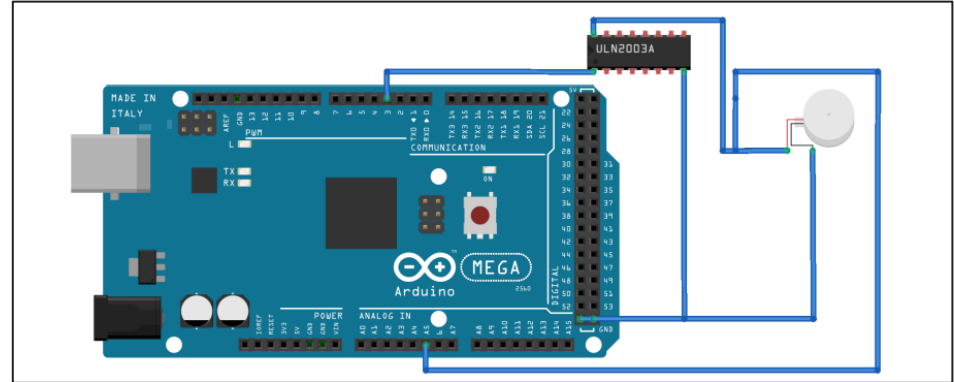
Framework architecture



Hardware implementation



Co-funded by the
Erasmus+ Programme
of the European Union



Rendering strategies



Co-funded by the
Erasmus+ Programme
of the European Union





Equations

• Force calculation: $F_i = k(t - d_i) - k_v v_i,$

• Vibration actuator: $D_i = \frac{\alpha F_i - F_{min}}{F_{max} - F_{min}},$

• Pitch frequency: $f_i = f_{min} \frac{\beta(F_i - F_{min})(f_{max} - f_{min})}{F_{max} - F_{min}},$

• Wavelength: $\lambda_i = f_{min} \frac{\gamma(F_i - F_{min})(\lambda_{max} - \lambda_{min})}{F_{max} - F_{min}},$

F – force;

k – stiffness;

k_v – damping constants;

t – distance tolerance of contact;

d – distance value of contact;

V_i – approaching velocity;

D – vibration actuator;

α – scaling factor;

F_{min} and F_{max} – minimum and maximum renderisable forces respectively;

f – pitch frequency

β – scaling factor

$f_{min} - f_{max}$ minimum and maximum renderisable pitch frequency

λ – wavelength range (visible spectrum)

γ – scaling factor

$\lambda_{min} - \lambda_{max}$ minimum and maximum renderisable wavelength frequency

Interaction with virtual object



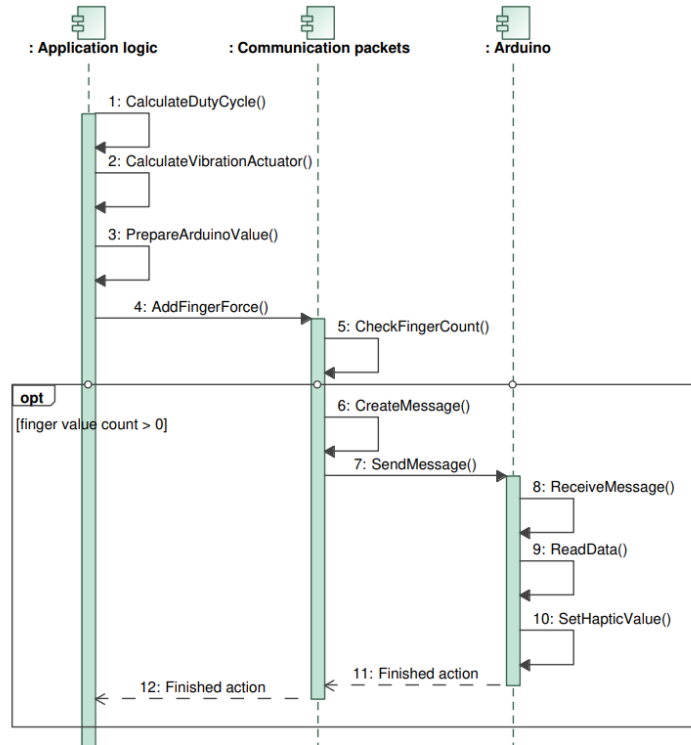
Co-funded by the
Erasmus+ Programme
of the European Union



Tactile feedback rendering



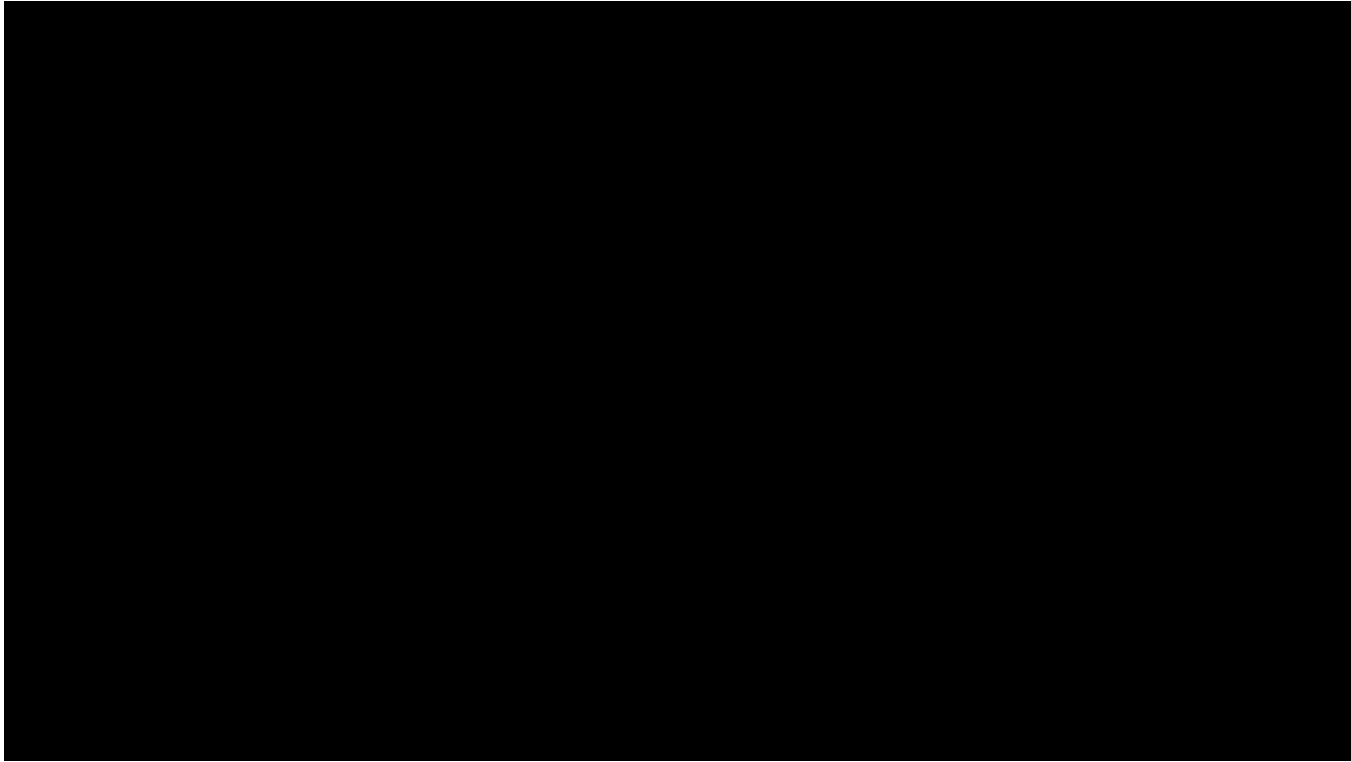
Co-funded by the
Erasmus+ Programme
of the European Union



Human subject study

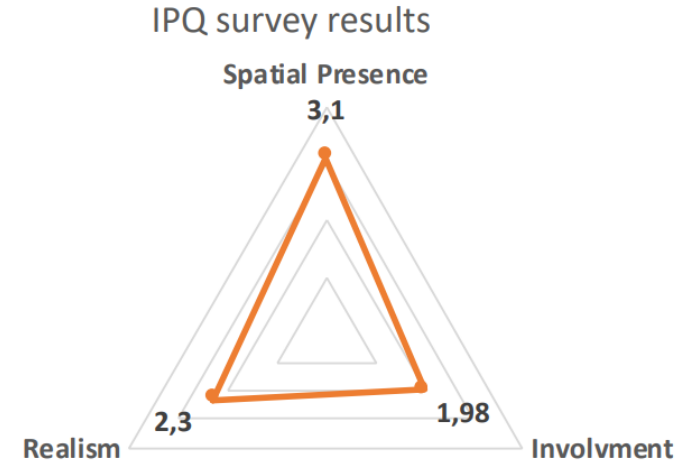
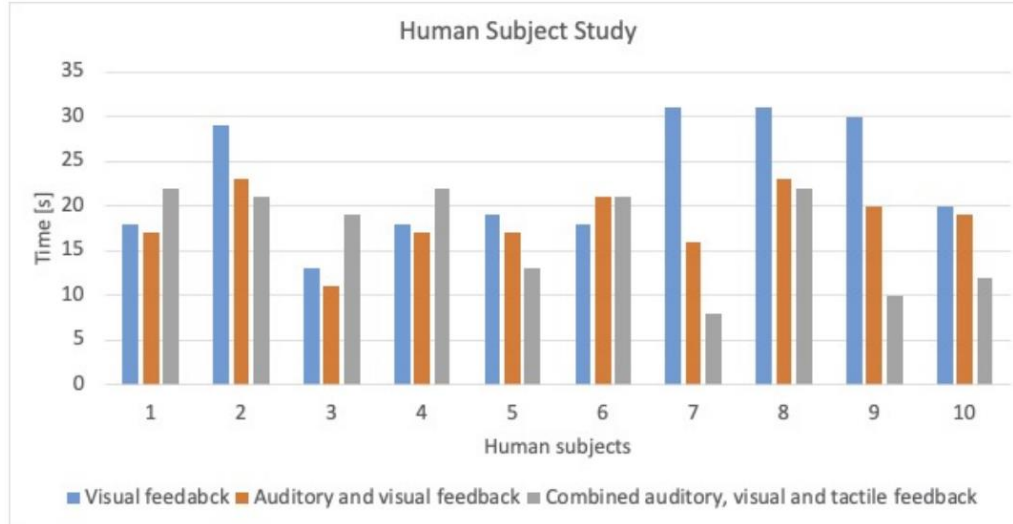


Co-funded by the
Erasmus+ Programme
of the European Union





Experimental results



[5] Panahi, S.M., Fathi, A.A., Azad, F.P., Montazer, G.A.: Reliability and validity of igroup presence questionnaire (IPQ) (2009).

Conclusions and Future work



Co-funded by the
Erasmus+ Programme
of the European Union

- Merge of virtual reality (VR) tools with a novel wearable haptic device and vibrotactile actuators helped in achieving the immersive learning experience;
- Conducted human subject research helped evaluate the developed framework;
- The framework could be used to develop teaching modules;





Co-funded by the
Erasmus+ Programme
of the European Union

Thank you for your attention!

Do you have any questions?





Co-funded by the
Erasmus+ Programme
of the European Union

References

1. Sanfilippo, F., Blažauskas, T., Salvietti, G., Ramos, I., Vert, S., Radianti, J., Majchrzak, T.A.: Integrating VR/AR with haptics into STEM education. In: Proc. of the 4th International Conference on Intelligent Technologies and Applications (INTAP 2021). Springer (2021), accepted for publication.
2. Facebook Technologies, LLC. “Oculus Touch”. 2021. url: <https://www.oculus.com/rift/>
3. Valve Corporation. “Valve Index Controllers”. 2021. url: https://store.steampowered.com/app/1059550/Valve_Index_Controllers/
4. HaptX Inc. “HaptX Gloves”. 2021. url: <https://haptx.com/>
5. Panahi, S.M., Fathi, A.A., Azad, F.P., Montazer, G.A.: Reliability and validity of igroup presence questionnaire (IPQ) (2009)