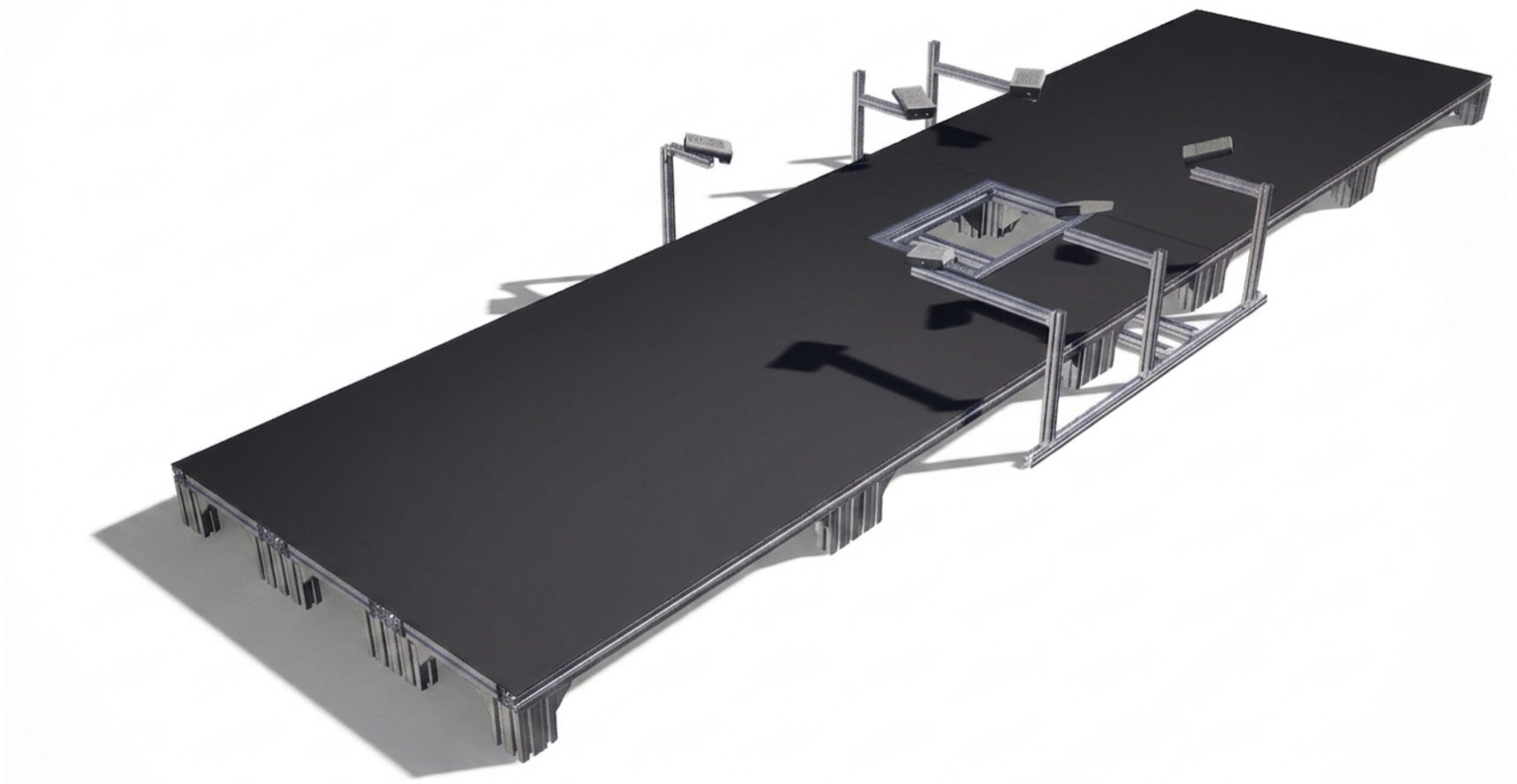
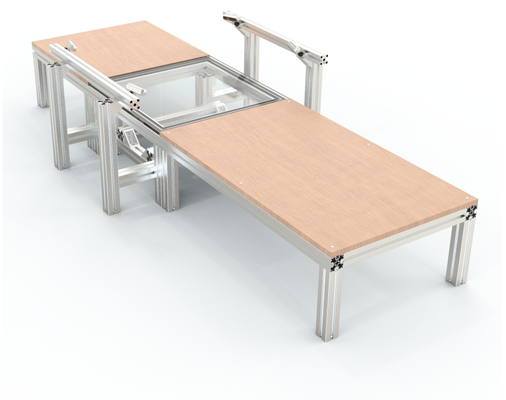
Redesigning a 4D scanner to facilitate natural walking



Starting point

Custom foot orthotics traditionally rely on static fitting methods, failing to account for dynamic foot deformations during gait (which can vary up to 8 mm). While previous 4D foot scanner prototypes (Vidmar, 2020; Kwa, 2021) successfully captured dynamic morphology, evaluation revealed several areas of possible improvements

Structural Vibrations: Mounting depth cameras directly to the walkway frame transferred footstep impact forces straight to optical sensors, degrading 3D scan quality.
Gait Alteration & Accessibility: A long focal length forced a steep 30 cm step-up height. Combined with a short 3 m walkway, patients experienced discomfort and altered their natural stride.
Resolution & Fidelity Constraints: The baseline Intel RealSense D435i resolution (848x480 px) lacked the pixel density required to achieve sub-millimeter surface accuracy for custom orthotic design.



Previous design by Kwa (2020)

Experiments

Three empirical studies were conducted to guide the hardware redesign
Foot Placement Study: Mapped natural heel-strike variance and derived a visual starting-guide method to consistently center foot contact. Which also atrritubuted to:
Camera Geometry Calculation: The foot placement study was used to calculate the optimal spatial coordinates, reducing mean 3D scanning error from 3.0 mm to 2.25 mm.
Walkway Gait Analysis (Gaitrite): Proved that a 3 m walkway significantly reduces step length (by 3.86 cm), whereas a 4.5–5 m length facilitates an unforced, natural stride.
VR Discomfort Study: Demonstrated that platform height and narrow width interact to induce subconscious distress and fear of falling.

Foot placement study

Vr studies

Key Improvevements

To resolve these hardware limitations, a mobile, decoupled conceptual prototype was engineered:

Modular Portability & Redirected Load Path:
All disassembled parts stay under 1 m to fit in a compact car trunk (VW Polo).
s on top of heavy-duty L-extrusions (capable of withstanding a 200kg waking patient).

Decoupled Camera Mounting:
Suspended cameras from an independent 3030-extrusion frame, completely isolating optical sensors from step-induced cadence vibrations.

Low-Profile Walkway (14.2 cm):
Implemented dual short-range Intel RealSense D405 active stereo cameras beneath the glass, sub-millimetre precision, shortening focal distance and reducing step-up height from 30 cm to 14.2 cm to accomadate patients with impaired movement.

Economic Viability:
Achieved a total hardware BOM cost of €6,048.89, well below the €30,000 clinical threshold.

Ergonomic Walkway (4.5 m x 1.2 m):
Extended and widened the platform with textured vinyl surfacing and visual lines to ensure patient confidence and natural walking.

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Dynamic Footprints, Redesigning 4D Scanning Hardware to Faciliatate Natural Walking
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