Ski Jump Launch Trainer

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October 3rd, 2025

Overview

- Problem Statement
- Background
- Competing Solutions
- Product Design Specification
- Preliminary Designs
- Design Matrix
- Future Work
- Testing and Results
- References and Acknowledgments

Figure 1: Design team picture

Problem Statement

Client Problem Statement:

- Difficult to give actionable and quantitative-based feedback
- Create a system allowing youth amateur ski jumpers to compare performance with experts and receive feedback

Refined Focus:

- Analyzing the biomechanics of takeoff and initial flight phases
- Biomechanical metrics (body angles, reaction forces, etc)

Goal:

- Identify key performance metrics
  - strong association with higher jump scores
- Actionable feedback for coaches

Background

- Athletes go down takeoff ramp, jump, and land as far as possible [1]
- Ski jump sizes
    - 5m hill up to 240m ski flying hills [1]
- Simple progression
- Dr. Ahmed's daughter is a youth ski jumper
    - Inspiration for project
- Year-round sport [1]

Figure 2: Flight phase V position

Figure 3: In-run phase on plastic surface

Background

Phases:

- In-run
  - Reduce drag and maximize speed
- Takeoff
  - Body position transition
- Flight
  - Body parallel to skis (V position)
- Landing
  - Style points [2]

Scoring (K-score/Jump score):

- K-point
  - Point where hill flattens
  - 60 points at K-point
    - (±)1 point per meter gained/lost [3]

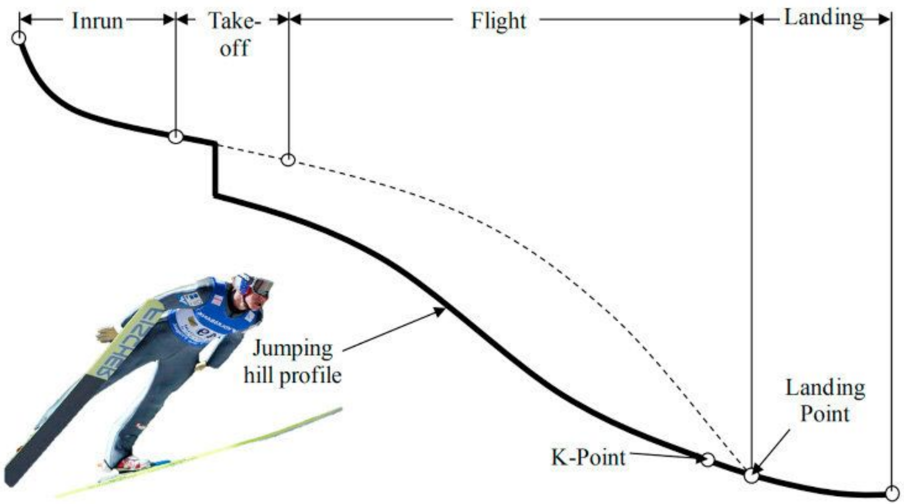


Figure 4: 4 phases of the ski jump

Competing Solutions

- Differential Global Navigation Satellite System (dGNSS)
  - Measured head trajectory of athletes
  - Derive point kinetics of athlete
- Markerless video-based pose estimation system (PosEst)
  - Key body angles
- Both methods showed agreement from 5 m after take-off [4]

Figure 5: Helmet and antenna of dGNSS and receiver backpack under suit

Figure 6: Key body angles before takeoff

Design Specifications

- Must capture lower-body joint angles, torso orientation, and vertical ground reaction forces
    - Enables comparison between youth athletes and expert reference data
- Sensors must achieve ±0.5% accuracy and less than ±3° precision for joint angle measurements [5]
- Weight less than 23.1 kg [6]
- All testing must follow IRB guidelines
    - Parental consent and child assent needed prior to testing [7]

Accelerometers (IMUs)

- **Inertial Measurement Units (IMUs)**
  - Provides high-frequency acceleration, angular velocity, and body orientation
  - IMUs placed on various parts of the body
  - IMUS connect to a central microcontroller [8]

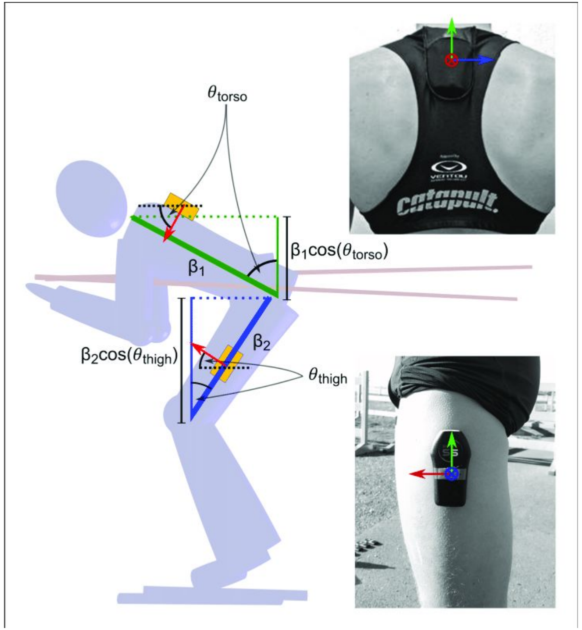


Figure 7: IMUs body harness and leg application

Force Plate Insoles and Motion Capture

- **Force Plate insoles**
  - Measures force exerted by jump
  - Analyzes ground reaction force
  - Pressure sensors [9]
- **Motion Capture**
  - Mobile Device and application to record movement

Figure 8: Force plate insoles

EMG Sensors

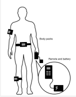
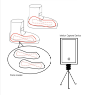
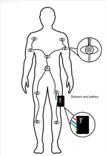
- **Electromyography (EMG)**
  - Electrical activity of muscles during contraction
  - Electrodes placed on skin surface detect electrical signals
  - Strength of voltage signal change [10]

Figure 9: EMG with electrodes

Design Matrix

- Chosen criteria
- Design 1 score standout
  - Data Feasibility
- Design 2 score standout
  - Repeatability
- Design 3 score standout
  - Athlete comfort & Ease of Use

Table 1: Design matrix for data collection modalities

		Design 1: Accelerometers (IMUS) 		**Design 2: Force Plate + Motion Capture** 		**Design 3: EMG Sensors** 	
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Repeatability	25	3/5	15	5/5	25	2/5	10
Accuracy	25	3/5	15	4/5	20	4/5	20
Athlete Comfort/Interference	15	3/5	9	4/5	12	2/5	6
Ease of Use (Setup and Takedown)	10	4/5	8	4/5	8	2/5	4
Data Feasibility/Processing Burden	10	1/5	2	4/5	8	3/5	6
Durability	5	4/5	4	4/5	4	2/5	2
Safety	5	5/5	5	5/5	5	5/5	5
Cost	5	5/5	5	3/5	3	5/5	5
Total (Out of 100):		63		85		58	

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Testing and Results

- OpenCap Simulation
  - Basic dynamic movements
  - Qualitative Assessment
- Failure Modes
  - Differing cameras
  - High velocity movements
- Further Testing
  - Ski Hill
  - Mounted, Identical Cameras
- Other Motion Capture Softwares:
  - Kinovea
  - Dartfish

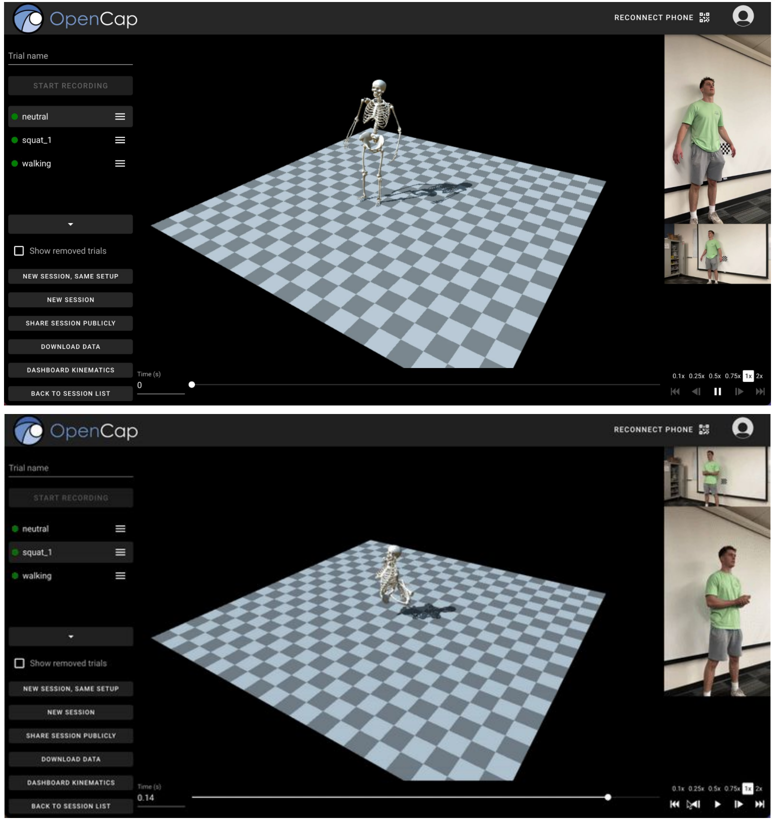
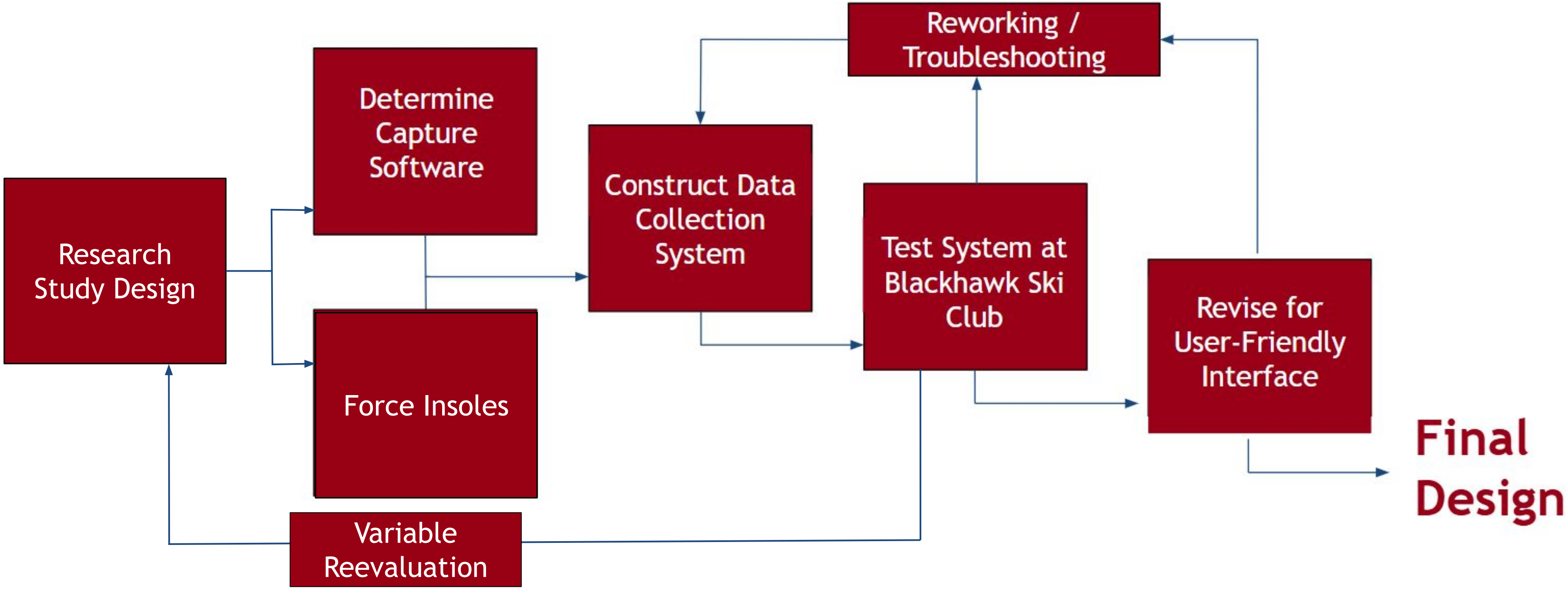


Figure 10: OpenCap 3d skeletal model for neutral stance and squat

Future Work


Research Study Design
Determine Capture Software
Force Insoles
Construct Data Collection System
Reworking / Troubleshooting
Test System at Blackhawk Ski Club
Revise for User-Friendly Interface
Variable Reevaluation
Final Design

Acknowledgments

Thank You!

Dr. Randy Bartels
Dr. Azam Ahmed
Dr. John Puccinelli

References

[1] "Ski Jumping 101," USA Ski Jumping. Accessed: Oct. 02, 2025. [Online]. Available: https://usaskijumping.com/ski-jumping-10

[2] "Fig. 2. Different phases of ski jumping [11-12].," ResearchGate. Accessed: Oct. 02, 2025. [Online]. Available: https://www.researchgate.net/figure/Different-phases-of-ski-jumping-11-12_fig2_331700125

[3] "Olympic Ski Jumping Scoring: Distance Points, Style Marks and Wind Compensation Explained | NBC Olympics." Accessed: Oct. 02, 2025. [Online]. Available: https://www.nbcolympics.com/news/ski-jumping-101-scoring

[4] O. Elfmark *et al.*, "Performance Analysis in Ski Jumping with a Differential Global Navigation Satellite System and Video-Based Pose Estimation," *Sensors*, vol. 21, 16, p. 5318, Jan. 2021, doi: 10.3390/s21165318.

[5] "Accuracy of force sensors | Accuracy of force sensors." Accessed: Sept. 18, 2025. [Online]. Available: https://www.me-systeme.de/en/force-sensors/accuracy

[6] "Backpack Airplane Travel: What Are The Dimension Limits? | Quartz Mountain." Accessed: Sept. 18, 2025. [Online]. Available:

[7] M. J. Field, R. E. Behrman, and I. of M. (US) C. on C. R. I. Children, "Regulatory Framework for Protecting Child Participants in Research," in *Ethical Conduct of Clinical Research Involving Children*, National Academies Press (US), 2004. Accessed: Sept. 18, 2025. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK25558/

[8] "Inertial Measurement - an overview | ScienceDirect Topics." Accessed: Oct. 02, 2025. [Online]. Available: https://www.sciencedirect.com/topics/engineering/inertial-measuremen

[9] H. Nodwell, "Salted Smart Insoles' NEW Technology," MyGolfSpy. Accessed: Oct. 02, 2025. [Online]. Available: https://mygolfspy.com/news-opinion/salted-smart-insoles-new-technology/

[10] "Mechanomyography Assisted Myoelectric Sensing for Upper-Extremity Prostheses: A Hybrid Approach | IEEE Journals & Magazine | IEEE Xplore." Accessed: Oct. 02, 2025. [Online]. Available: https://ieeexplore.ieee.org/document/7874103