

ClimbSmart: Implementation of AI in Indoor Rock Climbing

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Introduction

- Rock climbing has been gaining traction in cities like Hong Kong, especially with more indoor climbing gyms popping up. While it's a fun and rewarding sport, it comes with its share of risks—like falls, overuse injuries, and technical mistakes.
- The idea received a real boost when it was accepted into the Hong Kong Science and Technology Parks (HKSTP) ideation program, which provided access to resources and mentorship. At its core, the system uses a deep learning model—built in Python with YOLO object detection—to identify holds and assess route difficulty from images and videos.

Methodology

- Video Input & Preprocessing** Climbers' movements are captured via smartphone or static camera. Each video is preprocessed to extract the first frame for hold detection, significantly reducing computational load without compromising route analysis accuracy.
- AI-Based Hold Detection** A deep learning model, based on **YOLOv8 (You Only Look Once)**, was trained on a custom dataset of annotated climbing walls. This model identifies and classifies holds by type, position, and color within milliseconds. Confidence thresholds are adjusted to minimize false positives and optimize detection in diverse lighting conditions.
- Route Mapping & Performance Metrics** Using the detected holds, the system constructs climbing routes and estimates their difficulty. Additional motion data is analyzed to evaluate grip sequences, movement efficiency, and pause duration—offering metrics such as path optimality and performance smoothness.
- Feedback Generation & Reporting** Upon analysis, ClimbSmart produces a visual overlay of the climb with route highlights and annotated feedback. Personalized reports include improvement tips, movement breakdown, and potential injury risks, all exportable for use by climbers or gym coaches.



Objective

- To use technology to make indoor climbing both safer and smarter by analyzing routes and movement to help climbers avoid injury and improve their skills.

Project Evaluation

Advantages:

- ClimbSmart has demonstrated strong feasibility across both technical and operational domains:
- The AI system achieved **over 90% hold detection accuracy** and reduced analysis time to **under 80 seconds**, proving it can operate efficiently even on consumer-grade devices.
- Implementation using a single-frame detection method minimized computational load, making the system suitable for real-time use in gyms or through smartphone capture.

Areas for improvement

- User Interface:** A more intuitive and visually polished UI is needed for both individual users and gym operators. Current interactions rely on manual execution and scripts.
- Dataset Diversity:** Current training data is limited to a small number of gym environments. Broader data collection across different wall types, lighting conditions, and camera angles is required for better generalization.
- Real-Time Motion Tracking:** The system is currently limited to post-session feedback. Adding real-time motion analysis and pose estimation would improve immediacy and coaching quality.
- Onboarding & Gamification:** Incorporating onboarding tutorials and gamified challenges could improve adoption and engagement, especially for less experienced climbers.

Conclusion

ClimbSmart demonstrates strong potential to enhance indoor climbing with AI-powered route detection and performance feedback. Early tests show high accuracy and fast processing speeds, proving its feasibility for real-world use. With refinements to the UI, data diversity, and real-time tracking, ClimbSmart is on track to become a valuable tool for safer, smarter climbing.