VRPelviSim

Measuring Variability of Pelvic Standard Views in Virtual Reality

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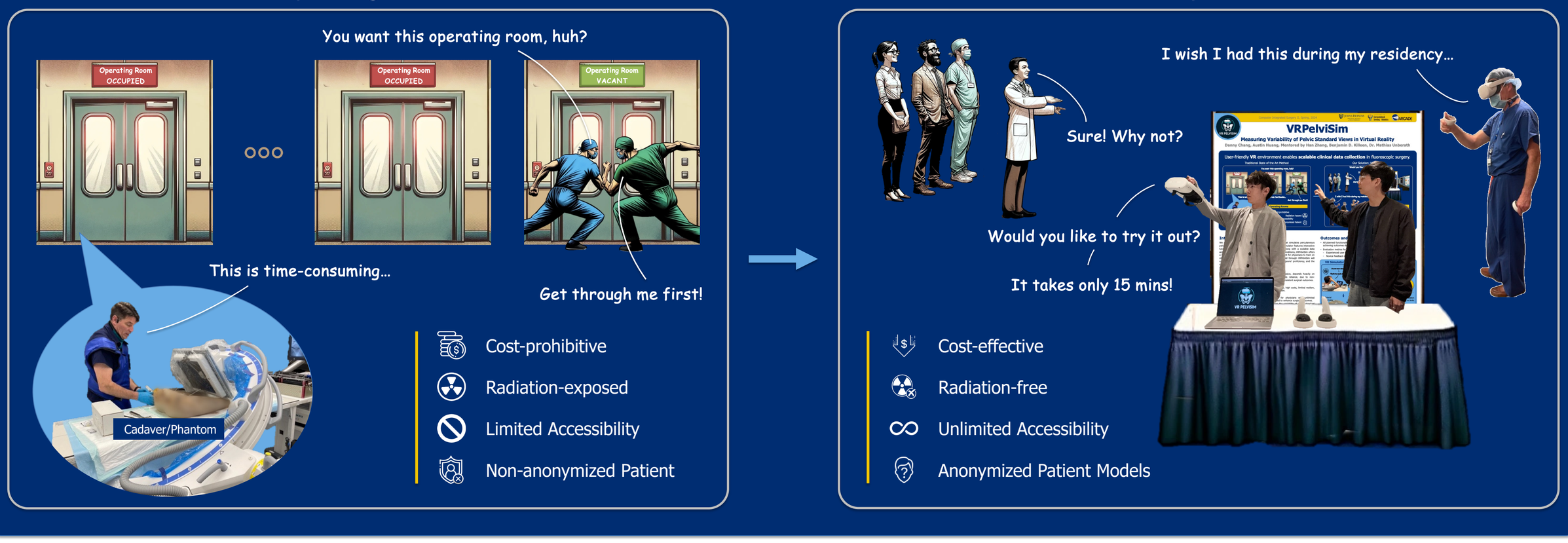
User-friendly **Virtual Reality** enables **scalable clinical data collection** in fluoroscopic surgery.



Introduction

We developed VRPelviSim, a virtual reality (VR) platform that simulates percutaneous pelvic fracture surgeries guided by C-arm fluoroscopy. This simulator features interactive tutorials, intuitive operations, realistic object interactions, along with a scalable data acquisition module. Designed to replicate real-world surgical conditions, VRPelviSim offers a risk-free, anonymized, and cost-effective training environment for physicians to train on obtaining pelvic standard views. The extensive data collected through VRPelviSim will enable precise quantification of inter-surgeon variability, surgeons' proficiency, and the radiation exposure received during actual surgeries.

The Problem

Percutaneous pelvic fracture surgery, though minimally invasive, depends heavily on fluoroscopic guidance, posing ionizing radiation risks. This reliance, due to non-standardized methods for obtaining pelvic views, leads to inconsistent surgical outcomes.

- State of the art solution:
  - Cadaveric and phantom training → radiation exposure, high costs, limited realism, limited accessibility, restricted anatomical representation.
- Necessity for a solution:
  - A safer and cost-effective training alternative for physicians with unlimited accessibility and anonymized patient data is needed to enhance surgical outcomes.
  - The absence of quantitative assessments leaves the variability of pelvic standard views, surgeons' proficiency in acquiring them, and the radiation exposure during surgeries unmeasured.

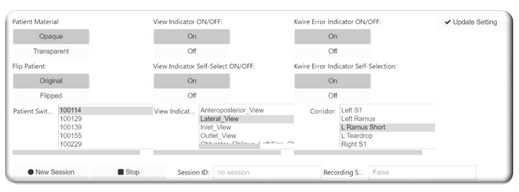
The Solution

VRPelviSim addresses the problem with the following capabilities:

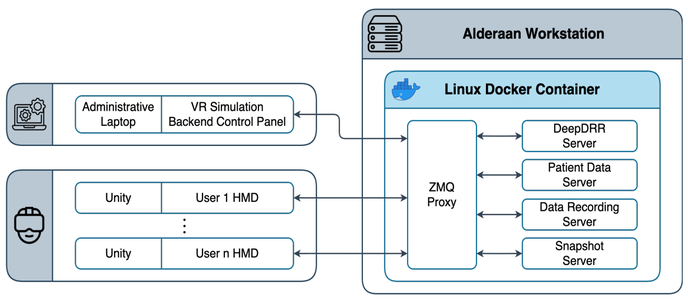
- Intuitive user control panel for VR interaction and for displaying C-arm parameters.
- Dual C-arm control modes offering precise and intuitive controls.
- Scalable hosting servers providing multi-user access and external network connectivity.
- De-identifiable, diverse patient models optimized for loading time and appearance.
- Backend administrator control panel for managing VR environment.
- Structured built-in tutorial featuring audio and visual signaling.
- Snapshot mode emulating real surgical scenarios with no omissions.
- Data acquisition module guiding users through collecting clinical data.

Case ID	AP	LAT	Inlet	Outlet	TL	TR
100114	3	2	2	5	2	2
100129	4	3	7	5	3	2
100139	2	3	1	4	3	3
100155	4	2	3	3	3	2
100229	3	7	4	4	3	4
Total	16	17	17	21	14	13
Average	3.2	3.4	3.4	4.2	2.8	2.6

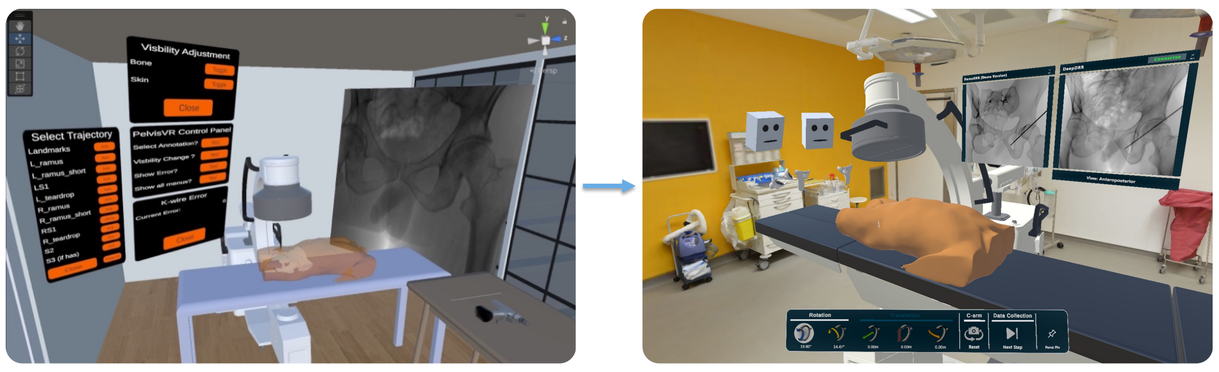
Data Acquisition Summary Table



Backend Admin Control Panel



Networking Block Diagram Overview

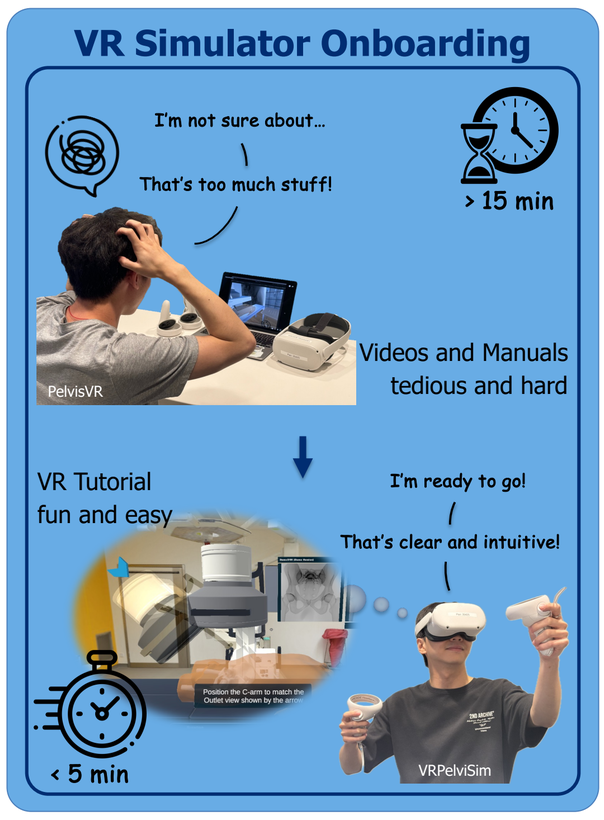


PelvisVR (Killeen et al., 2023)

VRPelviSim

Outcomes and Results

- **A surgeon new to VR was able to successfully complete the tutorial with minimal instruction and promptly began submitting data on standard views.**
- Evaluation metrics for VRPelviSim:
  - Experienced user feedback further refined VR functionalities.
  - Novice feedback enhanced VR interaction and interface intuitiveness.



Future Work

- Perform research studies to:
  - Gather a comprehensive dataset of X-ray anatomical standard views from orthopedic surgeons.
  - Quantify the inter-surgeon variability using a statistical shape model.
  - Quantify the radiation exposure surgeons endure during procedures.
- Automate the processing of raw CT data to develop adaptable patient models for immediate integration into VRPelviSim.
- Expand VRPelviSim's capabilities by developing additional surgical modules, thereby enhancing its training and educational scope.

Knowledge Gained and Lessons Learned

- Effective Project Management: Clear definition of System Requirements Specifications (SRS) and subsystem interfaces enhanced collaboration and facilitated the smooth achievement of project deliverables.
- User-centric Development in VR Applications.
- Network and Server Deployment: ZeroMQ (ZMQ), Cap'n Proto, Docker.
- Documentation Best Practices: Clear and thorough documentation enabled seamless continuation of work and ensured a robust framework for ongoing innovation.

Credits

- Danny Chang: Hosting Infrastructure, Diverse Patient Models, Backend Admin Control Panel, Data Acquisition Module.
- Austin Huang: User Control Panel, C-arm Control, Built-in Tutorial, Data Acquisition Module.

Special thanks to Han Zhang, Benjamin D. Killeen, and Dr. Mathias Unberath for their mentorship, and to Liam Wang for his insights.

- Benjamin D. Killeen, M. Unberath, H. Zhang, L. Wang, and Z. Liu, "PelvisVR: Recreating pelvic trauma surgery in virtual reality for the development of novel c-arm interface," 2023, submitted as project for Computer Integrated Surgery II, Johns Hopkins University.
- Philips Healthcare. (2018, August 27). Better Minimally Invasive Peripheral Procedures [Video]. YouTube. https://www.youtube.com/watch?v=c3qR9aZVpng