Computational Design Experiment for Older Adult's Footwear

Field-Driven Approach and Product Design Applications

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Abstract

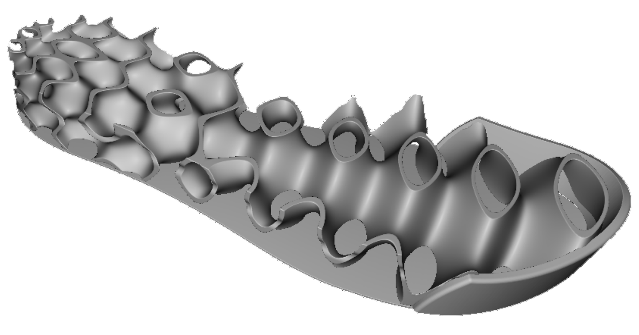
The purpose of the study is to build tailor-made footwear soles for older adults through field-driven design and technology to satisfy their unmet needs and respond to the two research questions: 1. How to translate people's feet pressure data to shape the three-dimensional model of footwear soles to generate customized products? 2. How has the field-driven design approach transformed the roles and responsibilities of product designers and thus shaped human-centered design (HCD)? One pervasive effect of aging is people's feet undergo a significant loss of cutaneous touch and pressure sensation. Their feet gradually become deformed and asymmetric depending on health, lifestyle, and walking postures. Mobility is a key factor to measure their life independence and we think footwear soles are the product most directly linked to mobility. Field-driven design is a computationally lightweight process that is applied to three-dimensional objects through a single mathematical formula reinterpreting a solid body. It has made the process intuitive to precisely control models, simulate results efficiently and effectively. This study showed how we translated feet pressure data to rebuild comfortable, safe, and customized footwear soles for older adults and discussed the future roles of designers and HCD impacted by field-driven design and technology.

Keywords: computational design; field-driven design; footwear; aging

Table 2. Four indoor footwear sole simulations

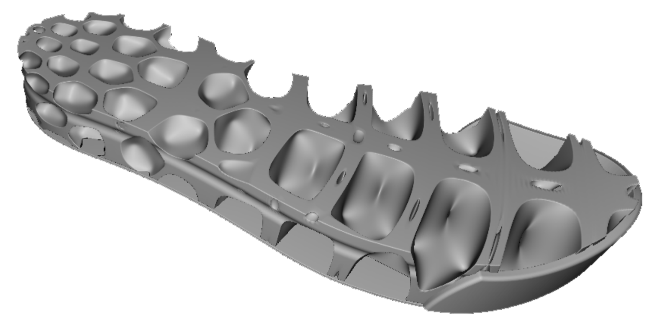
Simulation 1—Indoor footwear sole

Longitude count	20
Latitude count	20
Radius cell size	20
Approx. thickness	1
Approx. bias length	0
Fill type	Schwarz



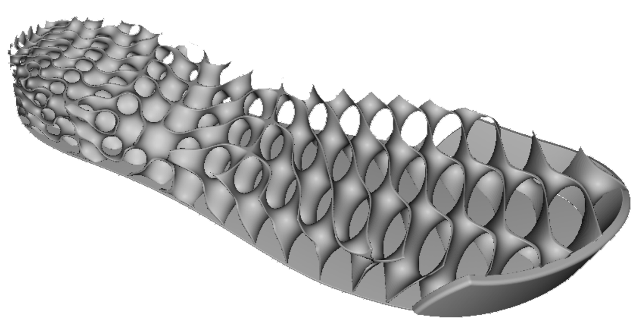
Simulation 2—Indoor footwear sole

Longitude count	20
Latitude count	20
Radius cell size	20
Approx. thickness	1
Approx. bias length	0
Fill type	Neovius



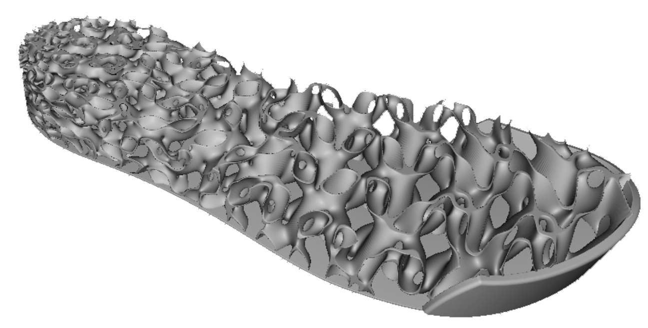
Simulation 3—Indoor footwear sole

Longitude count	20
Latitude count	20
Radius cell size	20
Approx. thickness	1
Approx. bias length	0
Fill type	Diamond



Simulation 4—Indoor footwear sole

Longitude count	20
Latitude count	20
Radius cell size	20
Approx. thickness	1
Approx. bias length	0
Fill type	Lidinoid



Project background

Field-Driven Design Approach

Older adults' feet gradually become deformed and asymmetric depending on health, lifestyle, and walking postures (Tomassoni et al., 2014; Menant et al., 2009). One pervasive effect of this is a significant loss of cutaneous touch and pressure sensation (Menz and Morris, 2005). We experimented with a field-driven design approach to prototype tailor-made footwear soles for older adults (Tang, 2021). A value of each point of 3D space is defined as a field, representing a set of spatial data of physical quantities, such as temperature, stress, or flow velocity (Allen, 2022a). We use field-driven software to translate 3D modeling data into scalar fields that can be modified by basic math operations to make them simpler or more complex. To show the difference between the field-driven approach and traditional CADing, we compare them in Table 1.

Table 1. Two models of CADing

	Traditional CADing process	Field-driven approach (focusing on implicit modeling)
Pro	• Build relatively simple CAD models for product design, furniture design. • Easy to track each CADing step, since commands follow linear, logical process. • Has many CADing files/templates. Some companies have already established virtual CADing libraries for reference.	• Decrease the size of CADing files efficiently. • Automatically translate test object's data into CAD models through algorithms or AI. • Software can be compatible with other CADing software. • Each CADing command is modular-based and gives users more flexibility. • Designed to create or solve complicated geometrical forms. • Users can see simulation result in real time.
Cons	• Must manually control and modify CAD models. • Hard to work on the same 3D model collaboratively.	• Need to consider the criteria to measure and calibrate the design result in advance. • Has fewer CADing files/templates.
Example	• SOLIDWORKS • Rhinoceros 3D	• nTopology (implicit modeling) • Oqton (AI-driven manufacturing) • Siemens NX (intelligence-driven design)

Methodology

We used a field-driven approach, demonstrating people's foot pressure data to remap it to fit the sole of our new indoor footwear design to simulate our hypothesis (Allen, 2022b). One key challenge lies in how to remap the pressure map data to the new shape of the sole. Figure 1 shows the steps to adjust the pressure map's shape to the new sole design. We tried different parameters of our indoor footwear CADing model to rebuild the sole of the indoor footwear model to prototype six product structures. We can use this computational design result to test older adults. Figure 2, 3, and Table 2 document our experimental process tweaking longitude count, latitude count, radius cell size, approximate thickness, approximate bias length, and fill type.

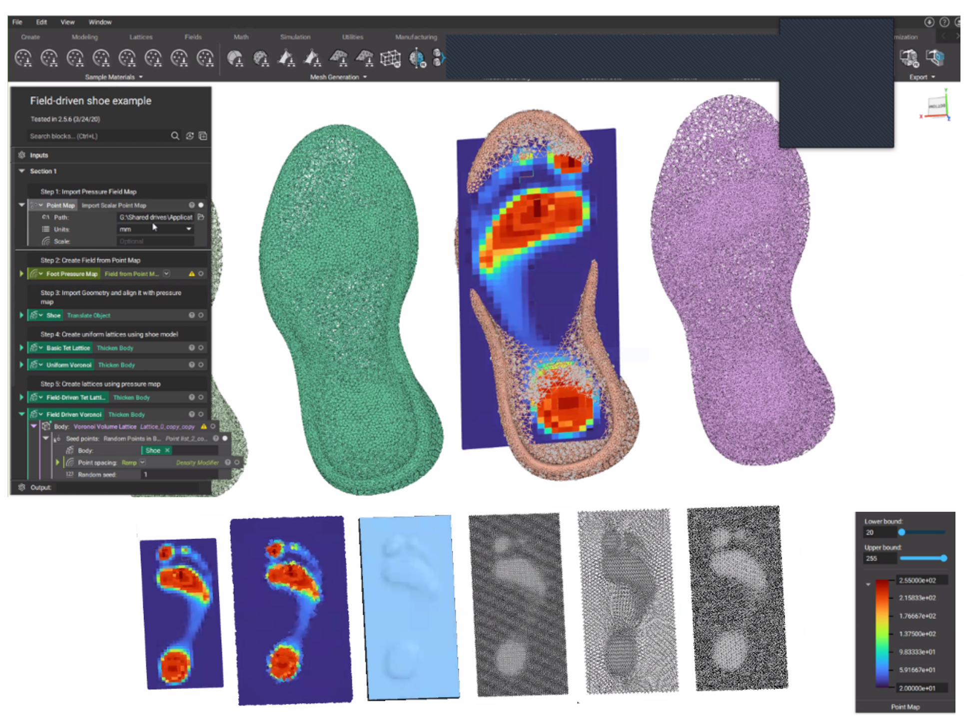


Figure 1. Translating people's feet pressure data into footwear sole design with complex lattice structure and designs (example from field-driven software)

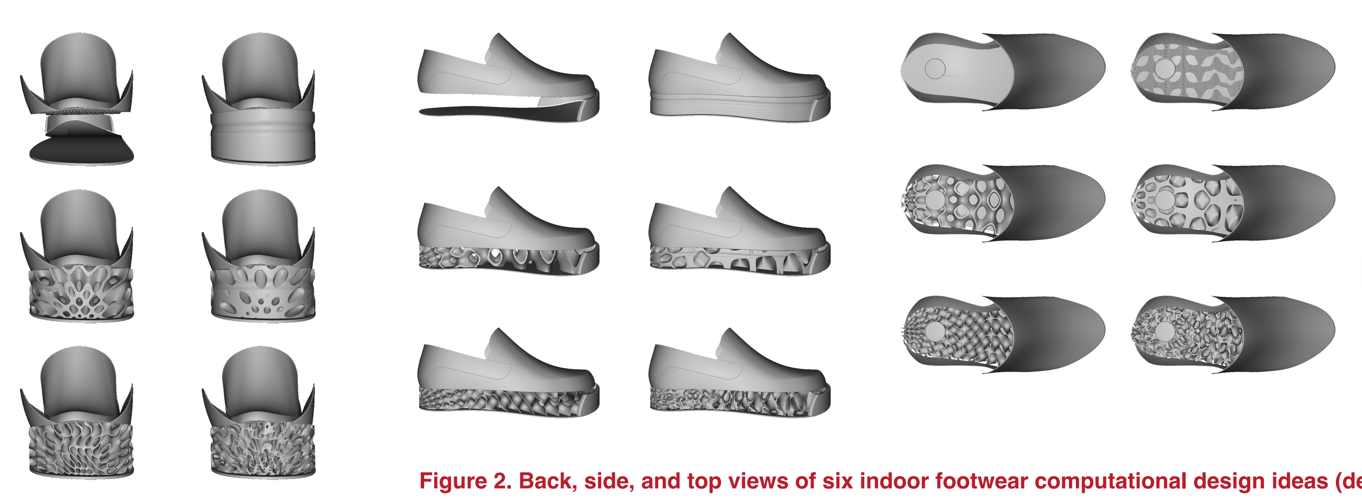


Figure 2. Back, side, and top views of six indoor footwear computational design ideas (designed by author)

Outcomes

Create affordable tailor-made services.

The field-driven approach makes CADing more efficient, especially working on complicated models. The speed achieved for CADing through a field-driven approach has enables faster iterations of the tailor-made footwear design catering to users' needs.

Leverage software compatibility.

Unlike traditional CADing software, field-driven software provides a platform with compatibility by integrating other 3D software to improve its engineering performance or aesthetics. The field-driven approach with compatibility provides an open platform to foster creativity.

Enable adaptive model-building workflow.

A field-driven approach offers the adaptiveness and scalability of workflow. Designers need only set up one workflow that can correlate measurable data, e.g., feet pressure, so the software can build solutions based on different parameters e.g., environmental conditions or materials. The effort lies in building the one workflow to solve complex geometries and create new possibilities.

Discussion

The field-driven approach can offer not only older adults' but all customers' an affordable tailor-made footwear service that has the potential to disrupt the current footwear design and manufacturing process and increase user expectations. By measuring people's feet before they purchase footwear, they will receive not only their own tailor-made footwear soles but also shoes whose style, pattern, or colors provide a more personal and comfortable wearing experience.

Figure 3. Envisioning future indoor footwear design for older adults using a field-driven approach (designed by the author)

Project Collaborators

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nTopology

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