1. Adaptive Virtual Cycling Tour for Cardiovascular Training

Key Equipment: Static Bike, Meta Quest 3

Tools & Libraries: Unity (C#), Optional HR sensor API

Learning Outcomes:

- Integrate hardware with immersive environments
- Apply game design for physical training engagement
- Evaluate perceived exertion and user experience

Subtasks:

- Integrate the programmable bike with Unity and Meta Quest 3. Adapt resistance dynamically.
- Create or use a dynamic virtual environment of a city. (e.g. Carla or other)
- Add real-time physiological feedback (e.g., HR sensor or proxy via cadence).
- Program exercise and simulate resistance using headwind as a proxy.
- Generate results of Cadence wrt difficulty, fatigue etc.
- Conduct user testing to evaluate performance and engagement.

2. Fatigue modeling Using Camera-Based Motion Tracking

Key Equipment: Camera, XR Headset

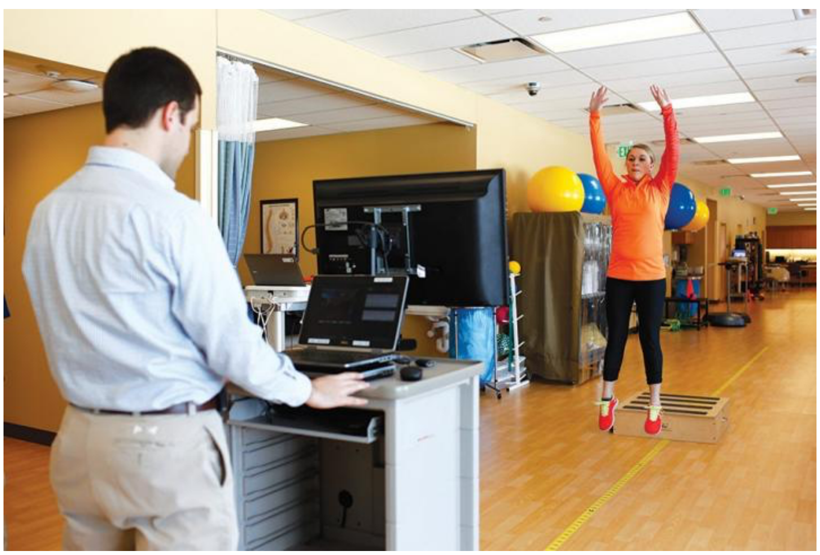
Tools & Libraries: Unity, OpenPose or MediaPipe, Python, OpenSim

Learning Outcomes:

- Implement vision-based tracking for physical therapy
- Design XR games for motor skill rehabilitation
- Analyze movement using OpenSim biomechanics toolkit

Subtasks:

- Set up real-time skeletal tracking using OpenPose or MediaPipe.
- Add feedback and scoring for range, accuracy, and speed.
- Include session logging and feedback visualization.
- Export joint trajectories to OpenSim for biomechanical evaluation.
- Model and detect fatigue. Analyze changes in velocity, symmetry, and tremor.
- Validate with self-reported fatigue ratings.
- Prototype a real-time fatigue alert system.



3. XR Climbing Tutor with Real-Time Visual Guidance

Key Equipment: Climbing Wall, Hololens or HTC Vive

Tools & Libraries: Unity (C#), Open Pose, etc Basic IMUs

Learning Outcomes:

- Use MR to enhance physical skill acquisition
- Apply spatial mapping and route optimization
- Provide motion feedback in complex 3D activities

Subtasks:

- Digitize the climbing wall layout for the MR system.
- Overlay optimal paths or gestures using MR cues.
- Track foot and hand placement using visual markers or small IMUs.
- Use OpenPose or any other tool for posture estimation.
- Use OpenSim to estimate the muscles activated for each posture. Assume or measure foot forces

4. Remote Gait Analysis using Camera-Based Tools and XR feedback

Key Equipment: Camera

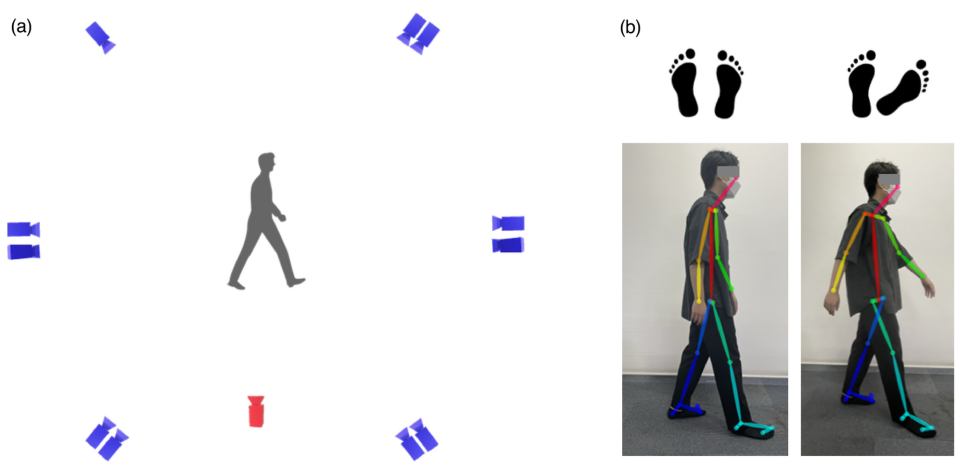
Tools & Libraries: Python, OpenPose/MediaPipe, OpenSim

Learning Outcomes:

- Extract and analyze gait metrics from 2D/3D video
- Design telehealth-friendly biomechanical tools
- Use OpenSim for musculoskeletal modeling

Subtasks:

- Build a guided video capture interface.
- Extract gait features (stride length, cadence, asymmetry).
- Include visual tracking sensors (VIVE) to encode feet distance and orientation
- Display gait metrics and changes over time.
- Model gait retraining procedure and give visual feedback in XR



5. Embodied Movement Feedback in XR for Learning Movement Sequences

Key Equipment: ROCOCO Suit, XR Headset

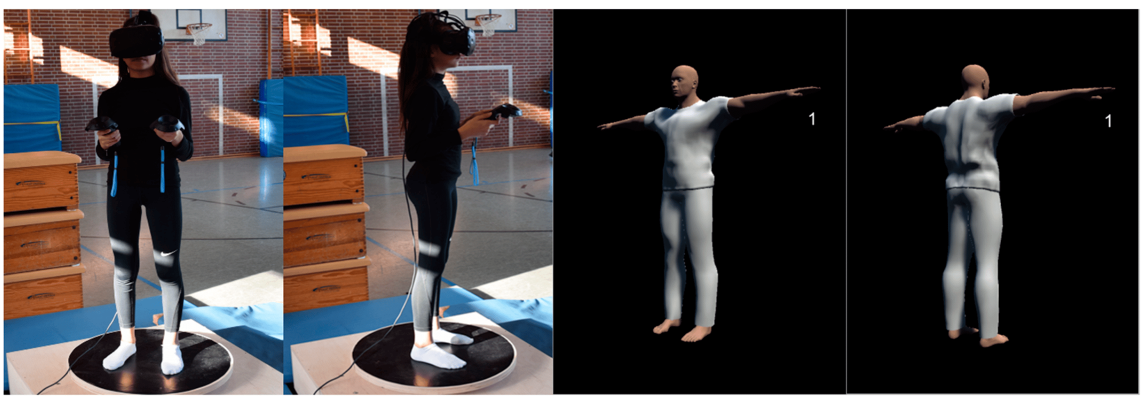
Tools & Libraries: Unity, OpenSim, Rococo interface

Learning Outcomes:

- Capture and analyze expert vs. learner motion
- Provide real-time avatar feedback for movement correction
- Use OpenSim to compare kinematic patterns and loads

Subtasks:

- Record expert movements using ROCOCO suit.
- Create a training app with first- or third-person view of avatar guidance.
- Record student attempts and compare against expert.
- Provide real-time guidance and similarity scores.
- Analyze joint kinematics/loads and coordination using OpenSim.



6. MR manipulation of physiology for training and preoperative planning

Key Equipment: Meta Quest 3

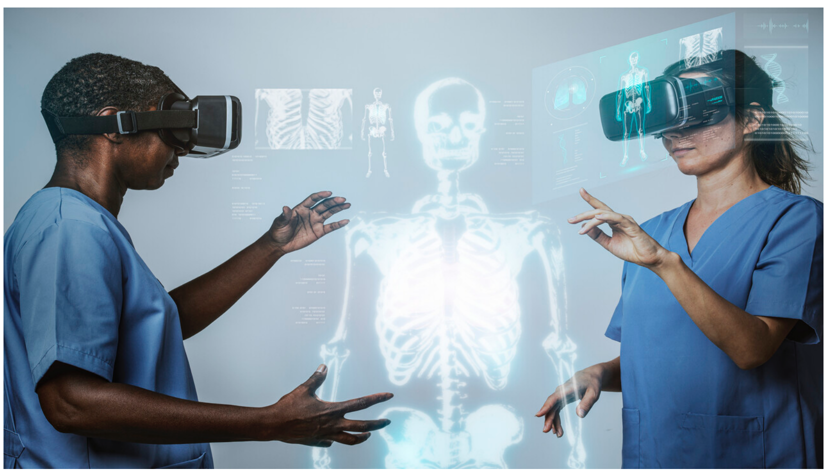
Tools & Libraries: Unity

Learning Outcomes:

- Design MR educational environment
- Manipulate organs, systems tools
- Interactive rendering and simulation of Physiology

Subtasks:

- Create a medical environment and import the Physiology model
- Define interactions with the elements
- Design a medical procedure and define interactions of specific organs and medical tools
- Allow the user to perform interactions
- Perform a user study
- Perform collaborative rendering and manipulation



7. Predictive Simulation of Weight – Bearing Gait with MoCo

Tools & Libraries: OpenSim, Moco

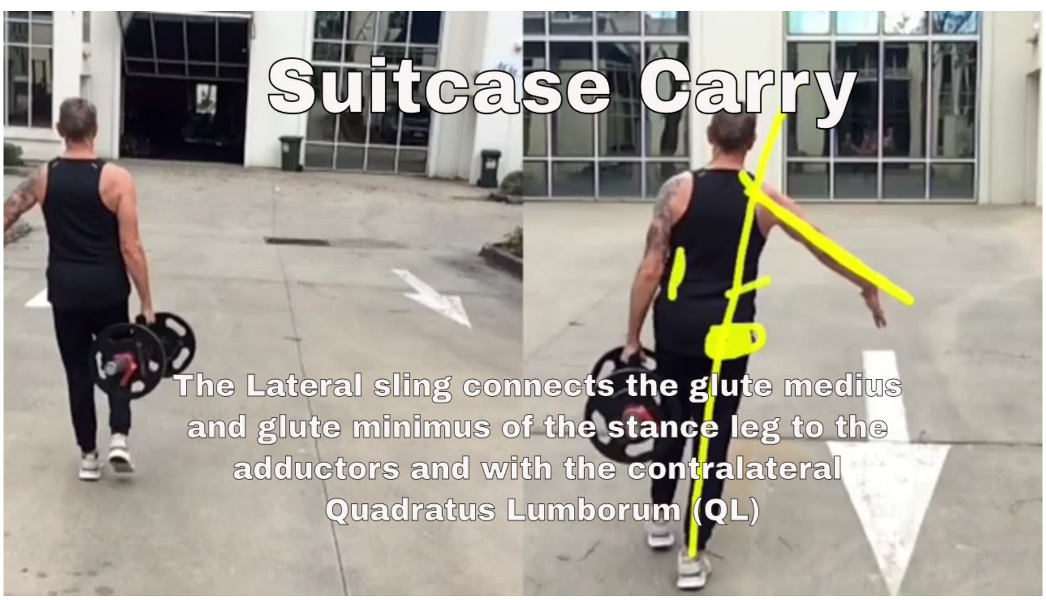
Weight-bearing gait is one of the most common daily life activities. Humans use backpacks to go to work, school, shopping etc. In this project, you are asked to perform what-if scenarios of gait using a suitable predictive biomechanics tool.

Learning Outcomes:

- Biomechanics simulation
- Kinematics, dynamics manipulation
- Predictive tools

Subtasks:

- Use a simple planar model and modify accordingly a given script in Matlab/Python to perform a predictive simulation of gait.
- Experiment with three different gait speeds.
- Model Weight-Bearing by adding a body on the model's back and suitable joints. The mass and mass distribution of the added body resembles a backpack.
- Experiment with different distributions of the backpack load (e.g., from left to right shoulder).
- Repeat the experiments with the different gait speeds.
- Perform Joint Reaction Analysis to evaluate knee joint loads and compare them with loads from Osteoarthritis datasets.
- References: [1], [2]



8. Simulation of Cycling Pedalling through OpenSim & MoCo

Tools & Libraries: OpenSim, Moco

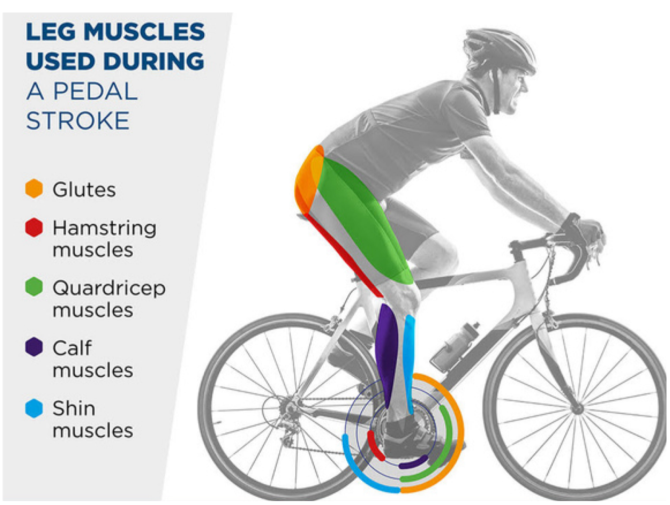
Cycling is one of the most frequent daily-life activities associated with healthy lifestyle. Also, it is highly recommended during rehabilitation after musculoskeletal injuries, such as Anterior Cruciate Ligament (ACL) rupture. Moreover, road bicycle racing is one of the most competitive and physically demanding professional sports. Therefore, studying the biomechanics of cycling is beneficial for clinicians to design improved strategies for strengthening, rehabilitation and sport coaching plans. In this project, you will use an OpenSim model that represents a cyclist to investigate various conditions of pedalling undertaking a predictive simulation approach.

Learning Outcomes:

- Biomechanics simulation
- Kinematics, dynamics manipulation
- Predictive tools

Subtasks:

- Create an OpenSim model that includes the rider and the crank mechanism (initially 2D), since the provided model does not include the upper body.
- Create a Python/Matlab script to setup a direct collocation analysis with MoCo.
- Define proper states for all degrees of freedom and auxiliary dynamics to achieve the pedalling pattern.
- Investigate the effects of different parameters on joint kinematics and muscle forces, such as rider weight, muscle strengthening and weaking, terrain level (crank resistance), leaning forward posture etc.
- Update the model to 3D and perform again the same experiments
- **References:** [2], [3], [4]



9. Stroke Rehabilitation Modelling

Tools & Libraries: OpenSim, Moco

Stroke is one of the main causes of biomechanical deficiencies in daily life activities such as gait and standing balance. For example, hemiparesis is a common post-stroke condition with substantial weakness of one entire side of the body. During hemiparesis the affected side is characterized by muscle weakness that leads to an abnormal posture behaviour. Rehabilitation strategies focus on muscle strengthening and gait re-training to improve the gait qualitative indices and restore normal gait speed. Additionally, Functional Electrical Stimulation (FES), ankle orthosis or botox injections are used. In this project you are asked to work with OpenSim and Moco or Scone tools to explore rehabilitation strategies of post-stroke patients.

Learning Outcomes:

- Biomechanics simulation
- Kinematics, dynamics manipulation
- Predictive tools

Subtasks:

- Explore the data provided in reference [6] and find three subjects with mild, medium and severe gait abnormalities.
- Process the data so they are ready to use in OpenSim.
- Perform the standard OpenSim analysis to estimate muscle forces and Joint Reaction Analysis (JRA).
- Using these results as baseline, apply muscle strengthening, or any other rehabilitation strategy in Moco and try to improve gait.
- References: [5], [6]

10. MR manipulation of tomography and superimposition

Key Equipment: Meta Quest 3

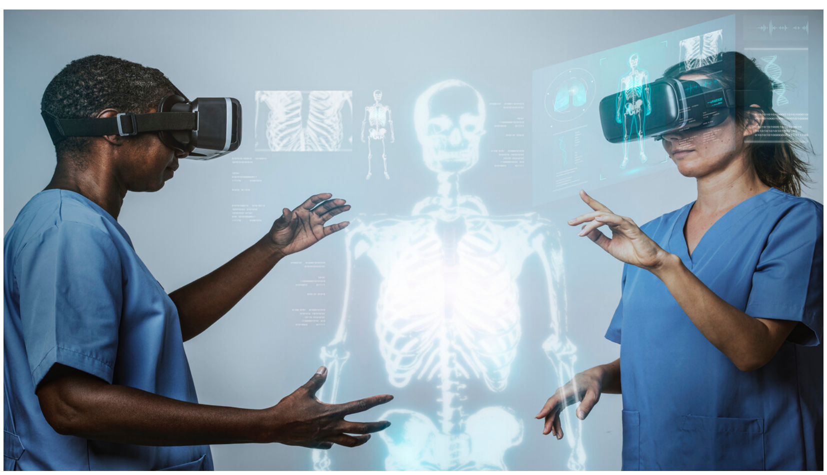
Tools & Libraries: Unity and more

Learning Outcomes:

- Design MR educational environment
- Manipulate organs, systems tools
- Interactive rendering and simulation of tomography scans

Subtasks:

- Reconstruct the bones from an MRI image
- Reconstruct any other structure of your choice
- Render the structure in a VR environment
- Superimpose the structure in an MR environment
- Register the rendering on top of a "patient"
- Provide interaction controls to show only the section asked for by the clinician
  - Use the source images
  - Use a synthetic section out of the reconstructed data



11. MR haptic manipulation of tomography

Key Equipment: Meta Quest 3

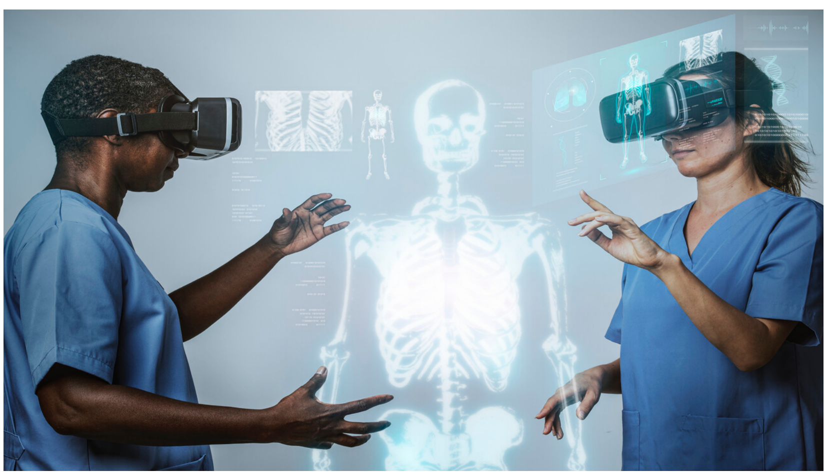
Tools & Libraries: Unity and more

Learning Outcomes:

- Haptic interaction with physiology models
- Manipulate organs, systems tools
- Interactive visuo-haptic rendering and simulation

Subtasks:

- Load and visualize physiology models
- Superimpose the structure in an MR environment
- Perform haptic interaction with the MR rendered model
- Register the rendering on the haptic device workspace
- Provide interaction controls necessary for the clinician



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[3] Park S, Caldwell GE, Umberger BR (2022) A direct collocation framework for optimal control simulation of pedaling using OpenSim. PLoS ONE 17(2): e0264346. https://doi.org/10.1371/journal.pone.0264346

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