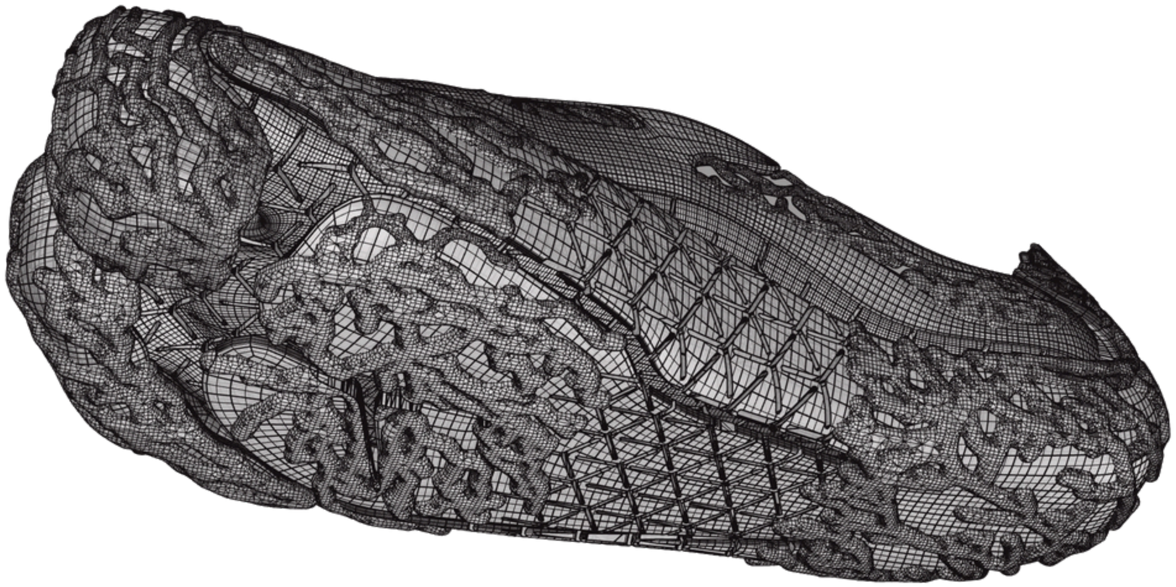


Un-Identical

"let the container take the shape.”

"If you don't care about clothes, you don't care about people."

Yojhi Yamamoto

Name: Iniyan Annadurai
Student ID: 24032507
MA Footwear 2024-2025
London College of Fashion
University of the Arts London
Word Count: 9827

I, Iniyan Annadurai, certify that this is an original piece of work. I have acknowledged all sources and citations. No section of this essay has been plagiarised.

contents

IIntroduction

Methodology

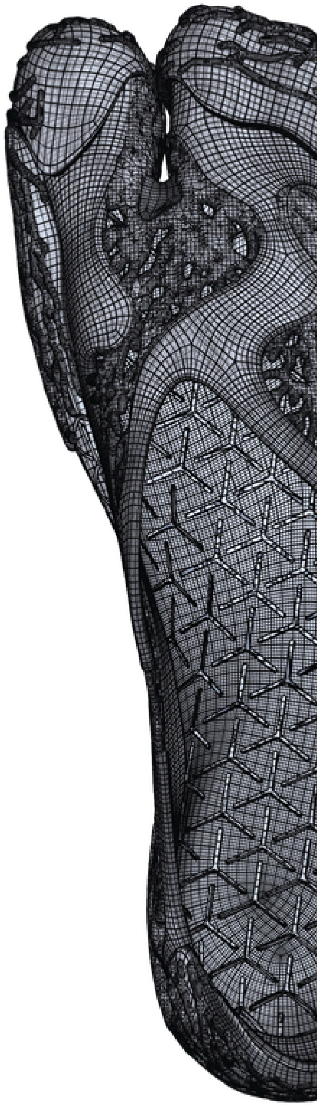
Research

Design & Development

LINE UP

DESIGN RATIONALIZATIOON

TECHNICAL DRAWINGS AND SPEC SHEETS



UNIDENTICAL

METHODOLOGY

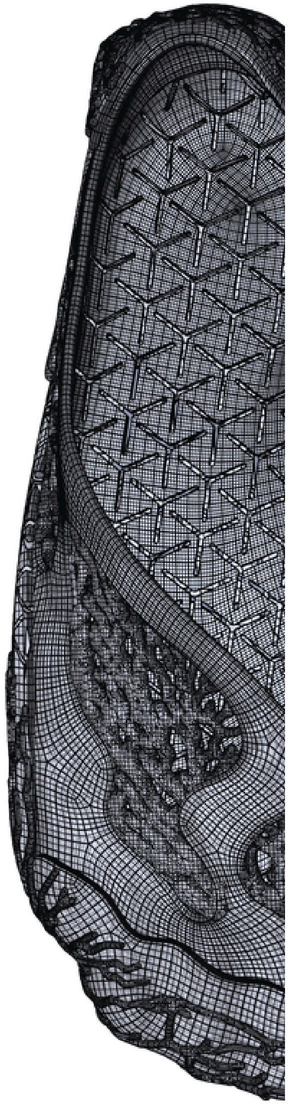
BUSINESS MODEL

CONCLUSION

FILM

BIBLIOGRAPHY (TEXTS)

BIBLIOGRAPHY (IMAGES)



introduction

Footwear sits between one’s body and earth. Every sole registers a route, a posture, and a way of standing in this world. Every upper carries traces of the wearer’s habits, values and personality. In that sense, shoes are not neutral objects but “material witnesses” of how human bodies are supported, shaped and standardized by the industry and the culture around us (Willems, 2015).

The contemporary footwear industry operates within a fast-moving, resource-intensive system. More than twenty billion pairs of shoes are manufactured every year, the vast majority constructed from bonded composites of foams, rubbers, textiles, leathers and adhesives that are almost impossible to disassemble at end-of-life (EOL).

Production follows a linear “take–make–dispose” model. Raw materials are extracted, processed, assembled around rigid plastic or wooden lasts, shipped globally, worn briefly, then incinerated or buried in landfill. This process generates enormous volumes of waste and microplastic pollution while locking designers into standardised forms and industrial tooling. At the same time, this system has normalised a narrow interpretation of the human foot. Standard lasts assume symmetry, fixed arch height and a tapered forefoot; they leave little space for anatomical difference or the natural spread of the toes under load. Biomechanical research suggests that such constraints are not something to take lightly. Studies of people who habitually walk barefoot or in very minimal sandals show stronger intrinsic foot muscles and wider, more splayed forefeet than those who grow up in conventional shoes (Curtis et al., 2016; Willems et al., 2014). Research on running injuries further indicates that thick cushioning reduces plantar sensory feedback, encouraging heavy heel-strike patterns and increasing impact forces at the joints (Robbins, Gouw and Hanna, 1989; Stoneham et al., 2021).

In other words, the modern shoe often weakens, rather than supports, the body it claims to protect. This project emerges from that tension between ecological waste and biomechanical dysfunction. It asks what footwear might look and feel like if it were designed from the logic of the body first, and industrial convenience second. Instead of treating the shoe as armour, it proposes footwear as a “second skin”: a responsive, mono-material lattice that cooperates with fascia, muscles and bones rather than restricting them.

The theoretical backbone of the project is biotensegrity, which describes the body as a continuous tension network (fascia, muscles, tendons) stabilising discrete compression elements (bones) (Levin, 2015). Rather than seeing the arch as a rigid structural span, biotensegrity frames it as an active, elastic system that constantly redistributes forces. This commentary explores how that principle can be implemented through 3D-printed geometry using fractal and auxetic structures. Instead of stacking different materials to approximate cushioning and support, the project uses variable geometry to build stiffness and elasticity directly into the structure.

aims

- To design and prototype a 3D-printed, mono-material footwear system that reproduces basic biomechanical behaviours of the human foot.
- Outline a circular production and business model in which mono-material shoes can be re-milled and re-printed within a closed loop.
- Reimagine footwear as a tool to strengthen the foot and restore natural gait

objectives

- Map the relationship between foot anatomy, movement and plantar pressure through gait observation
- Derive fractal and auxetic geometries that express controlled expansion, contraction and torsion.
- Translate these geometries into a multi-layer lattice sole and upper that behave analogously to skin, muscle and fascia.
- Fabricate wear-ready prototypes in recyclable flexible TPU using additive manufacturing, without conventional lasts, adhesives or multi-material construction.
- Study and map out the market, consumers and competition for such a experimental product if exists.

research questions

How can the logic of biotensegrity be applied to a 3D-printed structure/ footwear?

Can a mono-material system deliver both biomechanical performance and environmental responsibility?

How might such a system shift future notions of craft, authorship and sustainability within footwear design?

methodology

The project adopts a practice-based, research-through-design approach in which making, testing and reflecting are inseparable. It sits at the intersection of biomechanics, computational design and sustainable manufacturing.

Practice-based research and reflection

The project follows Schön's notion of the "reflective practitioner," where drawing, modelling and prototyping become forms of thinking in action (Schön, 1983). Each iteration—whether a sketch, parametric model or failed print—is documented, analysed and used to inform the next step. The studio functions as both workshop and lab, holding physical prototypes, annotated drawings and print logs alongside theoretical reading.

Biomechanical analysis

Empirical data collection supports and challenges design decisions. Simple gait observation, plantar pressure mapping, and photographic studies of toe splay and arch behaviour under different conditions act as primary research. These are contextualised with findings from barefoot and minimal footwear studies (Willems et al., 2014; Curtis et al., 2016; Allen et al., 2023) and research on plantar skin sensitivity (Strzalkowski et al., 2015).

Computational and parametric design

Rhinoceros 3D and Grasshopper form the digital core of the methodology. Parametric scripts translate anatomical and pressure data into lattice geometry. Tools such as Kangaroo Physics are used to simulate deformation and test different lattice parameters before printing. Rather than modelling a single shape, the workflow establishes a generative system: a set of rules that can output many variants.

Material-led experimentation

Physical experimentation with flexible 3D-printing filaments—mainly TPU 95A—feeds back into the digital work. Swatches, small lattice tiles and partial soles test how geometry, print orientation and wall thickness affect stretch, rebound and durability. Failed prints are treated as data rather than waste.

Sustainability and systems thinking

Alongside material experiments, the methodology includes mapping of supply chains and hypothetical circular flows. This involves sketching life-cycle diagrams, considering logistics for take-back schemes, and exploring how on-demand local printing could replace global inventory.

This mixed methodology allows the project to move constantly between body, code and material, ensuring that computational ambition is grounded in lived, physical experience.

rationale

Purpose and intention

The rationale crystallises around one belief- footwear should amplify the intelligence of the human foot instead of overriding it. The foot is a sensory-rich, self-adjusting system composed of twenty-six bones, thirty-three joints and over one hundred muscles, tendons and ligaments. Its function depends on continuous feedback between plantar skin, fascia, and the nervous system (Strzalkowski et al., 2015). Thick, uniform soles and rigid uppers interrupt this loop. The project therefore pursues a shoe that behaves less like a layer of separation and more like an external organ—protective yet permeable, structured yet responsive.

Conceptual rationale: biotensegrity and fractal logic

Biotensegrity reframes anatomy as a network of tension and compression rather than stacked segments (Levin, 2015). In this view, stability emerges from balanced forces, not from rigid

elements. Translating this into footwear means designing soles that distribute loads through continuous pathways rather than concentrating them under discrete support features like arch bars or medial posts. Fractal geometry provides a compatible formal language: complex global behaviour emerging from simple, repeated rules (Mandelbrot, 1982). As fractal branching deepens, structures become denser and stiffer without changing material.

The project combines these two frameworks. The lattice behaves as a tensegrity-like network: struts in tension and compression redirect forces dynamically, while fractal recursion controls local stiffness by modulating cell density. Auxetic patterns introduce another layer of responsiveness through negative Poisson's ratio behaviour, allowing a region to thicken under tension instead of thinning.

Sustainability rationale: mono-material and circularity

Conventional shoes rely on multi-material assembly: rubber outsoles, EVA midsoles, thermoformed heel counters, glued overlays, stitched uppers. Each component demands separate tooling and inhibits recycling. Even brand-led experiments in “sustainable” shoes often rely on complex blends or bio-foams that remain difficult to separate at end-of-life.

Additive manufacturing offers an alternative. By printing an entire shoe from a single flexible thermoplastic such as TPU, the project reduces the object to one material and one component. This mono-material logic enables genuine circularity: worn shoes can be shredded, cleaned and re-extruded into filament without disassembly. Production can be local and on-demand, reducing inventory and shipping impacts. The design philosophy thus aligns sustainability with structural intelligence rather than asking users to trade performance for ethics.

Research integration

The rationale is supported by several strands of existing research:

Barefoot and minimal footwear studies show that prolonged use of thin, flexible footwear can increase intrinsic foot strength and forefoot width, suggesting beneficial adaptation when the foot is allowed to work (Curtis et al., 2016; Allen et al., 2023).

Anthropological research on indigenous footwear points to lower rates of foot deformity and injury in populations using simple sandals or walking unshod (Willems et al., 2014; Ojiambo et al., 2013).

Physiological studies highlight the importance of plantar sensory thresholds for balance and gait regulation (Strzalkowski et al., 2015).

Research in additive manufacturing and flexible TPU indicates growing viability for performance footwear applications.

Together, these sources validate the project's ambition to create a minimal, sensory-rich, recyclable shoe that works with rather than against human anatomy.

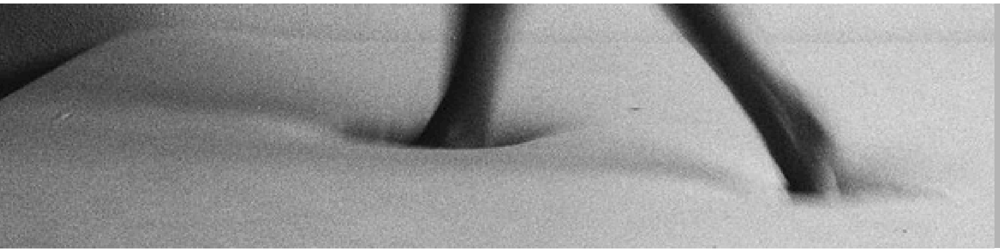
Research: Perspective

This project begins from a simple but uncomfortable observation: most modern shoes do not merely protect the foot; they reshape, mute and gradually retrain it away from its evolutionary capacities. My design lens is therefore critical rather than neutral. I approach footwear not as a solved typology to be decorated, but as an unresolved cultural, biomechanical and ecological problem. The "second skin" proposal emerges from this position: a deliberate attempt to question why we accept restrictive silhouettes, passive cushioning and industrial standardisation as normal, and to ask how design might instead amplify the body's existing intelligence.

Restrictive Silhouettes and the Legacy of Foot Binding-
The contemporary sneaker or dress shoe is rarely framed as a tool of restriction.

Yet, when we look critically at narrow toe boxes, rigid heel counters and aggressively tapered silhouettes, the parallels with historical practices of foot binding become difficult to ignore. In imperial China, the binding of girls' feet into the so-called "golden lotus" was a violent convergence of aesthetics, status and control; bone and soft tissue were physically rearranged to fit an idealised, miniaturised shoe shape rather than any functional requirement of the body.
Modern shoes obviously do not operate with the same explicit brutality, but the underlying logic is similar: the foot is expected to conform to the silhouette, not the other way around. Epidemiological links between restrictive footwear, hallux valgus and altered lower limb kinematics show how "fashionable" last shapes can drive real structural change in the foot and gait over time (e.g. Stoneham et al., 2020). Research on barefoot and minimal footwear populations further supports this, showing wider forefeet, healthier toe alignment and reduced incidence of certain pathologies where the foot is allowed to expand naturally (Curtis et al., 2016; Willems, 2015).

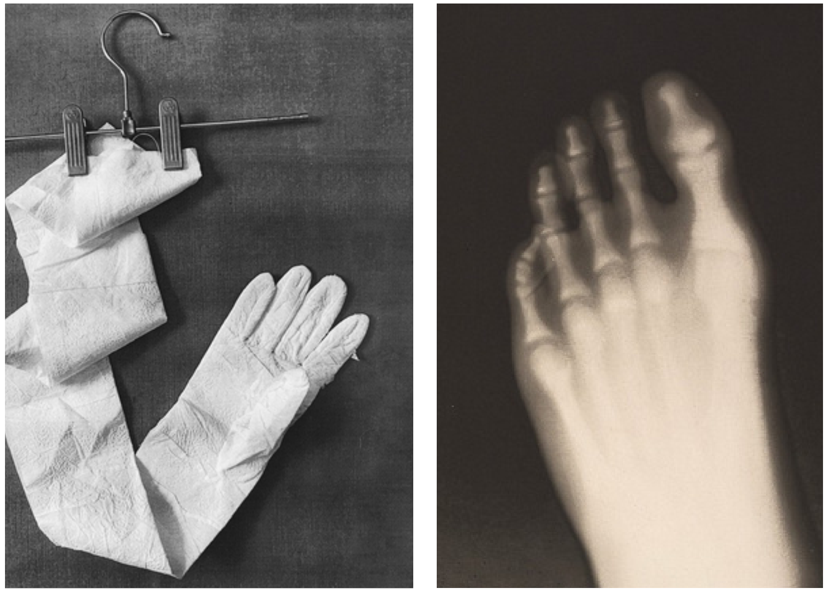
Within this context, the project treats standard shoe silhouettes as a form of soft, industrial foot binding. The biotensegrity sole and auxetic upper are conceived as an inversion of this logic: instead of compressing the foot into a pre-defined shape, the geometry is allowed to follow the real contours and expansion patterns of the individual foot. The aim is not to create a new “ideal” silhouette but to honour, and make visible, the messy, asymmetric reality of human anatomy.

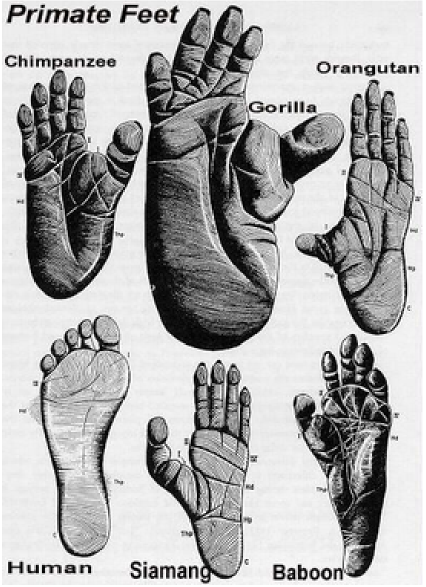


Forgetting How to Walk: Wall-E, Cushioned Soles and Learned Dependency-

A second narrative lens comes from popular culture specifically the hovering chairs in Pixar’s Wall-E. The humans on the spaceship have outsourced all locomotion to motorised sofas. Over time, their bodies atrophy, and they literally forget how to walk. In the film, the chair is as responsible for their condition as overconsumption of food. I feel modern highly cushioned footwear as a softer, subtler version of that chair. Thick foam midsoles, rigid arch supports and motion-control components are marketed as “protection” and “comfort”, yet they also reduce the need for the foot to react or respond based on impact, balance and terrain. Robbins et al. (1989) suggest that humans possess an innate impact-moderating behaviour—an automatic softening of gait when sensory feedback signals high loading. When that feedback is dampened by dense foam, the body is more likely to adopt a heavier, high-impact heel strike, potentially increasing joint loading rather than reducing it.From this perspective, the conventional running shoe is not just a product but a training device—one that trains the wearer to rely on an artificial cushioning system instead of their own musculature. Like the hovering sofa, it quietly encourages dependency. The project responds by treating geometry as a sensory amplifier rather than a dampener. The fractal and auxetic lattices are tuned to maintain and modulate ground feel, aiming to restore the feedback loop between sole and nervous system rather than sever it (Strzalkowski et al., 2015). In other words, the shoe should help the wearer remember how to walk, not invite them to forget.

The Foot as a Hand We No Longer Use.





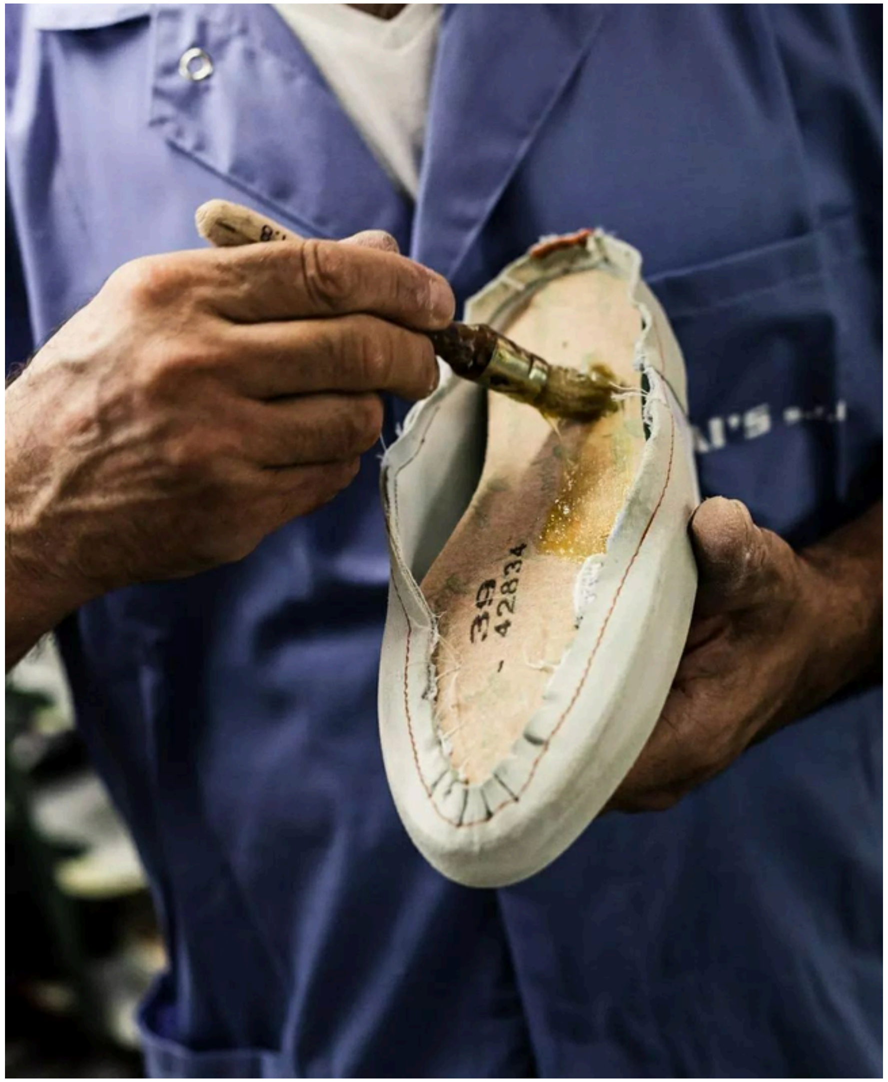
A third framing image is the idea of wearing a glove that is stiff across the palm. If the glove were rigid on the palmar side, the hand would still technically function. You could push, carry and brace but its ability to grasp, splay, climb or sense texture would be significantly impaired. This, for me, is the closest everyday analogy to what the standard midsole–outsole assembly does to the foot.

Anatomically, the foot is not a simple support block; it is a prehensile, adaptive structure with strong evolutionary ties to the hand. Anthropological and biomechanical studies of populations who habitually walk barefoot or in minimal indigenous footwear show broader forefoot shapes, pronounced toe splay and different loading patterns compared to habitually shod, urban populations (Willems et al., 2014; Willems, 2015).

Anatomically, the foot is not a simple support block; it is a prehensile, adaptive structure with strong evolutionary ties to the hand. Anthropological and biomechanical studies of populations who habitually walk barefoot or in minimal indigenous footwear show broader forefoot shapes, pronounced toe splay and different loading patterns compared to habitually shod, urban populations (Willems et al., 2014; Willems, 2015).

By contrast, the modern shoe behaves like that rigid-palm glove: it stabilises and protects, but it also flattens movement options. The plantar surface becomes a uniform contact patch, and the fine-grained, finger-like capabilities of the toes are underused. In my project, this critique translates into a conscious effort to “give the foot its fingers back” via geometry. The auxetic upper is designed to open and thicken around regions of natural expansion, while the sole lattice allows localised bending and twisting rather than enforcing a single roll-over pattern. The research lens here is not simply ergonomic; it is about re-acknowledging the foot as a richly expressive, grasping organ and asking what kind of shoe would be worthy of that complexity.

From shield to interface-
Questioning the Frozen Recipe of the Shoe, historically, footwear emerged as a pragmatic response to cold climates and harsh terrain: a simple shield against frostbite, sharp stones or hot sand. Early artifacts across cultures use rawhide moccasins, rope sandals, leather wraps that tend to be minimal, repairable and closely tied to available local materials.



Over centuries, however, while materials and manufacturing technologies have transformed from hand-stitched leather to petrochemical foams and injection-moulded plastics, the architectural recipe of the shoe has remained remarkably static: a sole, an upper, a lining, assembled around a rigid last.

I find this stagnation startling. In an era when architecture, textiles and even prosthetics have embraced parametric design, responsive materials and additive manufacturing, the everyday shoe still essentially follows a 19th-century logic of stacked layers and glued components. Even where brands employ advanced tools such as 3D-printed midsoles & knit uppers, the innovations are often inserted back into the same old sandwich: separate outsole, midsole, insole, upper, lining. The foot remains a guest in a pre-made box.

My project takes this “frozen recipe” as a provocation. Instead of adding new technologies into the existing stack, it asks whether the stack itself can be abandoned. The mono-material, 3D-printed prototype treats the shoe as a continuous interface rather than a set of parts: sole, midsole, upper and in-sock region are all expressions of a single lattice field with locally varying density. In biotensegrity terms, the shoe attempts to become an outer layer of the same tension–compression network that organises the skeleton and fascia (Levin, 2015). Protection is not discarded, but it is reimagined: rather than a thick shield, it is a strategic thickening of the same continuous mesh that also allows movement and sensation.

Positioning the Research Lens

Taken together, these analogies and references define the lens through which this project views footwear:

As a site of subtle bodily control, where standardisation and restrictive silhouettes echo historical practices of binding and shaping the body to fit cultural ideals.

As a technology of forgetting, where heavy cushioning and stiff structures retrain us away from innate impact moderation and sensory reliance.
As a missed opportunity, where a rich, grasping, responsive anatomy has been reduced to a flat support platform in most design briefs.
As a conservative typology in a rapidly evolving design landscape, where the recipe has remained largely unchanged despite the emergence of tools that could radically reconfigure it.

This context is not merely rhetorical; it directly informs the methodological choices of the project. The decision to work with pressure mapping and gait analysis comes from a desire to re-centre the felt experience of walking, as discussed in both barefoot and indigenous footwear research (Willems et al., 2014; Allen et al., 2023). The commitment to parametric lattices and mono-material printing arises from a refusal to accept the sole–upper–lining stack as a given, aligning instead with work in material ecology and computational morphogenesis (Oxman, 2015). The emphasis on proprioception and plantar sensitivity is anchored in physiological studies showing how skin thresholds on the foot sole influence balance and gait regulation (Strzalkowski et al., 2015).
Ultimately, my perspective is that this project is less about inventing a new “cool shoe” and more about re-opening a question that industrial design closed too quickly: What should a shoe be, if we start from the realities of the human foot and the planet, rather than from the constraints of old tooling and market habits? The “second skin” prototype is one attempted answer—imperfect, exploratory, provisional—but it is framed intentionally as part of a longer conversation about how design can shift from binding and buffering the body toward enabling it.

Research: Market & Competitors

market context

The global footwear market is saturated with products that prioritise branding, trend cycles and sculptural midsoles over anatomical fidelity or material responsibility. High-performance lines still depend on complex foam stacks and carbon plates; “sustainable” collections often replace one problematic material with another while maintaining the same linear production logic.
This environment creates space for a different offering: high-concept footwear where value comes from biomechanical logic, circular material flows and visible structural intelligence. The project positions itself in this gap.

competitor landscape:

- **Vivobarefoot** and the wider barefoot movement argue convincingly that thin, wide and flexible shoes can restore natural gait and strengthen intrinsic muscles. However, their shoes still rely on layered constructions, adhesives and multi-material components which limit recyclability and customisation.

- **Adidas Futurecraft 4D** and similar 3D-printed midsoles demonstrate that lattice geometry can replace foam as a cushioning medium. Yet these products typically use uniform lattice patterns and non-recyclable resins, and they focus only on the midsole, leaving uppers and outsoles conventional.

Nike ISPA explores modularity and experimentation within a mass-production system but stops short of genuine mono-material circularity or mass personalisation.

Smaller players such as **Ourownskin** experiment with scanning and custom fit but often treat geometry as surface styling rather than biomechanical infrastructure.

The proposed second-skin footwear synthesises the strongest aspects of these precedents, natural foot function, lattice performance, and custom fit while addressing their limitations through mono-materiality, data-driven geometry and a fully circular business model.

consumer profile and cultural opportunity

The intended user is a design-literate, eco-conscious early adopter who cares about how things are made as much as how they look. This audience overlaps with minimal-shoe wearers, trail runners, movement practitioners and people recovering from injuries or chronic foot issues. They are prepared to pay a premium for transparency, innovation and long-term value.

Culturally, the project aligns with a broader shift from product to system. Emerging discourses around regenerative design, biomimicry and distributed manufacturing encourage designers to think in terms of cycles rather than isolated objects (Manzini, 2015; Oxman, 2018). By making circularity and anatomical intelligence visible in the geometry itself, the project positions footwear as a site where these conversations can become tangible.

Research: Literature

My research sat at the intersection of three main bodies of literature:

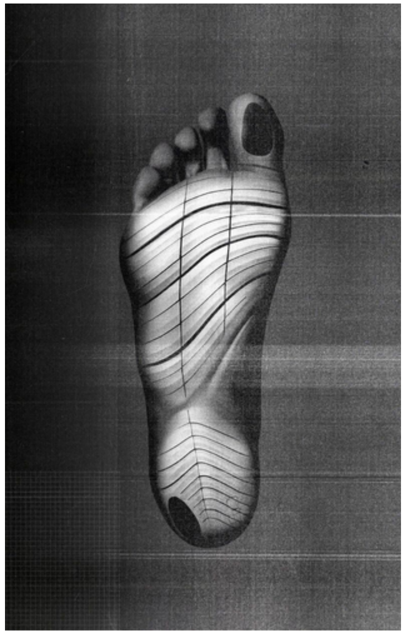
biomechanics and barefoot / indigenous footwear studies,
material and sensory physiology, and
digital / parametric design, fractals and biomimicry.

Rather than treating these as separate reading lists, I used them as three lenses looking at the same question: what should a shoe do if it genuinely respects the human foot?

At some point I realised: what better to look at for the best “foot replication” in nature than our own feet? That sounds obvious, but it shifted how I was reading. Instead of searching for ready-made “shoe answers”, I started reading for foot behaviour. How fascia loads, how toes splay, how pressure travels across the plantar surface?. So that the footwear could become a response, not an imposition. Learning from the Foot Instead of the Shoe.

The work of Willems, D’Août and colleagues was my anchor in understanding how anatomy, gait and footwear really interact. Willems’ PhD thesis The Birth of Feet, The Rebirth of Footwear (2015) and related studies on indigenous footwear showed that populations walking barefoot or in thin local sandals tend to display wider forefeet, healthier toe alignment and different pressure distributions than habitually shod urban populations (Willems et al., 2014; Willems, 2015). These “unstandardised” feet are closer to what my sole geometry is trying to support: splayed toes, dynamic arches, continuous adaptation rather than a frozen, last-shaped outline.

Multon et al. (2014) further frame gait as a consequence of anthropometry. How limb proportions and foot shape influence the way forces travel through the body. Reading this reinforced my decision to avoid a single “hero form” and instead build a parametric system that can be tuned to different foot proportions and loading patterns.



This literature pushed the project away from designing a beautiful object and toward designing a responsive field. The three-layer sole—fine upper lattice, directional auxetic middle layer, denser fractal base, came directly from trying to mirror the layered logic of skin–fat–fascia–bone described in therapeutic footwear texts such as Bennett and Haines (2018) and Nigg & Segesser (2010). Instead of stacking different materials to mimic these layers, the project uses one material and changes geometry to emulate similar behaviour.

Barefoot, Minimal Footwear and Indigenous Studies

The barefoot and minimal footwear research provided both encouragement and warning. Curtis et al. (2016) show that daily activity in minimal footwear can increase intrinsic foot strength, while Allen et al. (2023) demonstrate that walking in individualized 3D-printed minimal footwear can preserve function while allowing a customised interface. These findings validated my intuition that less shoe can mean more foot, as strategy. They gave me the confidence to treat ground feel as a functional requirement, not an optional "minimalist" aesthetic. Instead of maximising shock absorption, I aimed to modulate it:

In high-pressure zones (heel, metatarsal heads), the fractal lattice becomes denser and thicker, dispersing peak forces while still allowing the skin to read texture.

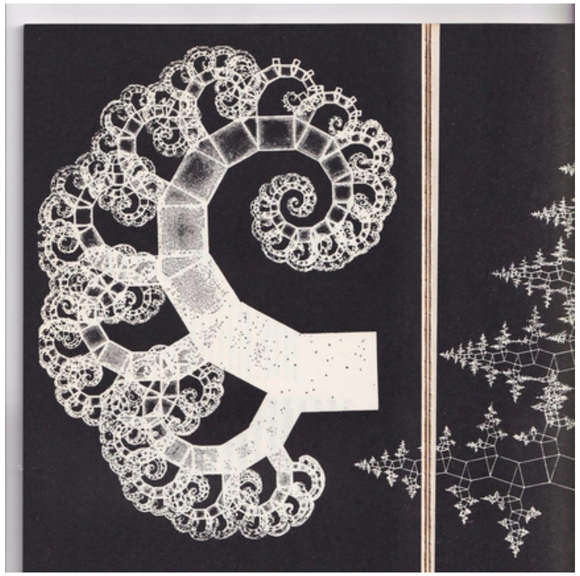
In low-pressure or torsional zones (arch, lateral midfoot), the structure opens up and becomes more compliant, allowing the foot to twist, splay and feel micro-variations in terrain.

This behaviour is an attempt to formalise Robbins' insight into geometry: the shoe should not override impact-moderating behaviour; it should invite it by letting the body actually sense that impact.

Fractals, Auxetics and Biomimicry

Fractals and auxetics entered the project initially as visual fascinations, but the literature transformed them into structural tools. Mandelbrot's The Fractal Geometry of Nature (1982) and Field's work on fractals in natural systems (2000) frame self-similarity as a way nature achieves structural efficiency at multiple scales: tree roots, vascular systems, bronchial branches. Oxman's writing on material ecology and computational morphogenesis (2015; 2018) then connects these ideas to digital fabrication, suggesting that we can design like nature by encoding rules rather than fixed forms.

In the project, this translated into a sole that is not "designed" in the traditional sense but grown via L-systems and diffusion-limited aggregation (DLA) algorithms, guided by pressure-map attractors. High-load zones become areas of high branching density; low-load zones remain sparse. This is my attempt to produce a biotensegrity-inspired outer fascia: a network of compression and tension that redistributes load across the



ong as basic protection is addressed.

Willems et al. (2014) and Ojiambo et al. (2013) look at indigenous or rural populations where minimal sandals or barefoot locomotion are normal. Their data link such environments to different patterns of physical activity, foot morphology and gait, suggesting that the human foot is naturally robust when not chronically constrained. I used this as a scientific "permission slip" to keep the sole visually porous and structurally light. Rather than filling gaps with foam "just in case", I allowed large voids in low-pressure regions, trusting that a healthy foot wants that space. At the same time, papers by Stoneham et al. (2020; 2021) and others show that simply throwing a person into minimal shoes is not a magic fix; changes in stride length, toe alignment and knee motion can be significant, and transition needs to be carefully considered. This informed the idea of three variations in the line-up (Minimalist, Hybrid, All-Terrain), each representing a different place on the spectrum between "barefoot-like" and "protected". The research acted as a reminder that design must scaffold behavioural change, not just assume it.

Proprioception, Skin Sensitivity and Impact Moderation

A second cluster of readings shifted my focus from bones and joints to skin and sensation. Strzalkowski et al. (2015) show that thresholds of plantar skin sensitivity are linked to mechanical properties of the sole of the foot, and that this sensitivity plays a role in balance and gait regulation. Robbins et al. (1989) propose the Innate Impact Moderation Hypothesis, arguing that humans instinctively adjust their landing strategy based on sensory feedback from the feet.

These two ideas—plantar skin as a sensor, and gait as a feedback-driven behaviour—directly shaped the geometry plantar surface in the same way the plantar fascia and ligaments redistribute it internally.

Auxetics—structures with a negative Poisson's ratio—came in as the missing link for the "second skin" idea. Tutorials and engineering case studies on re-entrant honeycombs, chiral auxetics and rotating squares showed that when these geometries are stretched, they expand laterally instead of thinning. For the upper and in-sock region, this is exactly what I needed: When the forefoot loads and the toes splay, the auxetic mesh can thicken and wrap instead of cutting into the foot.

Around the arch and ankle, directional auxetic fields can provide gentle hugging tension that increases with expansion, without adding rigid reinforcements.

This approach is a form of biomimicry, but instead of copying a specific bone or tendon, it imitates a behavioural pattern: expansion and contraction under load. The key question became: what geometries can perform biotensegrity-like behaviour in a printable, mono-material lattice?

The answer from the literature and my tests was a combination of:

Fractal branching for hierarchical stiffness and load distribution (heel → arch → toes).

Re-entrant auxetic cells for localised thickening around expansion zones.

Multi-layer stacking (fine mesh / auxetic / coarse lattice) to simulate the layered timing of skin–fat–fascia under impact.

These were not abstract geometric games; they were direct responses to what I was learning about fascia, tension networks and plantar mechanics in sources like Nigg & Segesser (2010), Bennett & Haines (2018) and Willems (2015).

Books on Footwear Science, Prosthetics and Skin-like Systems

Texts like The Science of Footwear (Nigg & Segesser, 2010), Therapeutic Footwear (Bennett & Haines, 2018) and Biomechanics of Running Shoes (Frederick & Hennig, 2011) helped me understand how the industry typically solves problems: more materials, more layers, more targeted support elements. They also highlighted very real needs—diabetic feet, deformities, overuse injuries—which made me cautious about dismissing all cushioning or structure as "bad".

Instead of simply rejecting those strategies, I asked: can I offer the same functional intentions—pressure redistribution, stability, comfort—using geometry rather than chemical layering? That question is essentially the core of the project.

Parallel reading in soft robotics, prosthetics and skin-like electronics (e.g. Huang et al., 2022; Rogers et al., 2021; Wang & Chen, 2020) sharpened my thinking about the "second skin" metaphor. These fields approach the body–technology interface as continuous, conformal and adaptive, not as a hard object strapped onto soft tissue. Their work reinforced my decision to keep the shoe monolithic and flexible, to avoid discrete stiff plates, and to treat the lattice as a soft robotic structure rather than a static shell.

Digital Design, TPU and Additive Manufacturing

On the technical side, documentation and tutorials from Rhino/Grasshopper, Kangaroo and platforms like Parametric House and Parametric3D helped me translate biomechanical intentions into parametric logic. Grasshopper's physics-based tools allowed me to simulate deformation under load before printing, which was critical for tuning strut thickness and cell size.

Articles on TPU footwear applications and flexible filaments (e.g. industry reports on TPU 3D printing and All3DP overviews) grounded my material assumptions: typical Shore hardness ranges, fatigue behaviour, recyclability and print constraints. This literature confirmed that TPU could realistically survive repeated compression cycles and be re-milled into new filament, supporting the circularity claim, while also revealing its limitations—warping, sensitivity to temperature, and the need for careful feature-size thresholds.

These constraints fed back into the geometry: minimum strut diameters, maximum overhang angles, and decisions about whether to pursue support-free FDM versus powder-bed processes. In other words, the literature on digital fabrication didn't just sit in a methods section; it actively shaped what kinds of fractals and auxetics were printable and therefore what kind of "second skin" was even possible.

Design Theory, Systems Thinking and Circularity

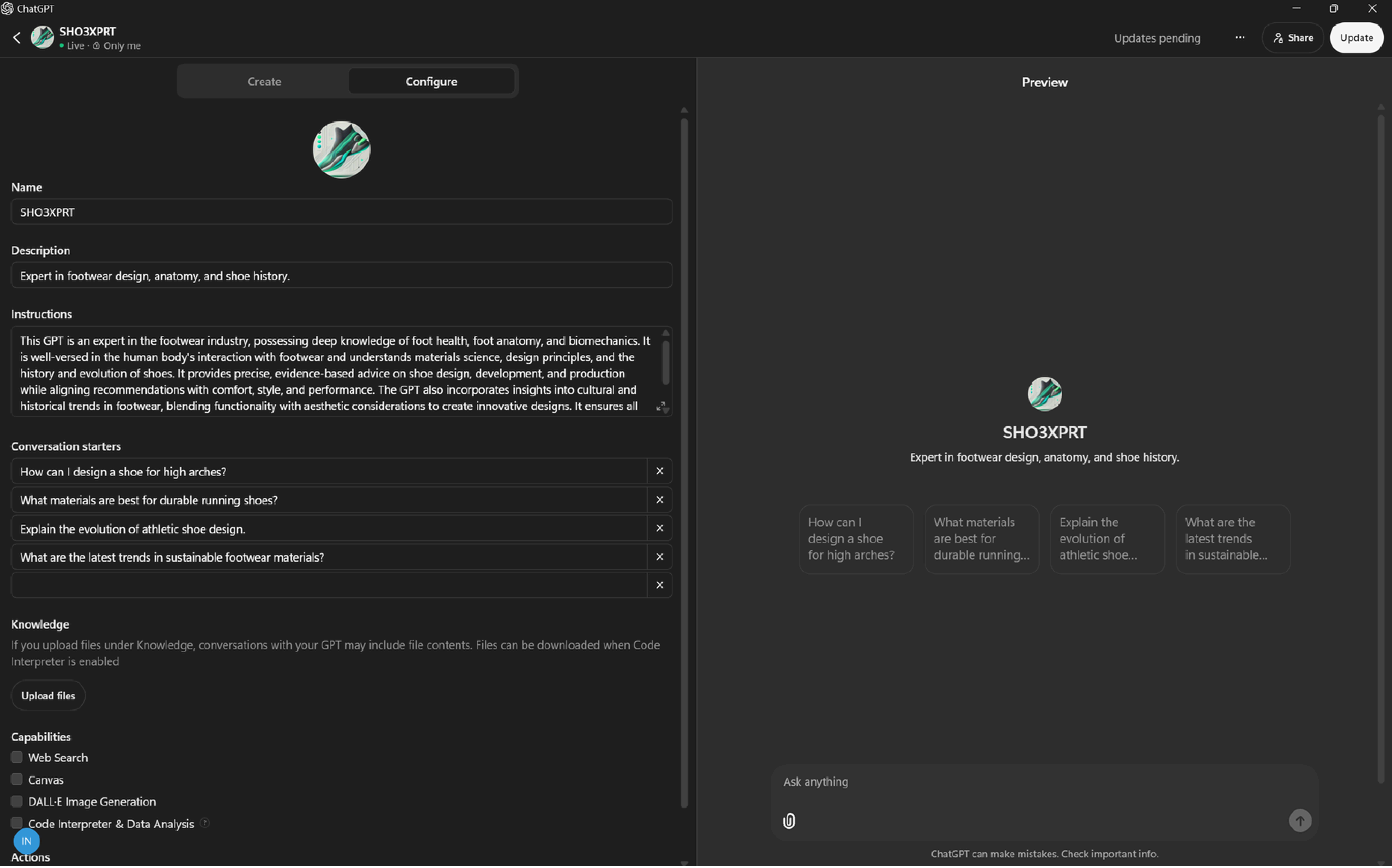
Finally, design and cultural texts—Antonelli's Broken Nature (2019), Manzini's Design, When Everybody Designs (2015), Pallasmaa's The Thinking Hand (2009), Oxman's Age of Entanglement (2015)—gave me a language for what I was intuitively trying to do: treat the shoe as a system rather than an isolated object.

These authors emphasise entanglement between material, body, ecology and technology. That thinking underpins the decision to pursue a mono-material, closed-loop model and to design packaging and return logistics as part of the project rather than afterthoughts. It also justifies the heavy investment in parametric scripting: the real "product" is not one shoe, but a reproducible, adaptable process that can generate many anatomically tuned variations.

Reading this work also pushed me to document failure, ambiguity and iteration honestly, rather than pretending the design emerged cleanly. The reflective practice lens (Schön, 1983, also implicit in this literature) encouraged me to treat each print, misprint and test as a research artifact in itself.

In summary, the books and articles did not sit in a separate "theory" box; they continuously redirected my design decisions. Barefoot and indigenous studies told me to trust the foot and make space for it. Physiology and biomechanics papers convinced me to prioritise sensation and impact moderation. Fractal and auxetic literature offered concrete geometric tools to implement biotensegrity-like behaviours in a single material. Digital fabrication sources set the boundaries of what could actually be made. And design theory helped me see the shoe as a living system within larger ecological and cultural networks.

All of that leads back to the initial intuition: if the aim is to create footwear as a second skin, the research has to begin not with shoes, but with feet—and with the systems, geometries and materials that can genuinely support them.



Name

SHO3XPRT

Description

Expert in footwear design, anatomy, and shoe history.

Instructions

This GPT is an expert in the footwear industry, possessing deep knowledge of foot health, foot anatomy, and biomechanics. It is well-versed in the human body's interaction with footwear and understands materials science, design principles, and the history and evolution of shoes. It provides precise, evidence-based advice on shoe design, development, and production while aligning recommendations with comfort, style, and performance. The GPT also incorporates insights into cultural and historical trends in footwear, blending functionality with aesthetic considerations to create innovative designs. It ensures all

Conversation starters

- How can I design a shoe for high arches?
- What materials are best for durable running shoes?
- Explain the evolution of athletic shoe design.
- What are the latest trends in sustainable footwear materials?

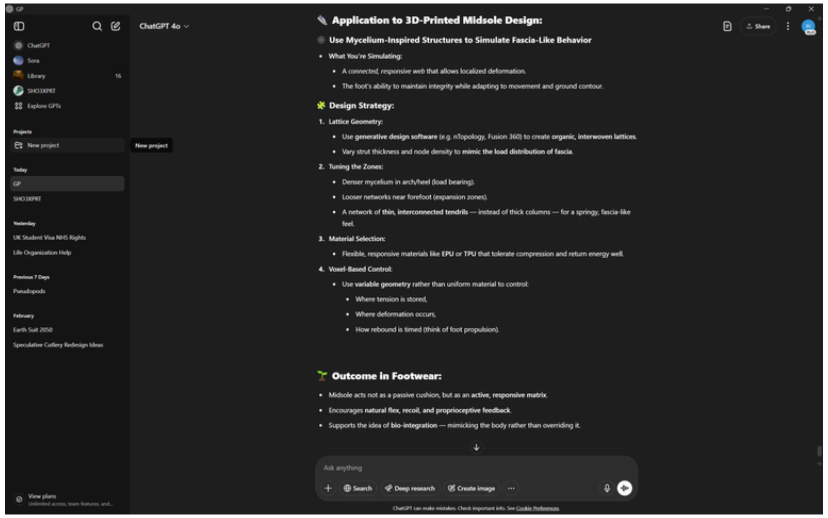
Knowledge

If you upload files under Knowledge, conversations with your GPT may include file contents. Files can be downloaded when Code Interpreter is enabled

Capabilities

☐ Web Search
☐ Canvas
☐ DALL·E Image Generation
☐ Code Interpreter & Data Analysis

Actions



Application to 3D-Printed Midsole Design:

Use Mycelium-Inspired Structures to Simulate Fascia-Like Behavior

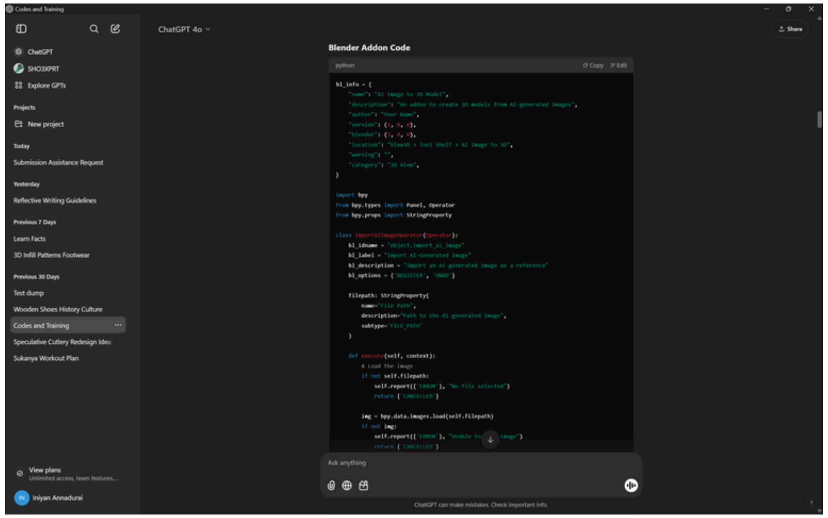
- **What You're Simulating:**
  - A *connected, responsive web* that allows localized deformation.
  - The foot's ability to maintain integrity while adapting to movement and ground contour.

Design Strategy:

1. **Lattice Geometry:**
   - Use **generative design software** (e.g. nTopology, Fusion 360) to create **organic, interwoven lattices**.
   - Vary strut thickness and node density to **mimic the load distribution of fascia**.
2. **Tuning the Zones:**
   - Denser mycelium in arch/heel (load bearing).
   - Looser networks near forefoot (expansion zones).
   - A network of **thin, interconnected tendrils** — instead of thick columns — for a springy, fascia-like feel.
3. **Material Selection:**
   - Flexible, responsive materials like **EPU** or **TPU** that tolerate compression and return energy well.
4. **Voxel-Based Control:**
   - Use **variable geometry** rather than uniform material to control:
     - Where tension is stored,
     - Where deformation occurs,
     - How rebound is timed (think of foot propulsion).

Outcome in Footwear:

- Midsole acts not as a passive cushion, but as an **active, responsive matrix**.
- Encourages **natural flex, recoil, and proprioceptive feedback**.
- Supports the idea of **bio-integration** — mimicking the body rather than overriding it.



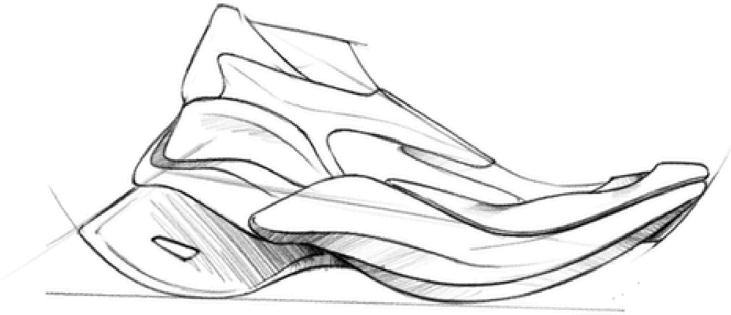
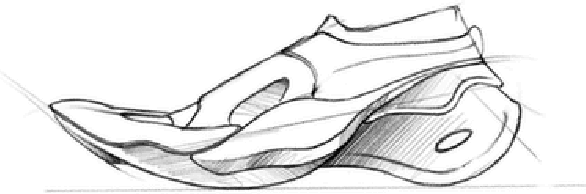
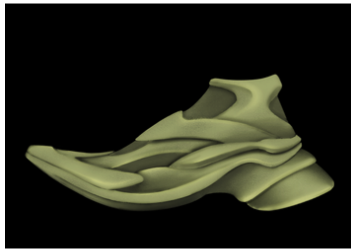
Blender Addon Code

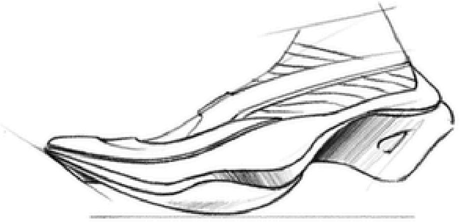
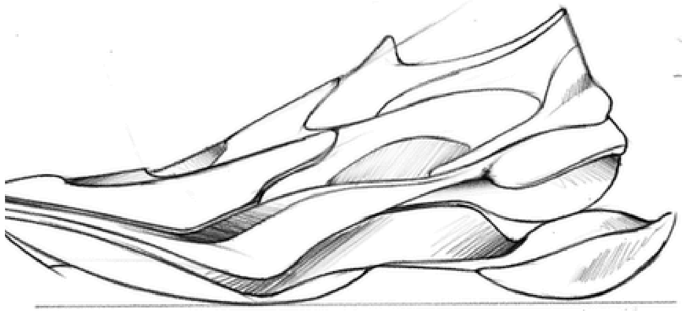
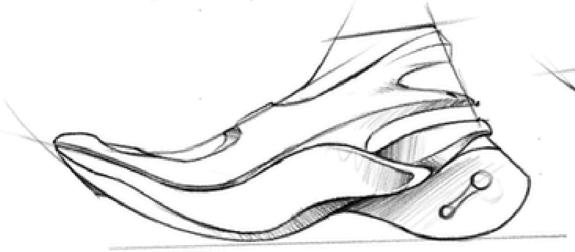
```python
bl_info = {
    "name": "AI Image to 3D Model",
    "description": "An addon to create 3D models from AI-generated images",
    "author": "Your Name",
    "version": (1, 0, 0),
    "blender": (3, 0, 0),
    "location": "View3D > Tool Shelf > AI Image to 3D",
    "warning": "",
    "category": "3D View",
}

import bpy
from bpy.types import Panel, Operator
from bpy.props import StringProperty

class ImportAIImageOperator(Operator):
    bl_idname = "object.import_ai_image"
    bl_label = "Import AI-Generated Image"
    bl_description = "Import an AI-generated image as a reference"
    bl_options = {'REGISTER', 'UNDO'}

    filepath: StringProperty(
        name="File Path",
        description="Path to the AI-generated image",
        subtype='FILE_PATH'
    )

    def execute(self, context):
        # Load the image
        if not self.filepath:
            self.report({'ERROR'}, "No file selected")
            return {'CANCELLED'}

        img = bpy.data.images.load(self.filepath)
        if not img:
            self.report({'ERROR'}, "Unable to [illegible] image")
            return {'CANCELLED'}
```

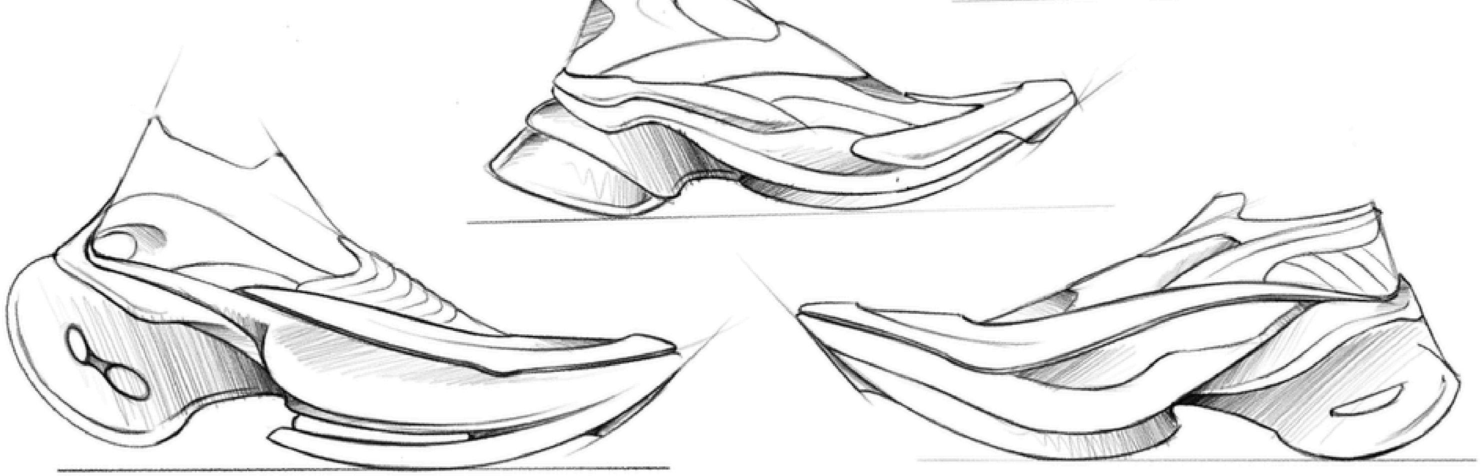
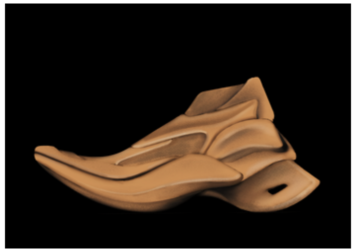
Research: AI

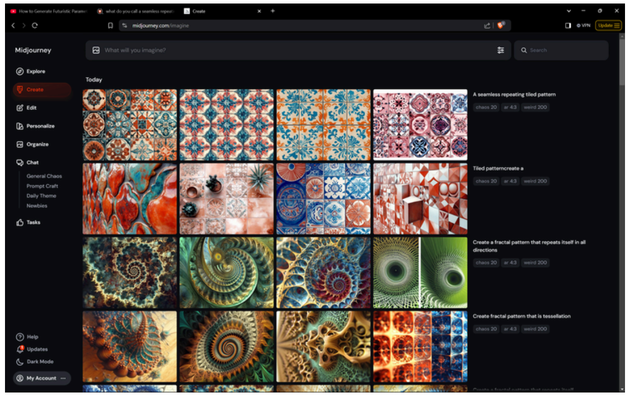
each print, misprint and test as a research artifact in itself. In summary, the books and articles did not sit in a separate “theory” box; they continuously redirected my design decisions. Barefoot and indigenous studies told me to trust the foot and make space for it. Physiology and biomechanics papers convinced me to prioritise sensation and impact moderation. Fractal and auxetic literature offered concrete geometric tools to implement biotensegrity-like behaviours in a single material.

each print, misprint and test as a research artifact in itself. In summary, the books and articles did not sit in a separate “theory” box; they continuously redirected my design decisions. Barefoot and indigenous studies told me to trust the foot and make space for it. Physiology and biomechanics papers convinced me to prioritise sensation and impact moderation. Fractal and auxetic literature offered concrete geometric tools to implement biotensegrity-like behaviours in a single material.



A seamless repeating tiled pattern

chaos 20 ar 4:3 weird 200

Tiled patterncreate a

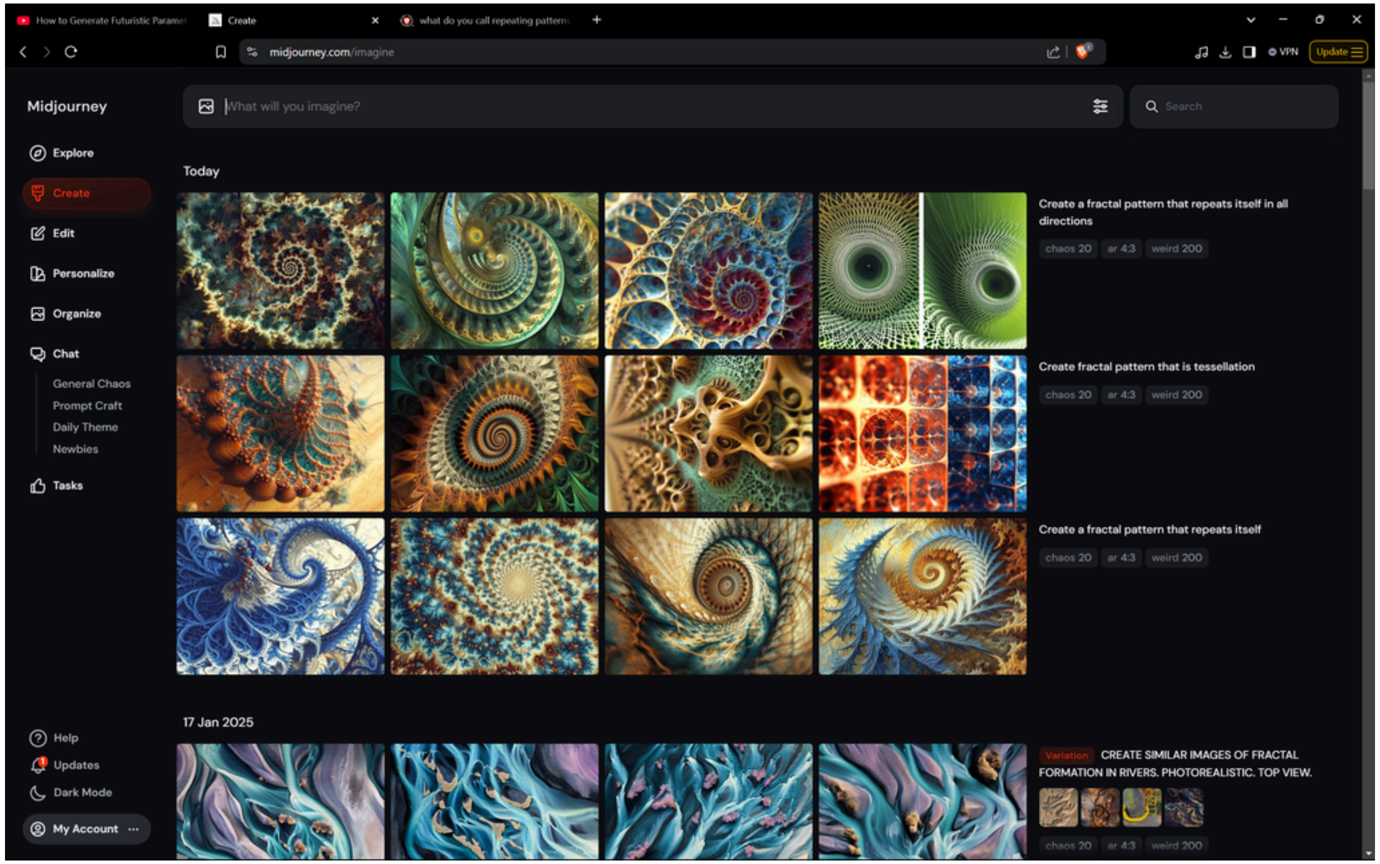
chaos 20 ar 4:3 weird 200

Create a fractal pattern that repeats itself in all directions

chaos 20 ar 4:3 weird 200

Create fractal pattern that is tessellation

chaos 20 ar 4:3 weird 200



Create a fractal pattern that repeats itself in all directions

chaos 20 ar 4:3 weird 200

Create fractal pattern that is tessellation

chaos 20 ar 4:3 weird 200

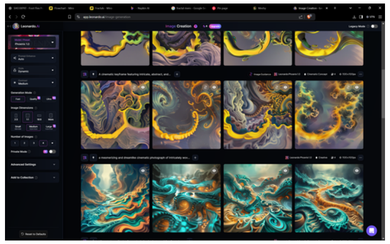
Create a fractal pattern that repeats itself

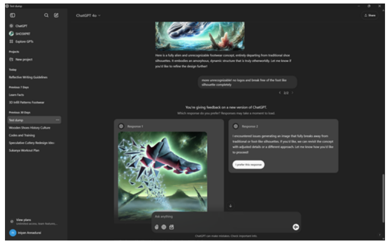
chaos 20 ar 4:3 weird 200

Variation CREATE SIMILAR IMAGES OF FRACTAL FORMATION IN RIVERS. PHOTOREALISTIC. TOP VIEW.

chaos 20 ar 4:3 weird 200

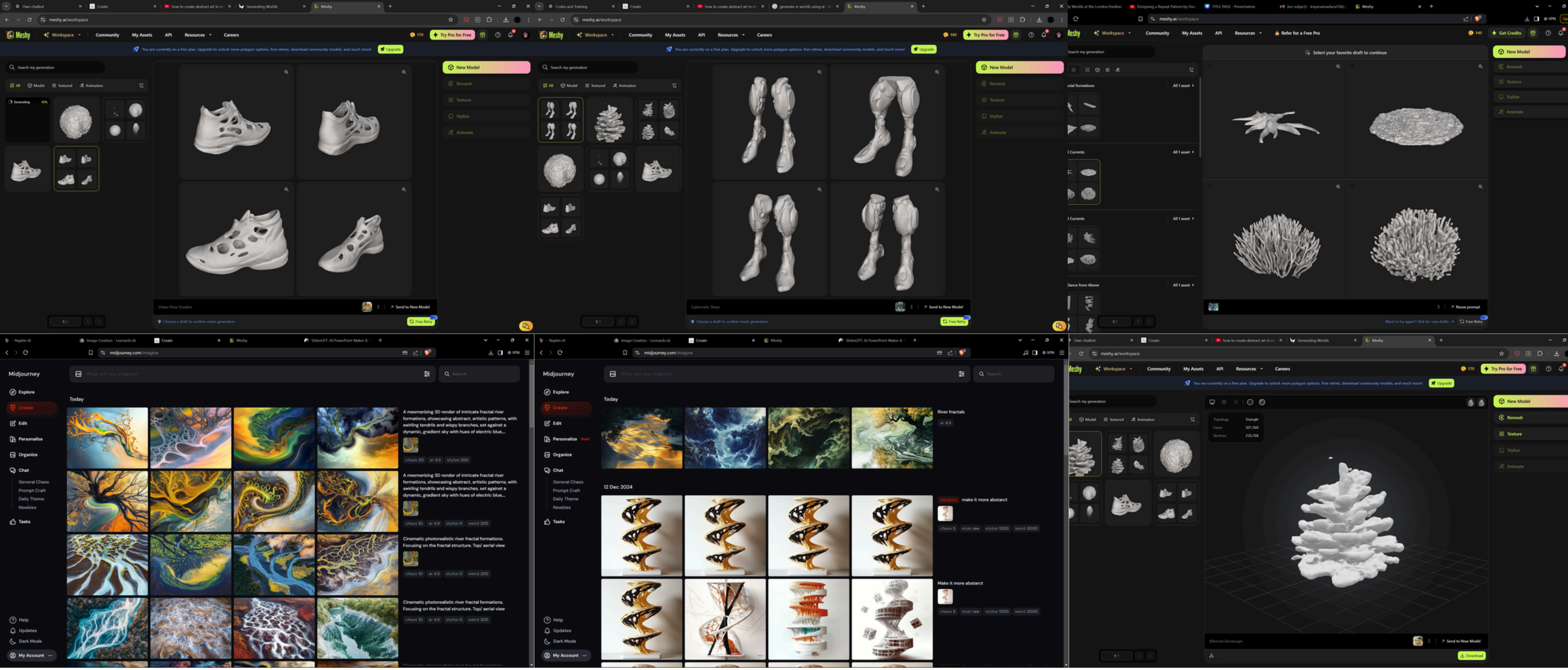
Multiple images were generated using various text-to-image AI platforms, while maintaining consistent prompts across tools. The primary variables adjusted during this process were parameters related to realism, creativity, and visual interpretation. Through several iterative rounds of generation, outputs were progressively refined by using the closest results as visual references for subsequent prompts. This iterative feedback loop allowed the imagery to move closer to the intended design vision.





Alongside refinement, the process actively tested the limits of the AI's creative capacity. The objective was not to reproduce existing visual references commonly found in online datasets, but to prompt the system to speculate and generate unfamiliar spatial, material, and structural configurations which has the potential to expand the designer's visual and spatial imagination beyond familiar representational references.

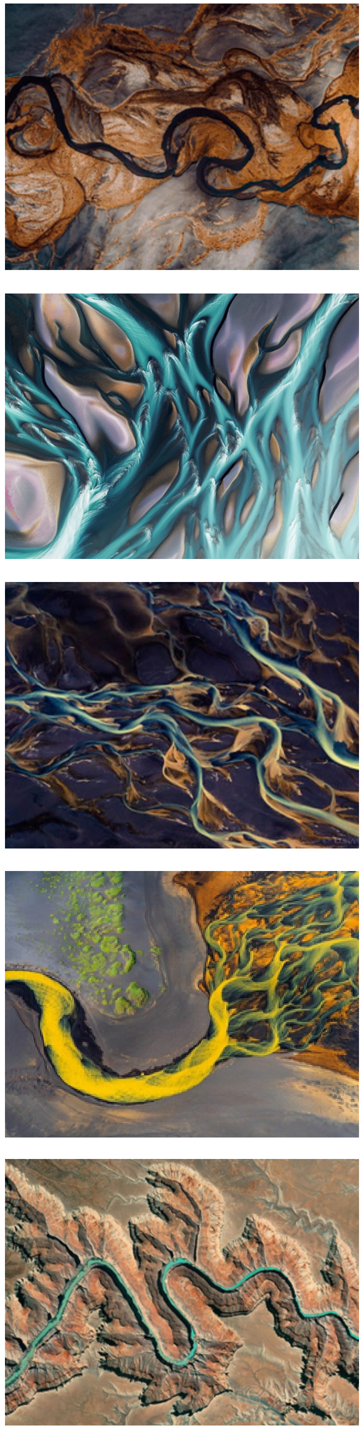
This approach was an attempt to use AI not as a tool for visual recycling, but as a generative partner for imagining forms beyond readily available precedents which ultimately fell short of the intended expectations.

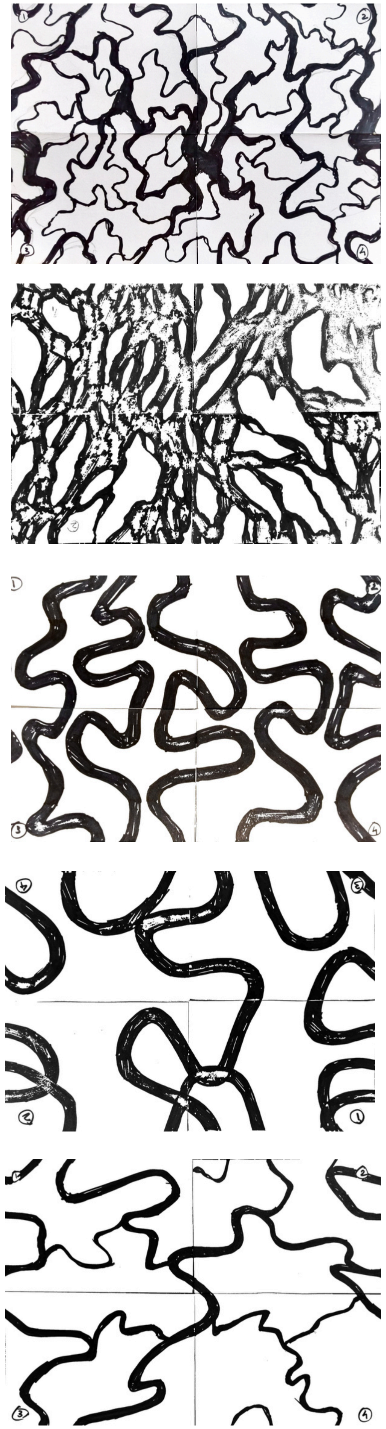


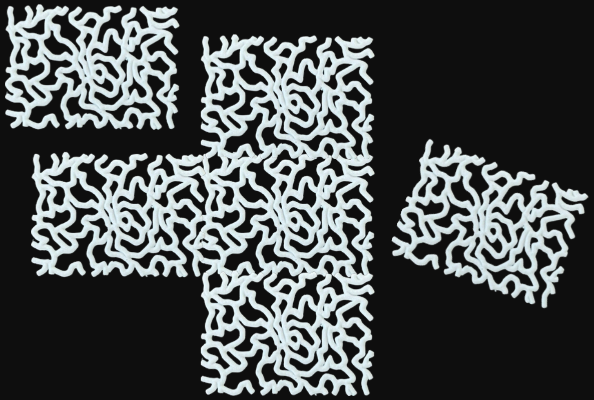
Another component of the project involved actively tracking emerging digital tools and technologies that could be meaningfully integrated into the design process. Particular attention was given to recent developments in artificial intelligence–based generative software. One such tool explored was image-to-3D model generation software, specifically Meshy3D.

Motivated by the potential of this technology, sculptural and abstract forms were first generated using text-to-image AI systems. These images were then used as inputs for image-to-3D generation software, translating two-dimensional visual prompts into three-dimensional digital objects. This workflow was intentionally adopted to shift the source of inspiration from conventional two-dimensional imagery to volumetric, spatial references. By engaging with three-dimensional inspiration at an early conceptual stage, the process challenged traditional image-based ideation methods and supported a more spatially informed design exploration.

This approach opens possibilities for augmented reality (AR), where three-dimensional inspirations can be placed directly within the workspace, allowing designers to engage with reference material as a spatial presence rather than a flat image.

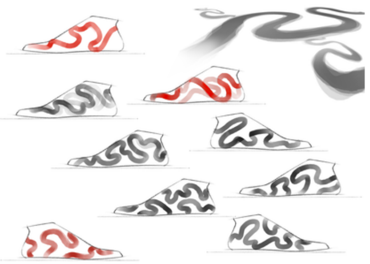


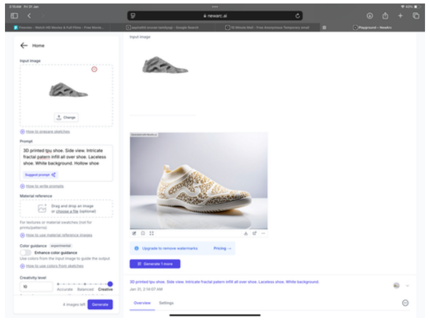




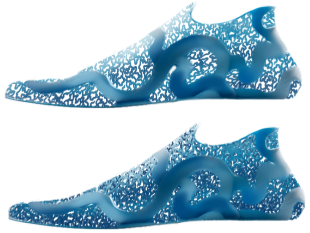
Drawing inspiration from the top-view flow patterns of rivers generated through AI, I sketched my own fractal patterns, which I later translated to modular pieces. Each piece connects seamlessly from all sides, creating a continuous pattern that gives the impression of an organic, naturally occurring form.

AI generated images were used as inspiration to create seamless fractal patterns.





In the early stages of the project, I attempted to develop fractal-pattern-inspired footwear concepts by generating renders from initial sketches using multiple AI-assisted design tools, including Vizcom and Newarc AI. While some outputs achieved a high level of visual realism, a recurring limitation became apparent. Despite detailed and explicit prompts, the generated images consistently reproduced conventional footwear typologies. Most notably the familiar tri-part structure of sole, upper, and lining. This repetition reflects the inherent bias of these AI systems, which are trained predominantly on existing, historically standardized footwear imagery. As a result, the tools tended to reinforce the very structural conventions the project seeks to critique, inadvertently mirroring the problem of entrenched design logic within the contemporary footwear industry.



In response to these limitations, selected AI-generated images that aligned partially with my design intent were taken forward into Procreate for further refinement. This manual intervention allowed me to redraw, adjust, and re-render key visual elements, correcting proportions, structural logic, and surface articulation to more accurately reflect the conceptual and formal direction of the project.

This hybrid workflow of combining AI generation with hands-on digital drawing gives greater control over the final visual outcomes, ensuring they remained aligned with the project's critical stance rather than defaulting to conventional footwear aesthetics.

Research: Play & Prototyping

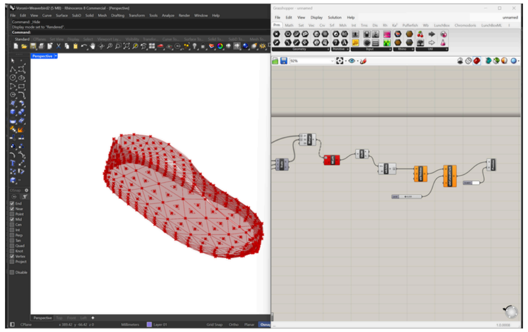


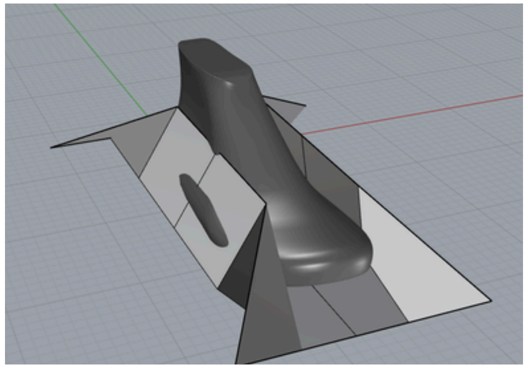


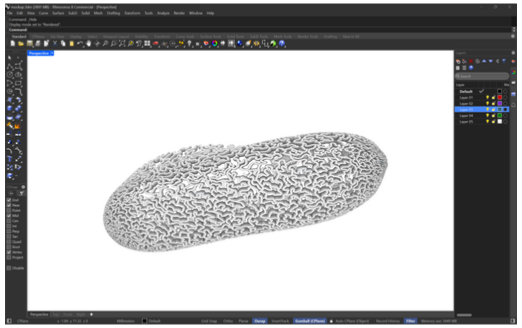

An early studio prototype explored these ideas through an experimental concept shoe in which the conventional midsole was replaced by a network of tubular channels filled with Oobleck, a non-Newtonian shear-thickening fluid. This prototype functioned as a speculative investigation rather than a performance-ready shoe, aimed at externalising the relationship between gait, emotion, and bodily awareness.

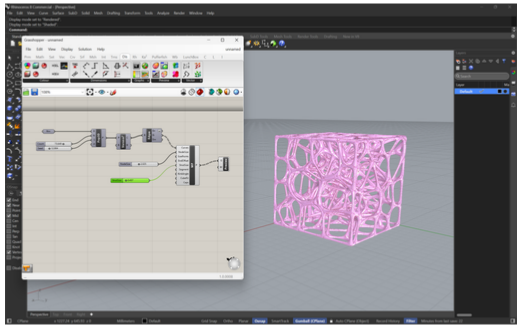
The underlying concept was to make the wearer consciously aware of their movement patterns. When loaded gently, the fluid remained compliant, offering insufficient structural support and encouraging instability.

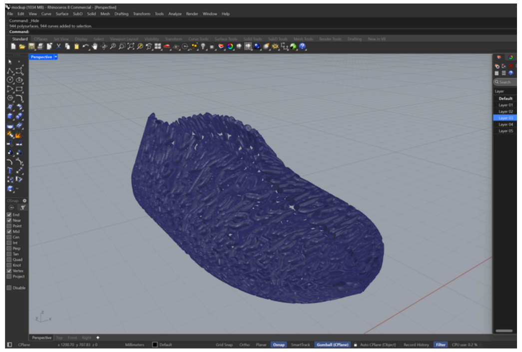
Conversely, excessive force or abrupt stomping caused the fluid to stiffen, producing discomfort through sudden resistance. In this way, the shoe acted as a form of behavioural feedback system. Developed in response to a brief exploring how footwear might influence emotional states, the prototype treated gait as an expression of mood—recognising that stress, anger, or agitation often manifest as heavier, more erratic steps. The shoe therefore operated as a form of “training wheel,” discouraging harmful movement patterns and prompting more controlled, attentive walking. While impractical in its early form, this experiment laid the conceptual foundation for later explorations into pressure-responsive systems and embodied feedback within the project.



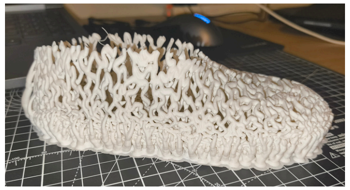




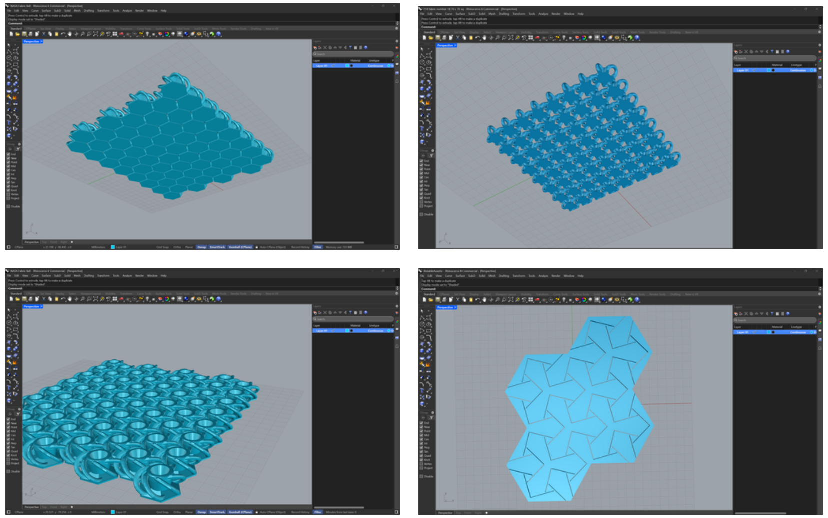




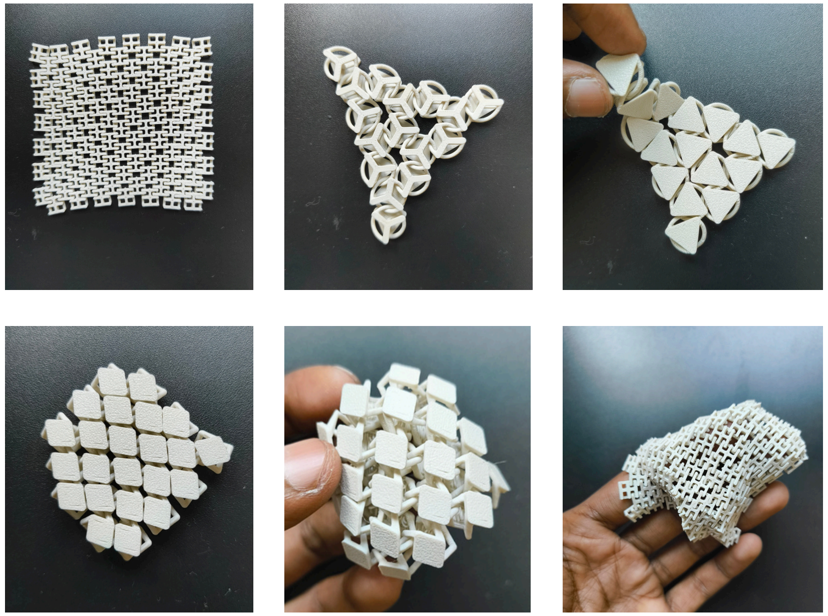
Parallelly, I began developing technical proficiency in 3D modelling and additive manufacturing, with a particular focus on parametric design workflows in Grasshopper. This phase involved active learning through experimentation, tutorials, and iterative testing, allowing computational logic to gradually become an integral part of the design process rather than a representational tool.

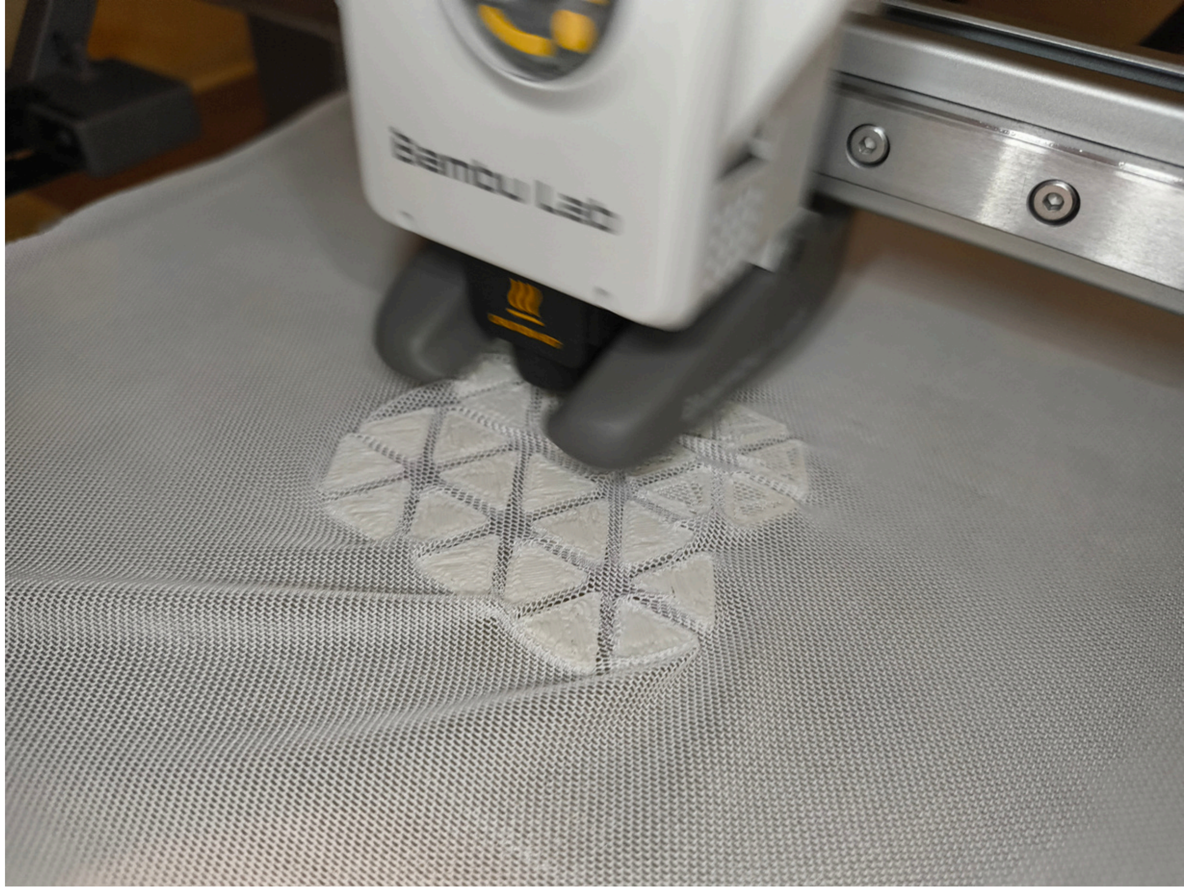


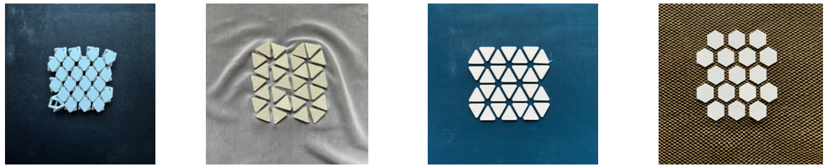
A small-scale prototype was fabricated using PLA to test the seamless fractal pattern developed during the earlier design phase. This physical model functioned as a proof of concept, allowing the evaluation of pattern continuity, structural behaviour, and geometric legibility in three dimensions before progressing further.



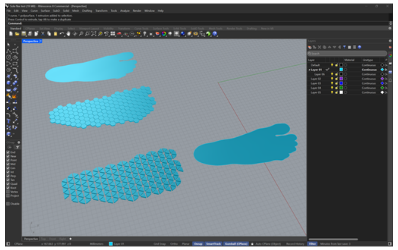
I also 3D printed chainmail structures. These behave like fabrics when enough of them are stringed together.

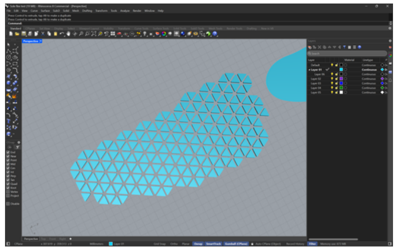




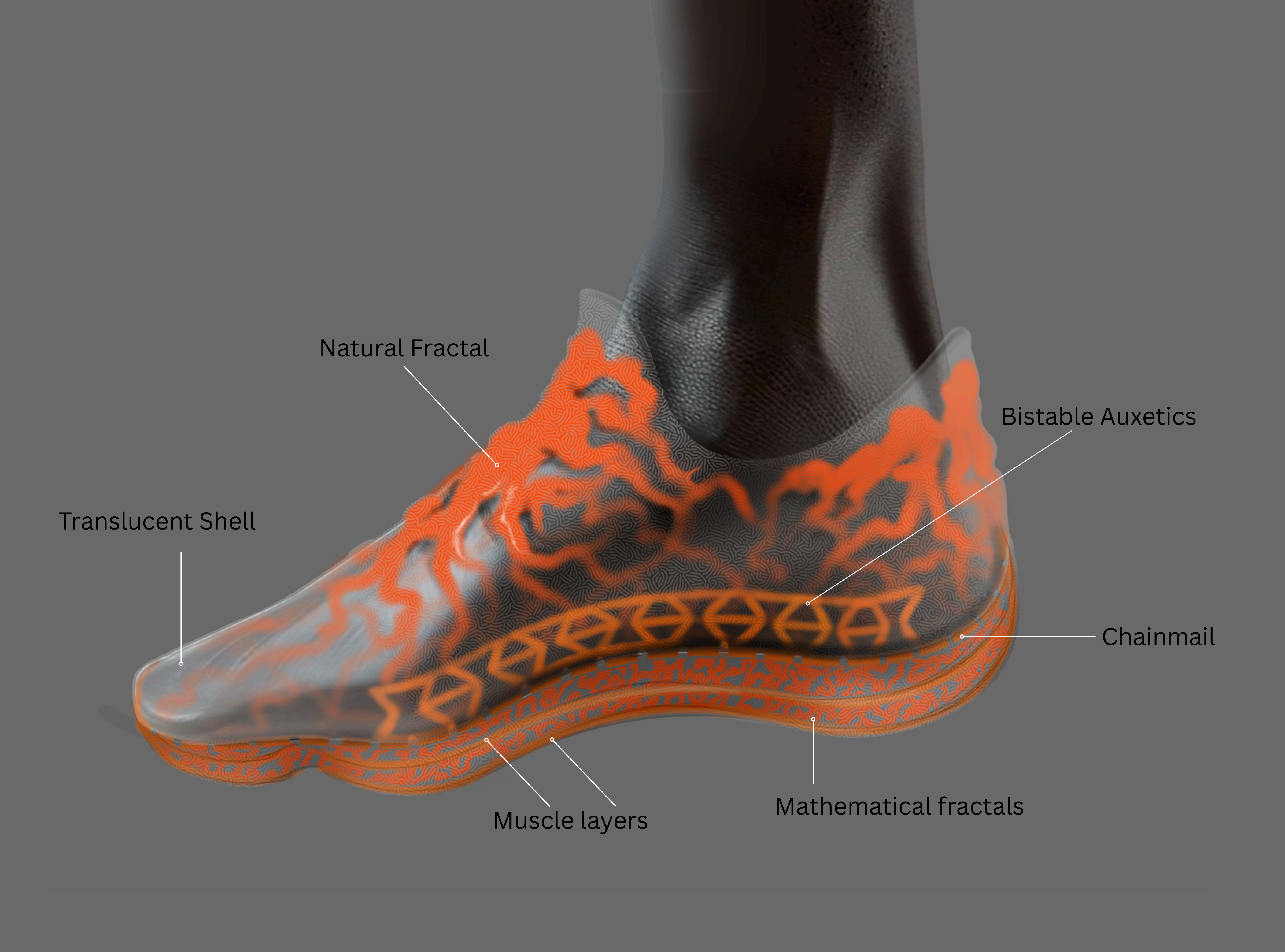


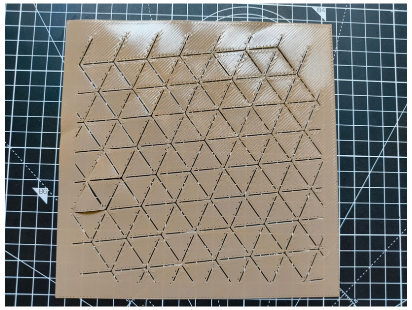
Another important technique was 3d printing on fabric. For this I used various patterns on different fabrics.

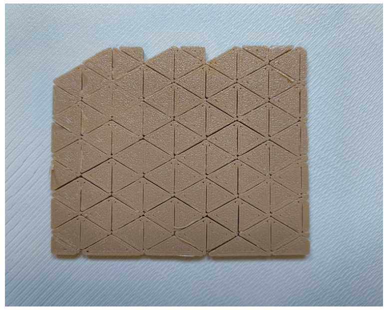


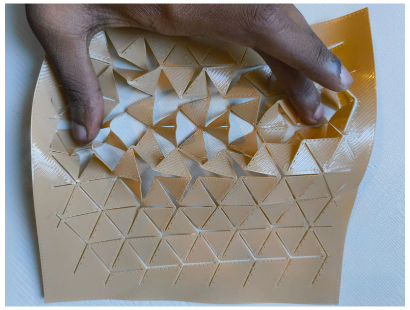


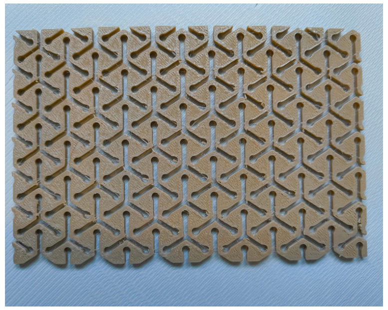
Later the 3D printing on fabric technique was used to create an early concept/ prototype to create more flexibility and movement on the plantar part of the foot.

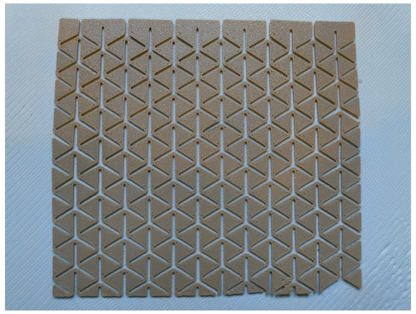

Natural Fractal
Translucent Shell
Bistable Auxetics
Chainmail
Muscle layers
Mathematical fractals

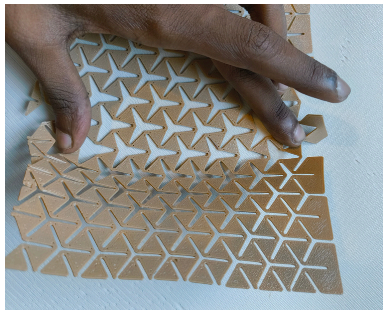






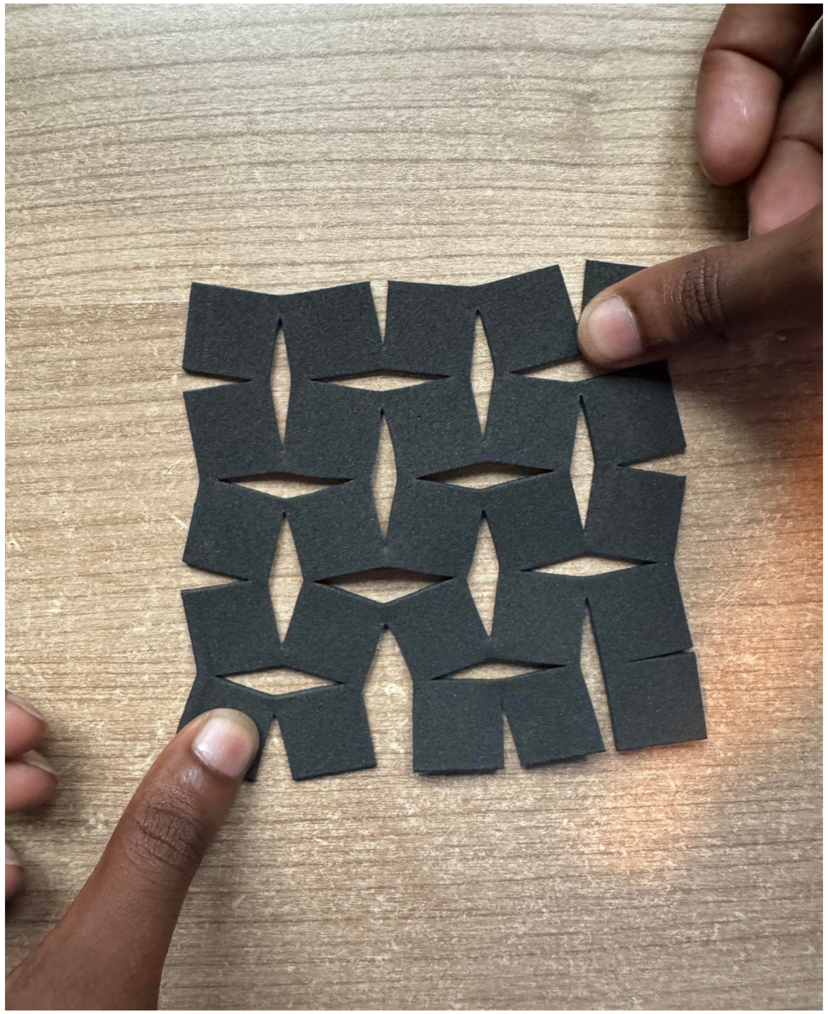


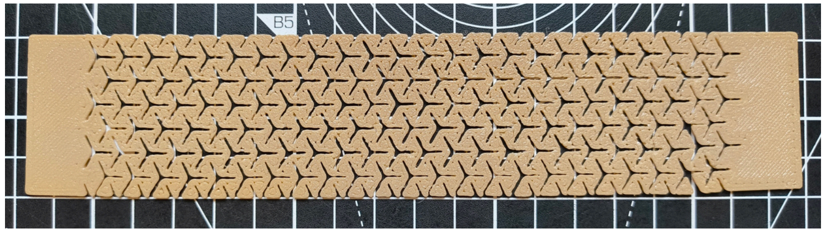


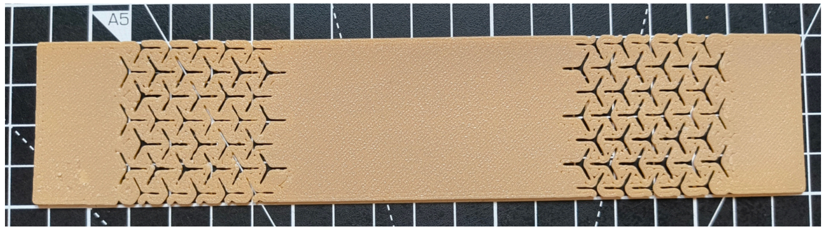


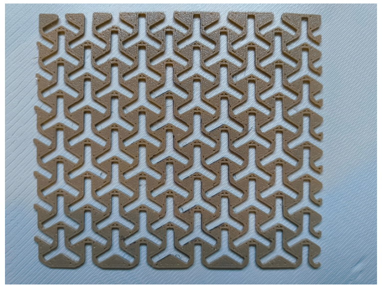
Auxetic structures are a type of geometry that behave in the opposite way to most everyday materials. When you stretch them, instead of becoming thinner, they actually expand sideways, and when you compress them, they contract inward. This behaviour does not come from the material itself, but from the way the geometry is designed, using forms such as re-entrant angles or rotating units.

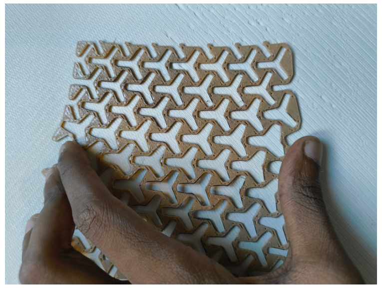
I found auxetics particularly relevant for footwear because the human foot naturally expands, spreads, and changes shape while walking. By using auxetic structures, the shoe can move and adapt with the foot rather than resisting it, allowing for toe splay, muscle engagement, and a closer, more responsive fit. This makes the footwear feel less like a rigid object and more like a second skin that reacts to the body in motion.

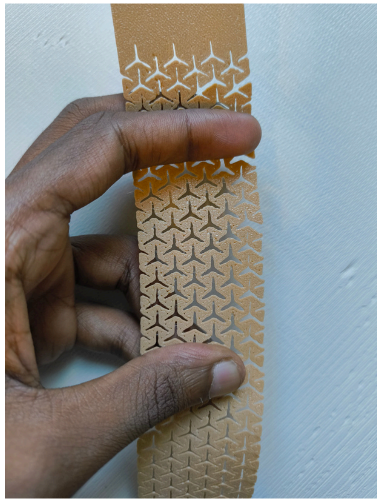


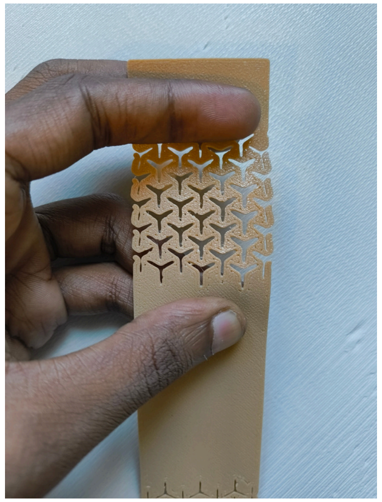


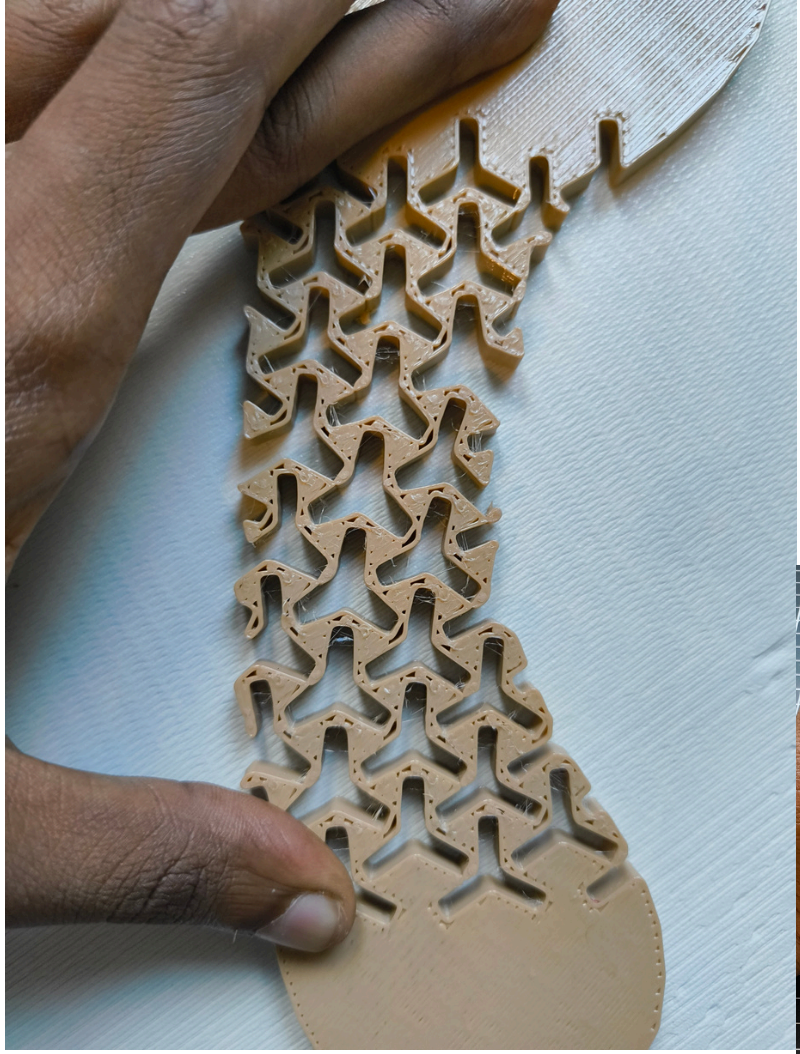




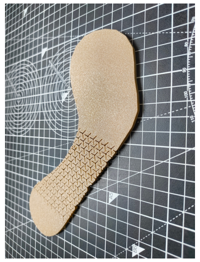


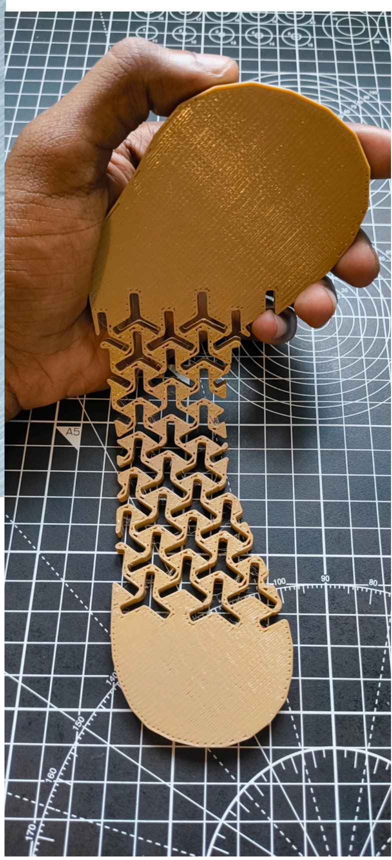






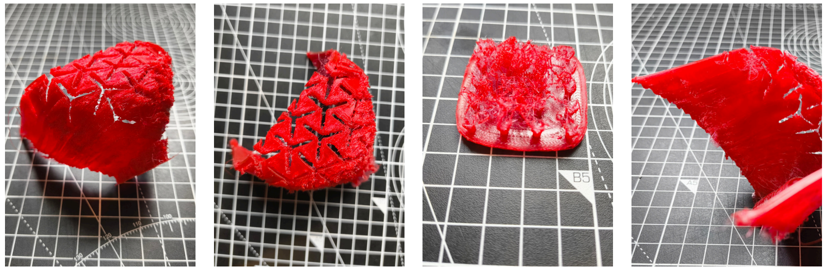
Tried variations in thickness, shapes and TPU materials.





Prototype 1

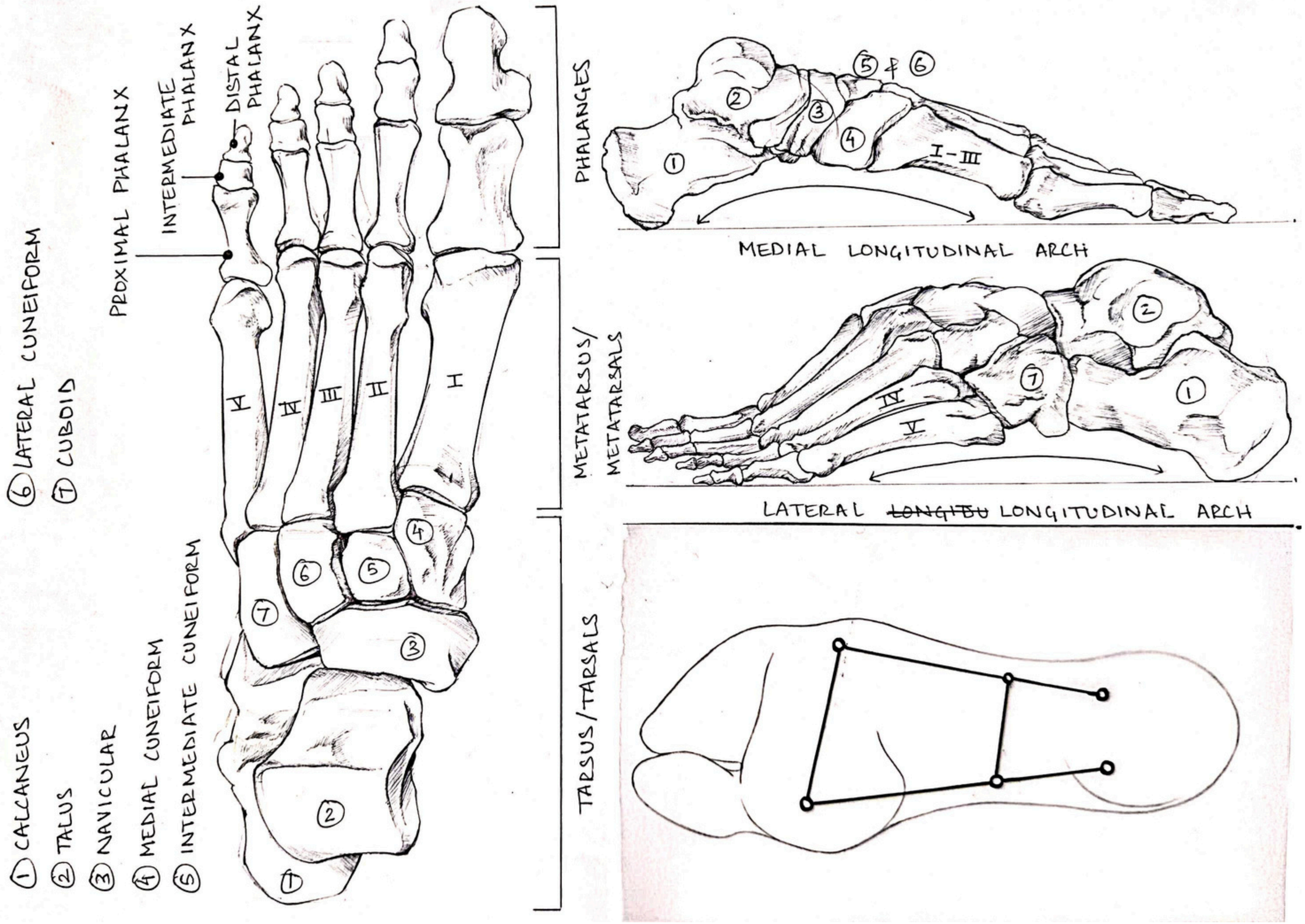
Prototype 2

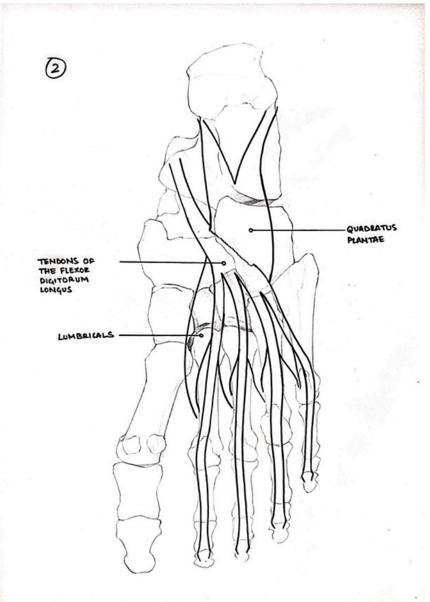


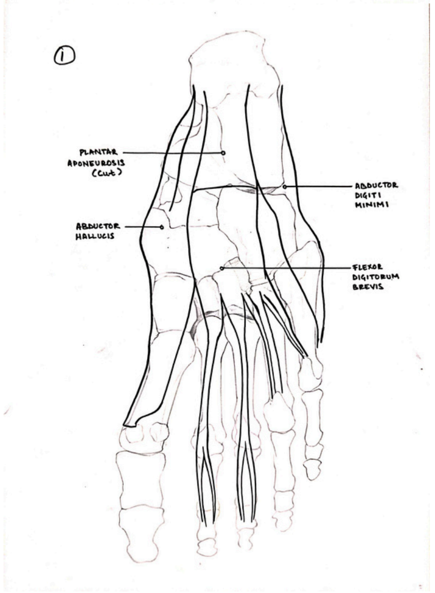
After repeated trial and errors I figured out the best settings and orientation to print the auxetic structures on my prototypes.

Prototype 3

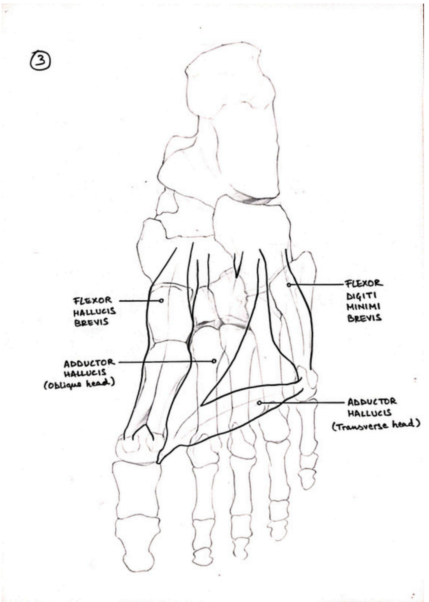
Design Development

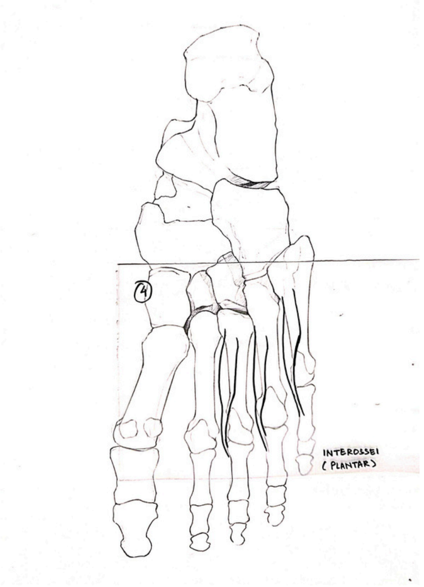




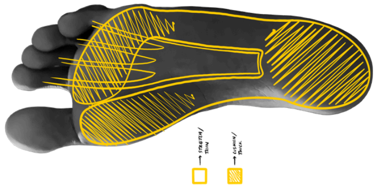


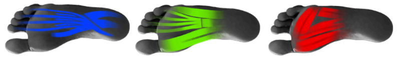
eAll of that leads back to the initial intuition: if the aim is to create footwear as a second skin, the research has to begin not with shoes.

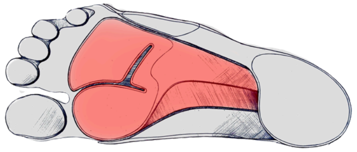


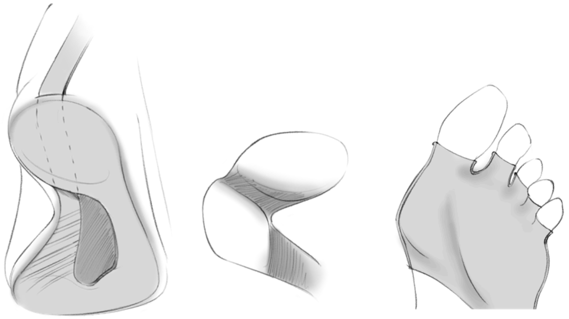


eAll of that leads back to the initial intuition: if the aim is to create footwear as a second skin, the research has to begin not with shoes.

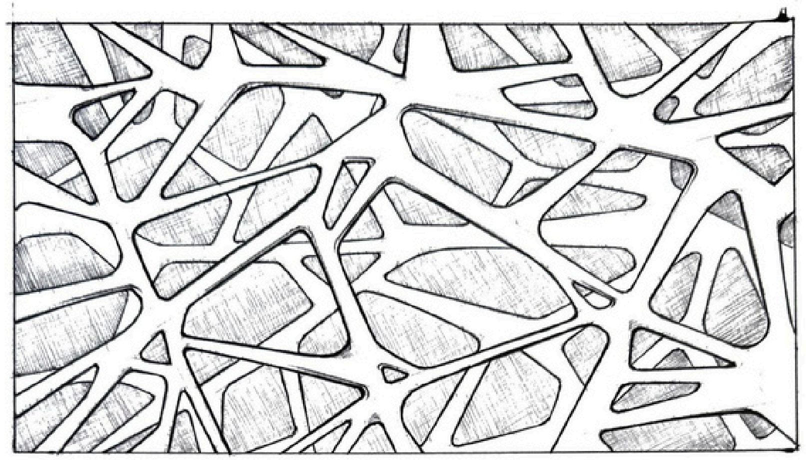


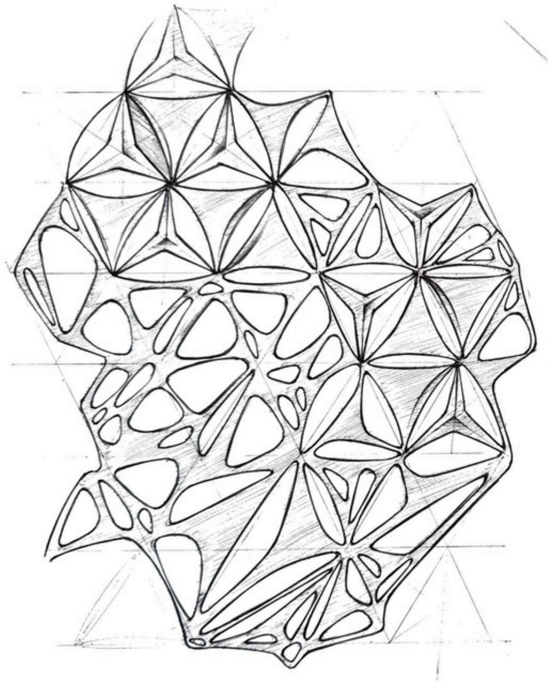


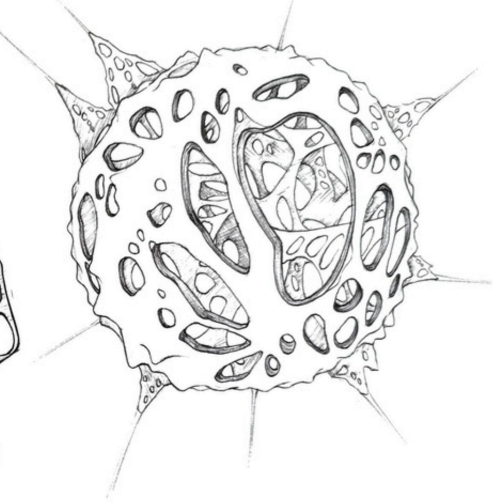


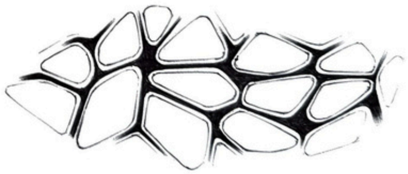


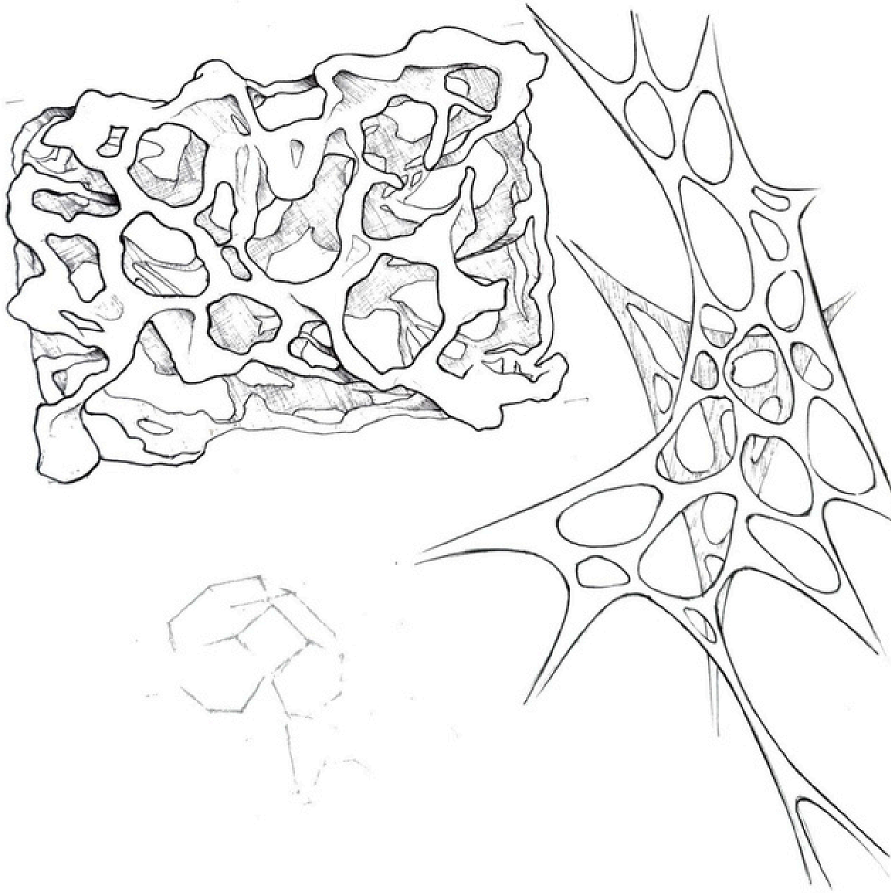
I broke down the basic foot muscle movements and created a 3 piece outsole which would allow maximum movement with minimal complexity.

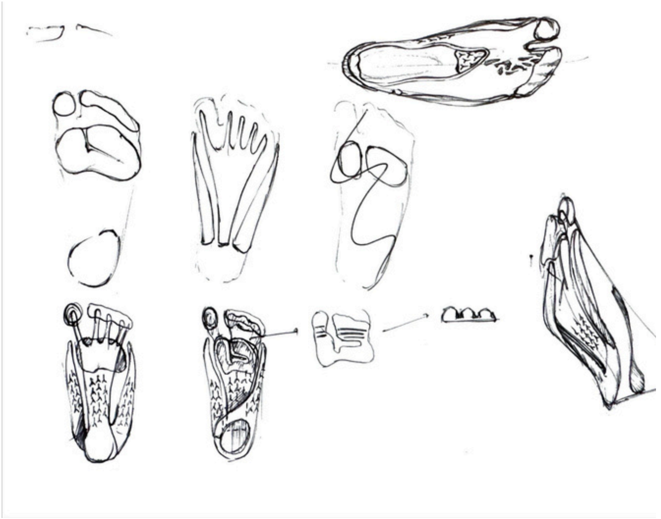


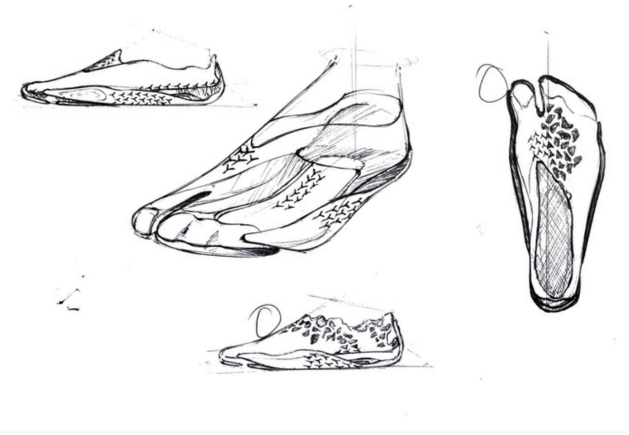


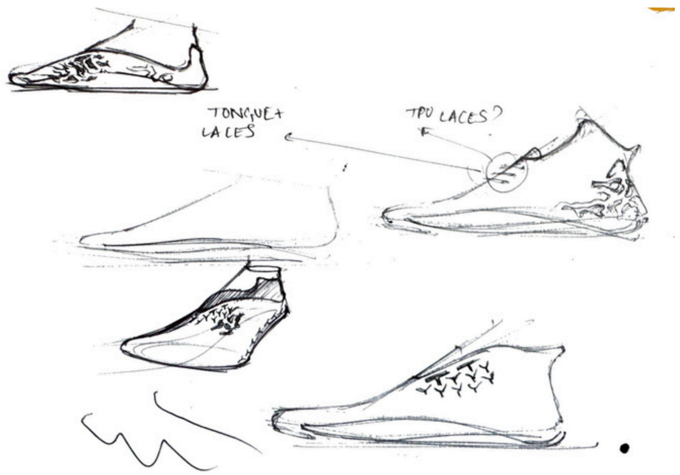


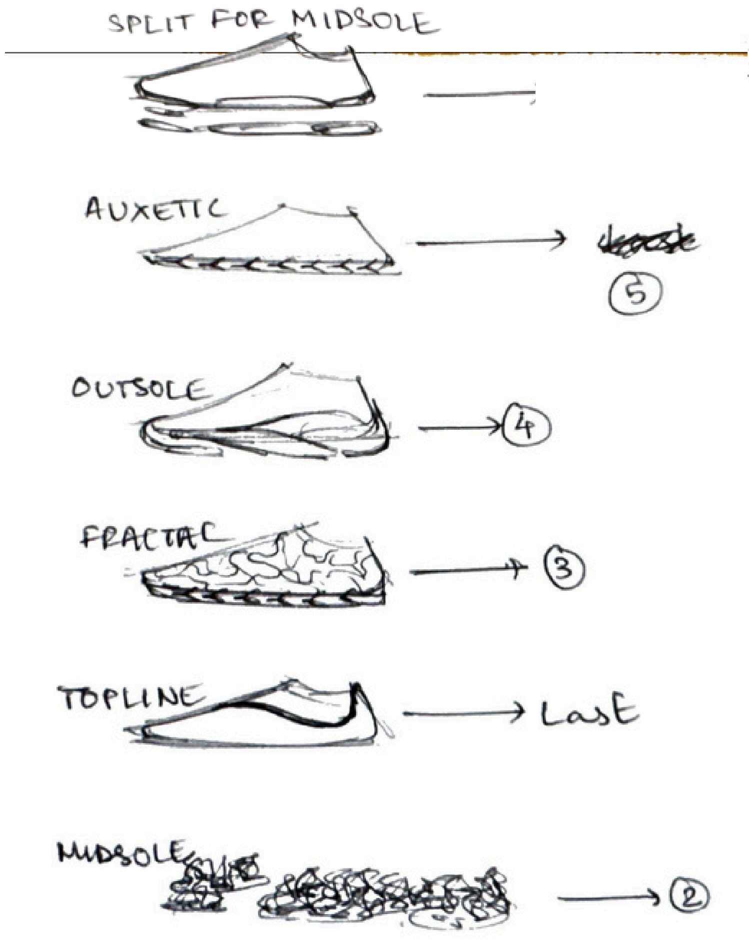


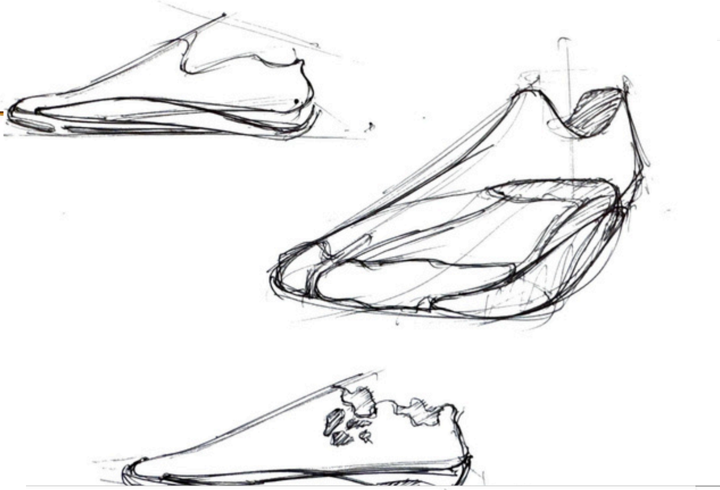


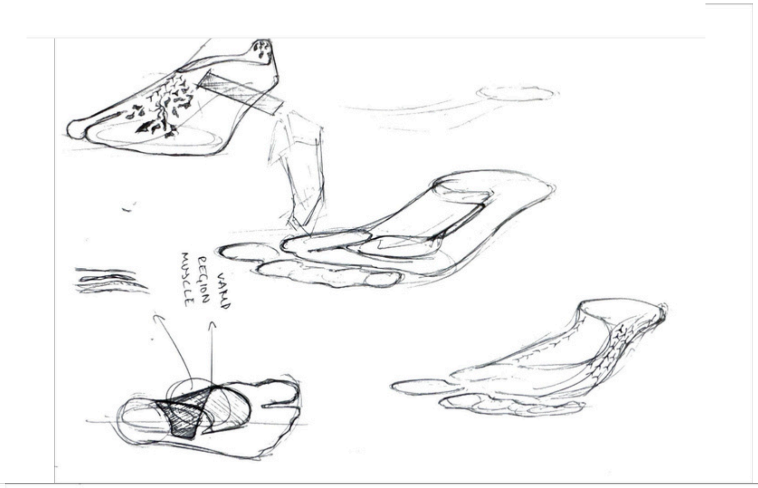


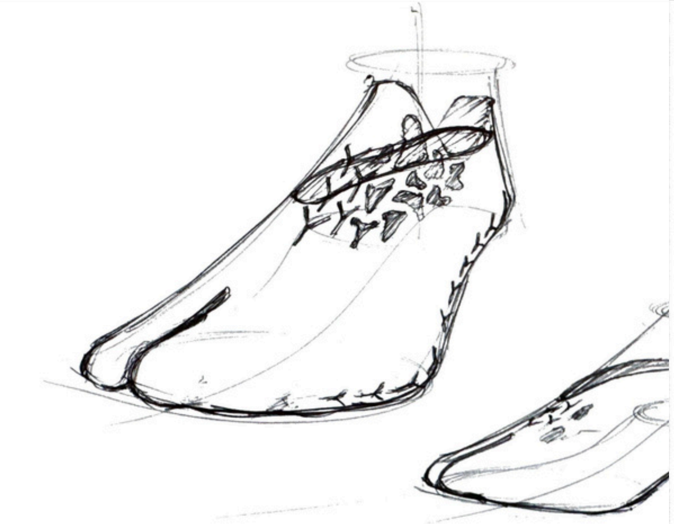


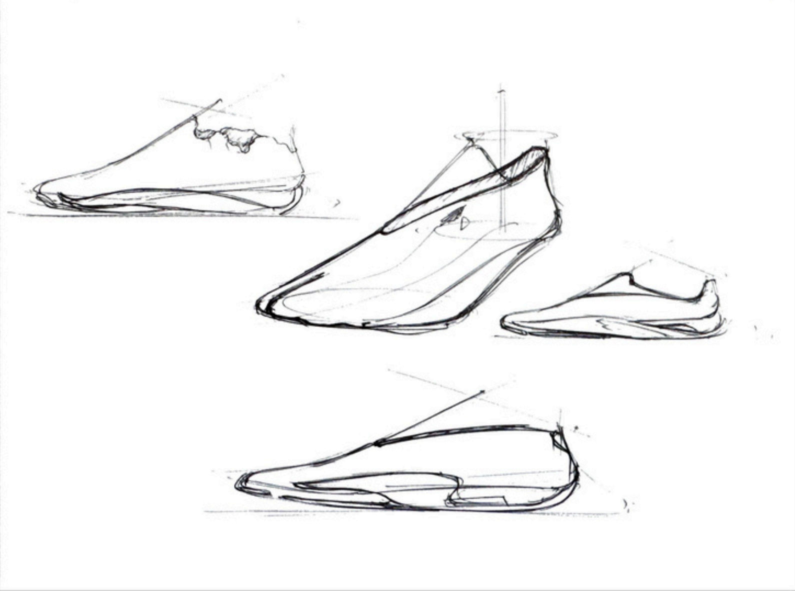

TONGUE+ LACES
TPU LACES?

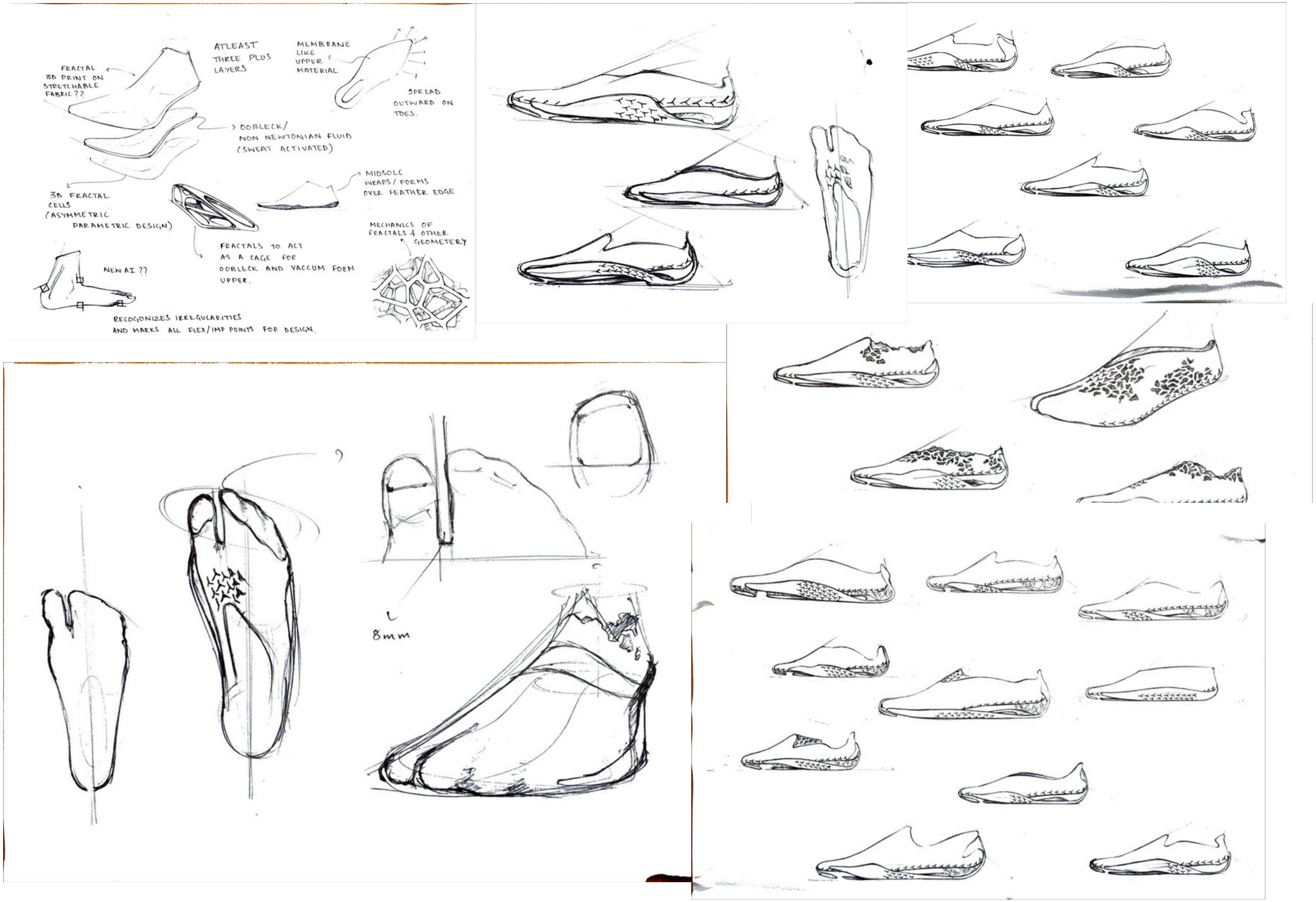

SPLIT FOR MIDSOLE
AUXETIC
5
OUTSOLE
4
FRACTAL
3
TOPLINE
Last
MIDSOLE
2



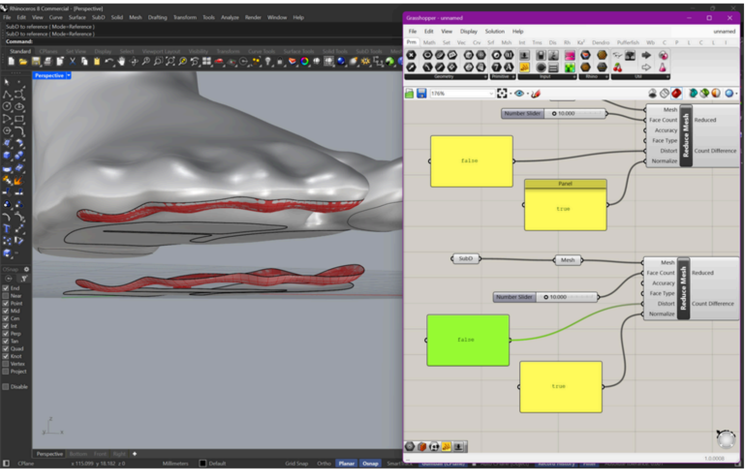

VAMP
REGION
MUSCLE

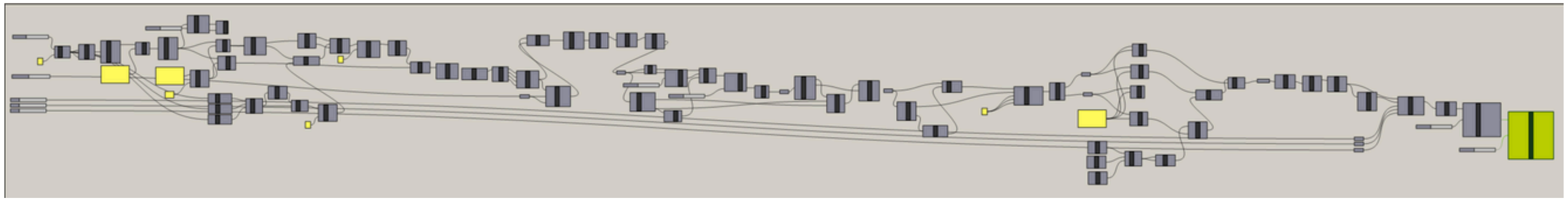


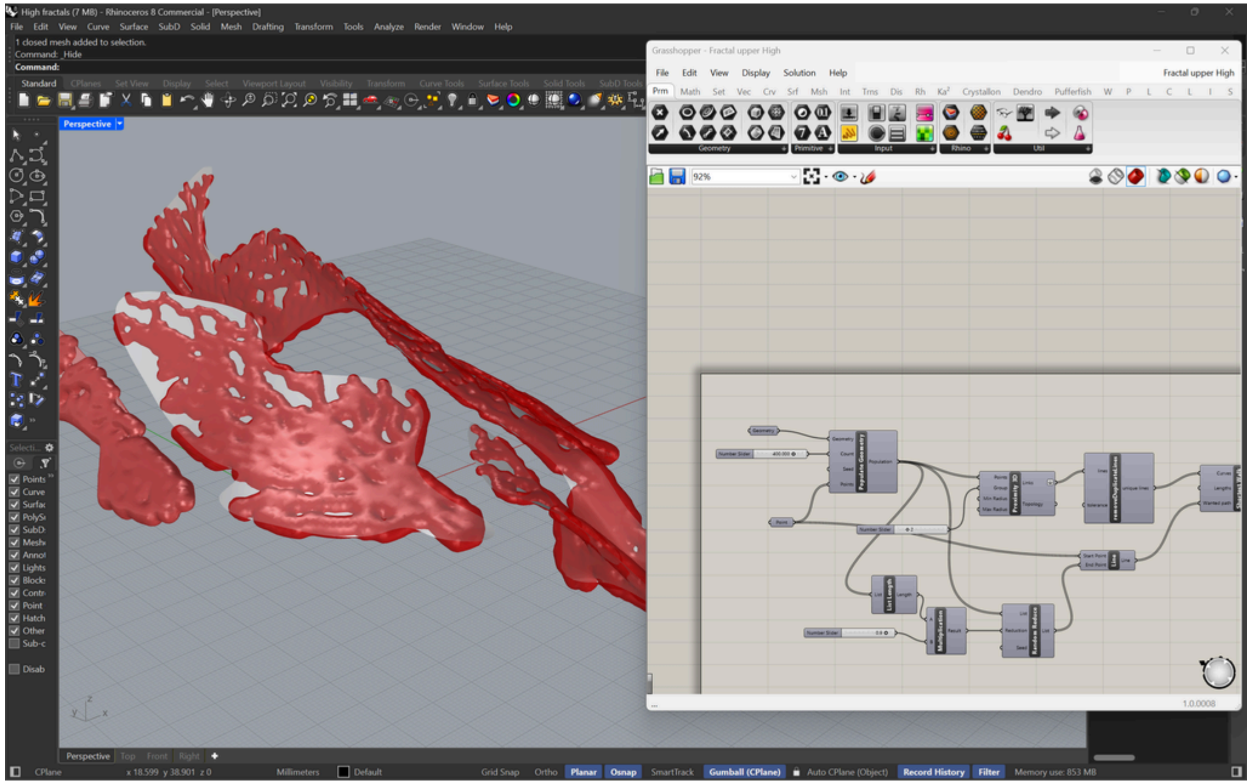



FRACTAL
3D PRINT ON
STRETCHABLE
FABRIC ??
ATLEAST
THREE PLUS
LAYERS
MEMBRANE
LIKE
UPPER
MATERIAL
SPREAD
OUTWARD ON
TOES.
OOBLECK/
NON NEWTONIAN FLUID
(SWEAT ACTIVATED)
MIDSOLE
WRAPS / FORMS
OVER FEATHER EDGE
3D FRACTAL
CELLS
(ASYMMETRIC
PARAMETRIC DESIGN)
MECHANICS OF
FRACTALS & OTHER
GEOMETERY
FRACTALS TO ACT
AS A CAGE FOR
OOBLECK AND VACCUM FORM
UPPER.
NEW AI ??
RECOGONIZES IRREGULARITIES
AND MARKS ALL FLEX/IMP POINTS FOR DESIGN.
8mm

Grasshopper

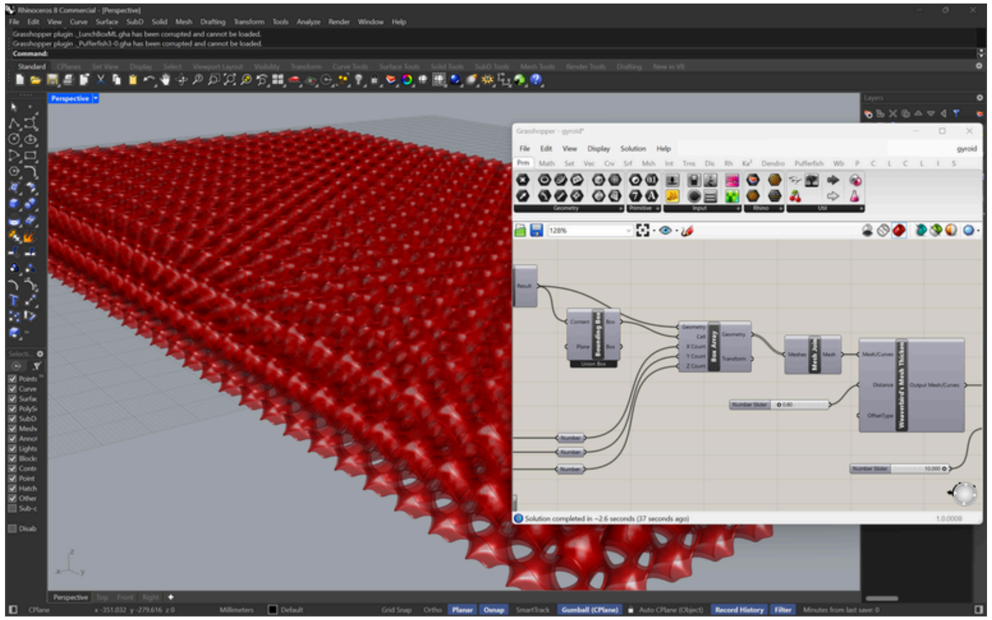






High fractals (7 MB) - Rhinoceros 8 Commercial - [Perspective]

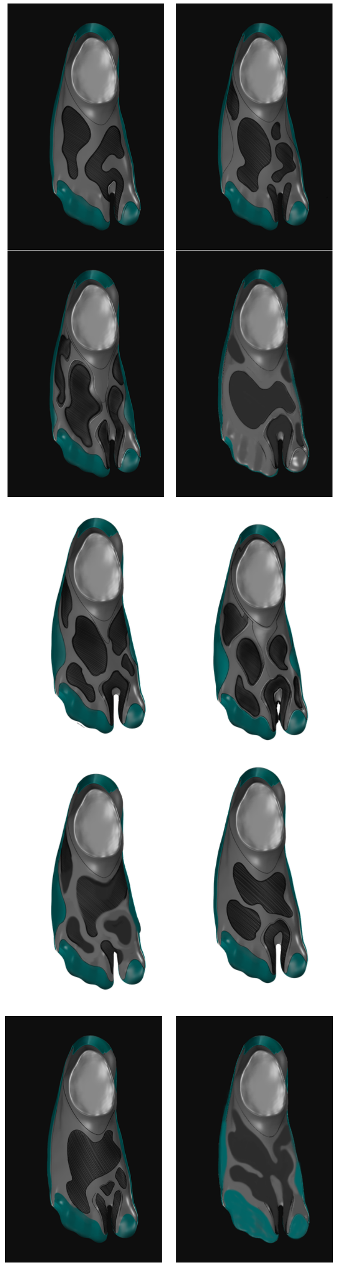
```
1 closed mesh added to selection.
Command: _Hide
Command:
```



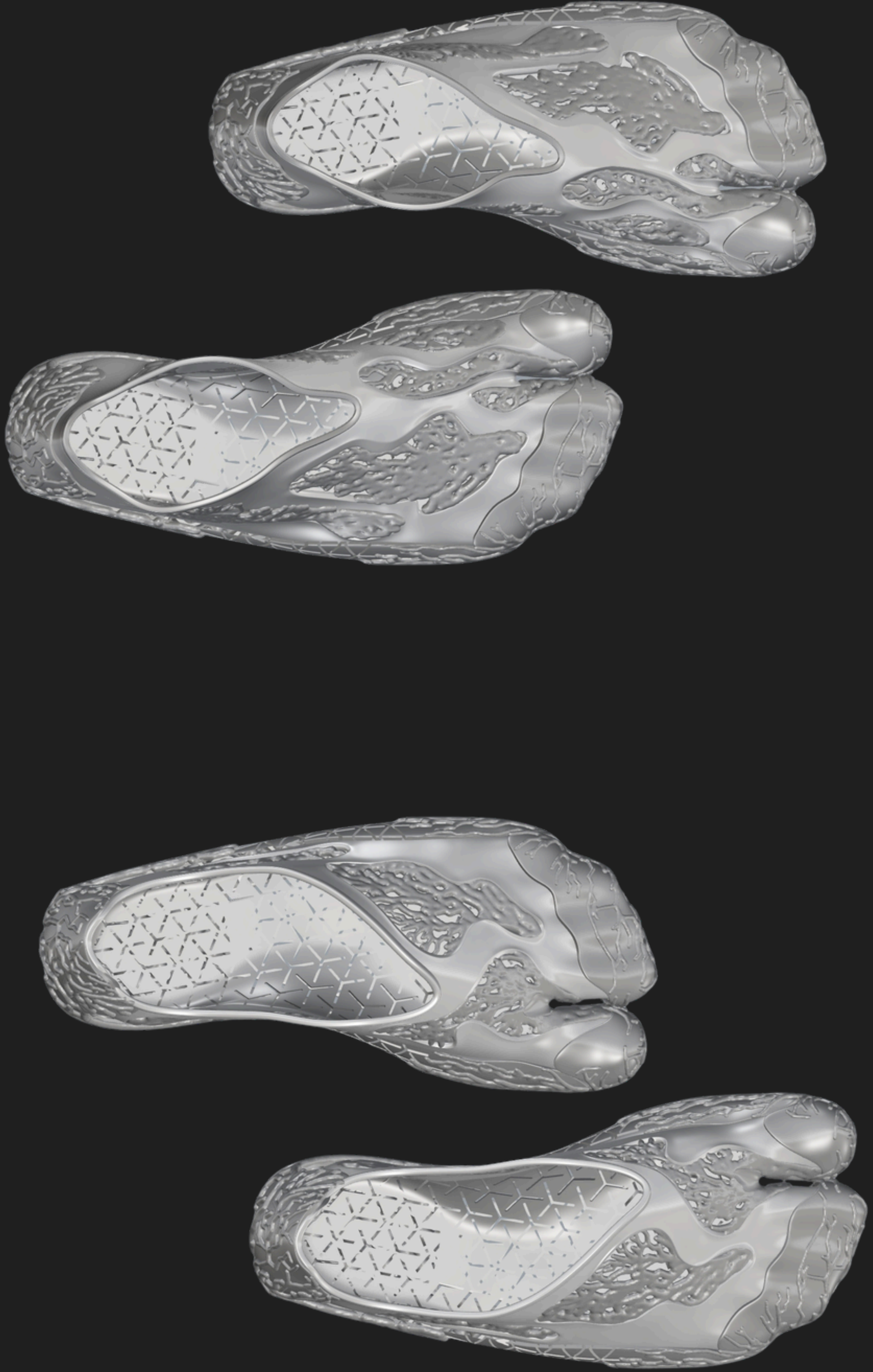
Rhinoceros 8 Commercial - [Perspective]

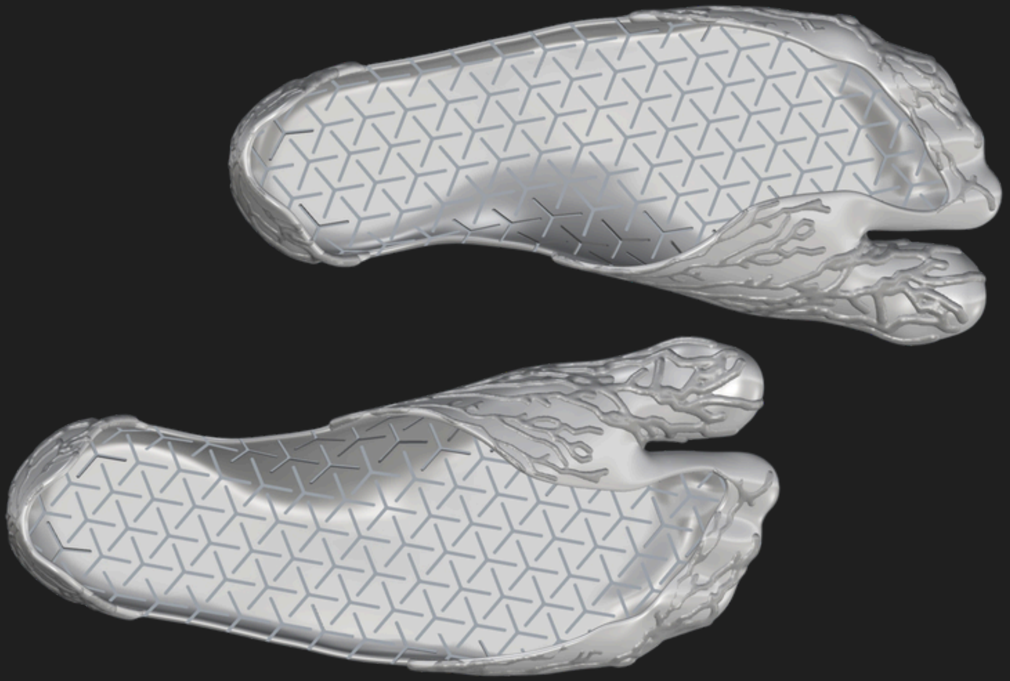
```
Grasshopper plugin _LunchBoxML.gha has been corrupted and cannot be loaded.
Grasshopper plugin _Pufferfish3-0.gha has been corrupted and cannot be loaded.
Command:
```

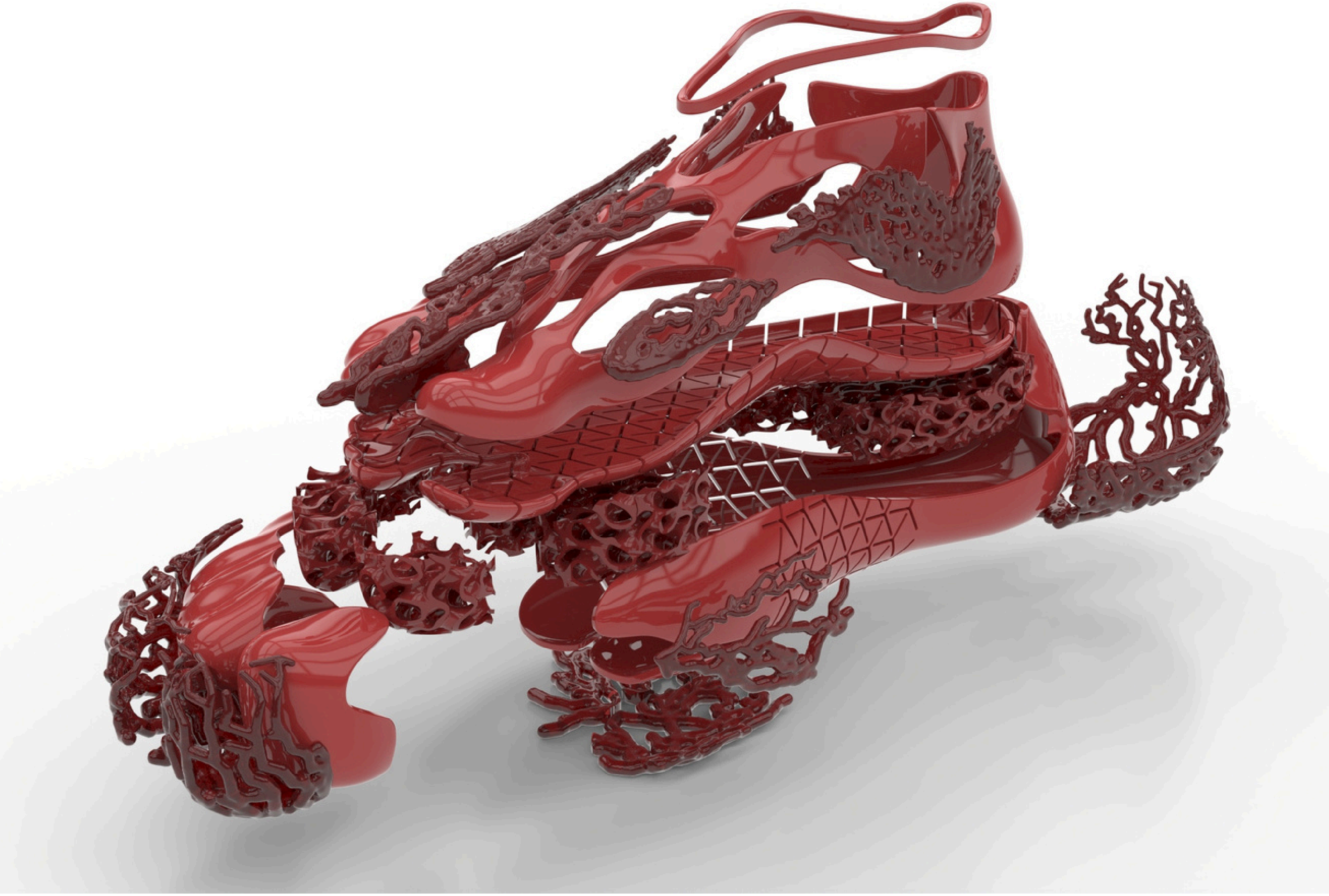
Solution completed in ~2.6 seconds (37 seconds ago)



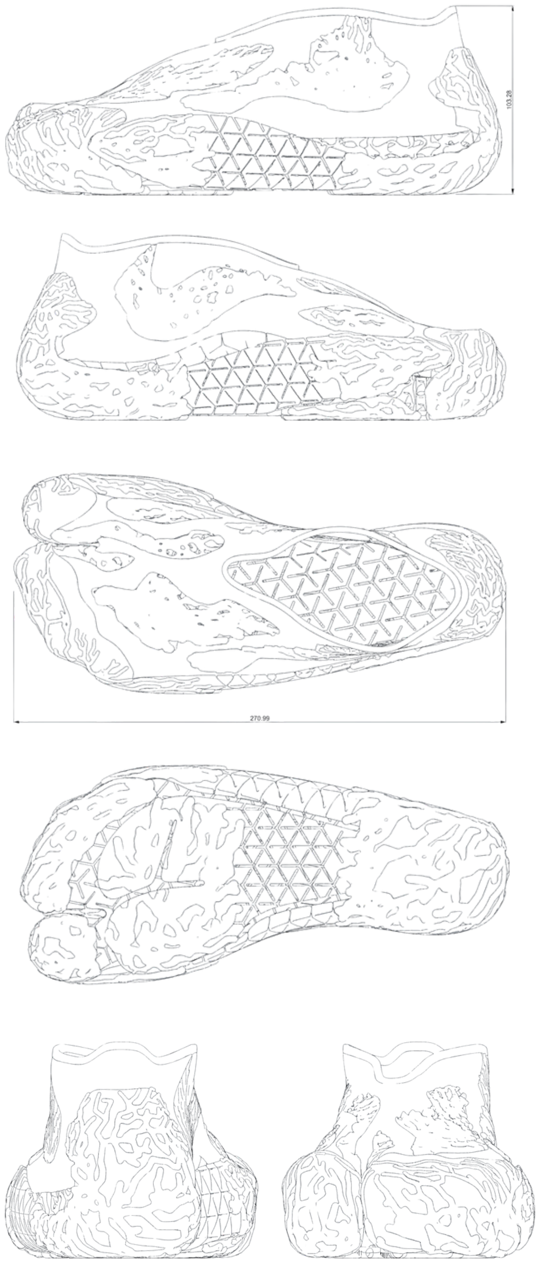
Line Up







Techpack Design 1



Collection Name: UN-IDENTICAL

Type: Concept Sample

Last: Foot Scan

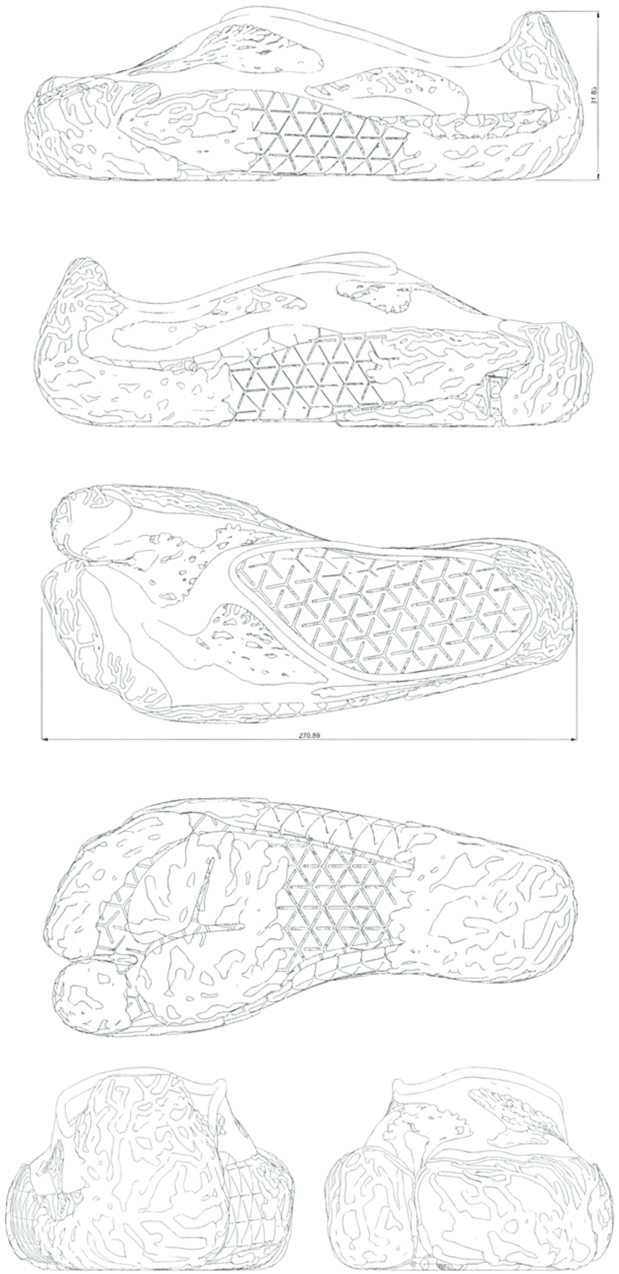
Date:

Material: TPU 95A

Colour

🟧 Pantone orange 021C

Techpack Design 2



Collection Name: UN-IDENTICAL

Type: Concept Sample

Last: Foot Scan

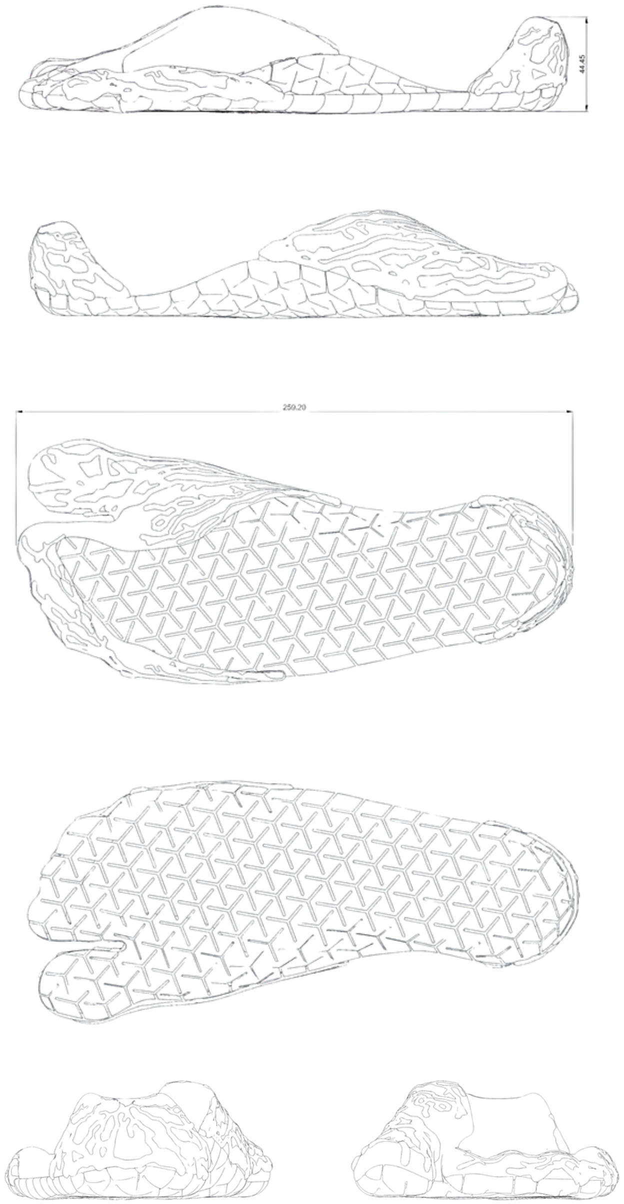
Date:

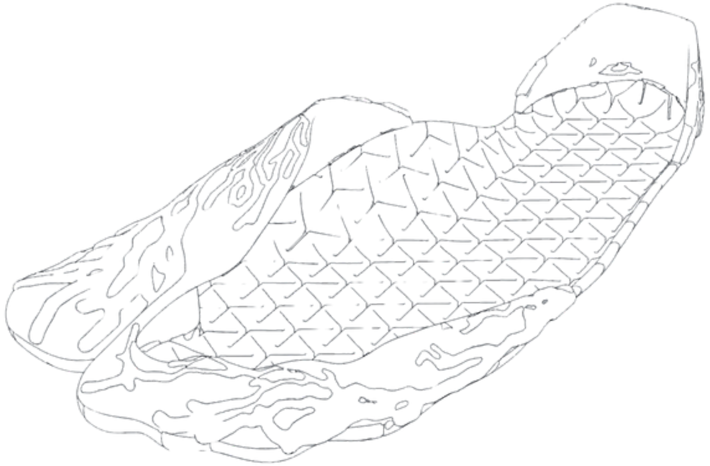
Material: TPU 95A

Colour

🟦 Pantone teal 3541C

Techpack Design 3





Collection Name: UN-IDENTICAL

Type: Concept Sample

Last: Foot Scan

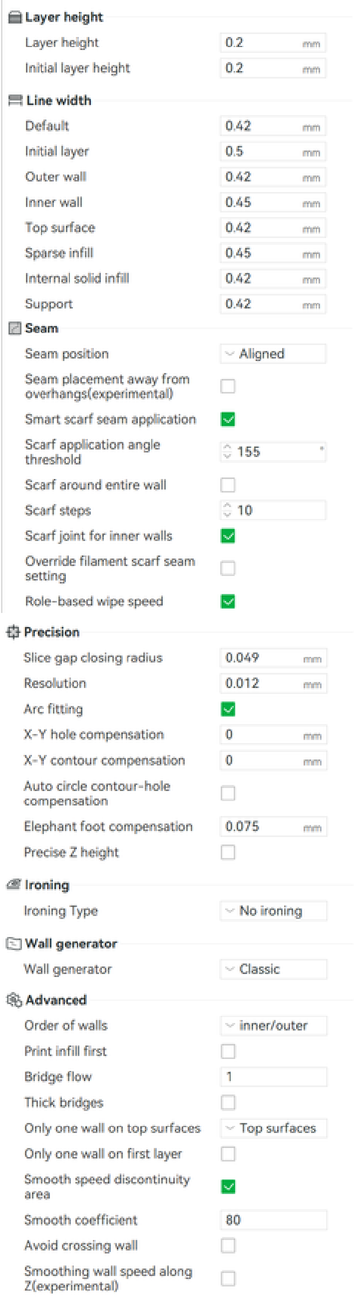
Date:

Material: TPU 95A

Colour

Pantone teal
3541C

quality



Layer height

Layer height	0.2 mm
Initial layer height	0.2 mm

Line width

Default	0.42 mm
Initial layer	0.5 mm
Outer wall	0.42 mm
Inner wall	0.45 mm
Top surface	0.42 mm
Sparse infill	0.45 mm
Internal solid infill	0.42 mm
Support	0.42 mm

Seam

Seam position	Aligned
Seam placement away from overhangs(experimental)	☐
Smart scarf seam application	☑
Scarf application angle threshold	155 °
Scarf around entire wall	☐
Scarf steps	10
Scarf joint for inner walls	☑
Override filament scarf seam setting	☐
Role-based wipe speed	☑

Precision

Slice gap closing radius	0.049 mm
Resolution	0.012 mm
Arc fitting	☑
X-Y hole compensation	0 mm
X-Y contour compensation	0 mm
Auto circle contour-hole compensation	☐
Elephant foot compensation	0.075 mm
Precise Z height	☐

Ironing

Ironing Type	No ironing

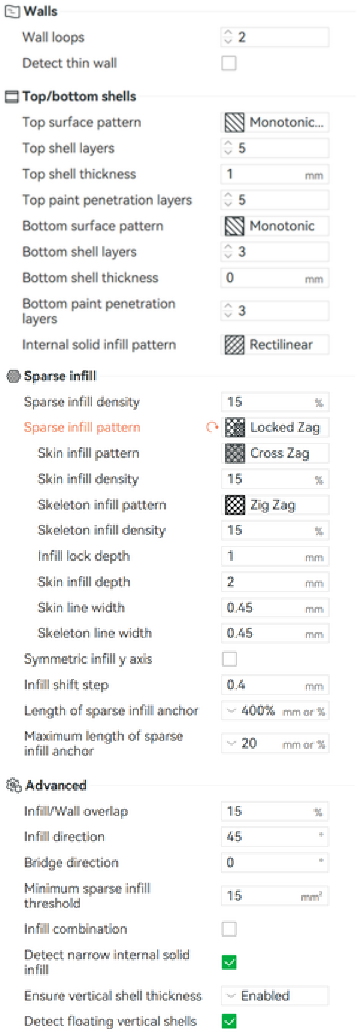
Wall generator

Wall generator	Classic

Advanced

Order of walls	inner/outer
Print infill first	☐
Bridge flow	1
Thick bridges	☐
Only one wall on top surfaces	Top surfaces
Only one wall on first layer	☐
Smooth speed discontinuity area	☑
Smooth coefficient	80
Avoid crossing wall	☐
Smoothing wall speed along Z(experimental)	☐

strength



Walls

Wall loops	2
Detect thin wall	☐

Top/bottom shells

Top surface pattern	Monotonic...
Top shell layers	5
Top shell thickness	1 mm
Top paint penetration layers	5
Bottom surface pattern	Monotonic
Bottom shell layers	3
Bottom shell thickness	0 mm
Bottom paint penetration layers	3
Internal solid infill pattern	Rectilinear

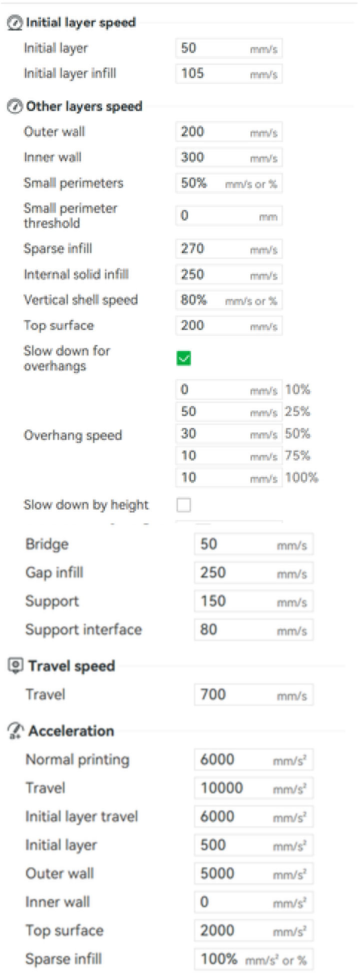
Sparse infill

Sparse infill density	15 %
Sparse infill pattern	Locked Zag
Skin infill pattern	Cross Zag
Skin infill density	15 %
Skeleton infill pattern	Zig Zag
Skeleton infill density	15 %
Infill lock depth	1 mm
Skin infill depth	2 mm
Skin line width	0.45 mm
Skeleton line width	0.45 mm
Symmetric infill y axis	☐
Infill shift step	0.4 mm
Length of sparse infill anchor	400% mm or %
Maximum length of sparse infill anchor	20 mm or %

Advanced

Infill/Wall overlap	15 %
Infill direction	45 °
Bridge direction	0 °
Minimum sparse infill threshold	15 mm^2
Infill combination	☐
Detect narrow internal solid infill	☑
Ensure vertical shell thickness	Enabled
Detect floating vertical shells	☑

speed



Initial layer speed

Initial layer	50 mm/s
Initial layer infill	105 mm/s

Other layers speed

Outer wall	200 mm/s
Inner wall	300 mm/s
Small perimeters	50% mm/s or %
Small perimeter threshold	0 mm
Sparse infill	270 mm/s
Internal solid infill	250 mm/s
Vertical shell speed	80% mm/s or %
Top surface	200 mm/s
Slow down for overhangs	☑
Overhang speed	0 mm/s 10% 50 mm/s 25% 30 mm/s 50% 10 mm/s 75% 10 mm/s 100%
Slow down by height	☐
Bridge	50 mm/s
Gap infill	250 mm/s
Support	150 mm/s
Support interface	80 mm/s

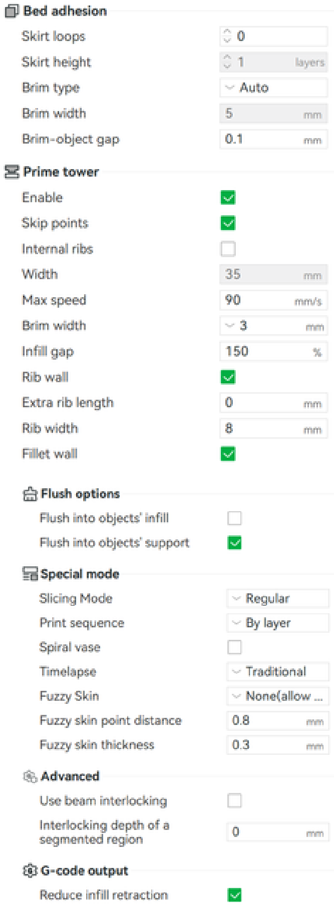
Travel speed

Travel	700 mm/s

Acceleration

Normal printing	6000 mm/s^2
Travel	10000 mm/s^2
Initial layer travel	6000 mm/s^2
Initial layer	500 mm/s^2
Outer wall	5000 mm/s^2
Inner wall	0 mm/s^2
Top surface	2000 mm/s^2
Sparse infill	100% mm/s^2 or %

support



Bed adhesion

Skirt loops	0
Skirt height	1 layers
Brim type	Auto
Brim width	5 mm
Brim-object gap	0.1 mm

Prime tower

Enable	☑
Skip points	☑
Internal ribs	☐
Width	35 mm
Max speed	90 mm/s
Brim width	3 mm
Infill gap	150 %
Rib wall	☑
Extra rib length	0 mm
Rib width	8 mm
Fillet wall	☑

Flush options

Flush into objects' infill	☐
Flush into objects' support	☑

Special mode

Slicing Mode	Regular
Print sequence	By layer
Spiral vase	☐
Timelapse	Traditional
Fuzzy Skin	None(allow ...
Fuzzy skin point distance	0.8 mm
Fuzzy skin thickness	0.3 mm

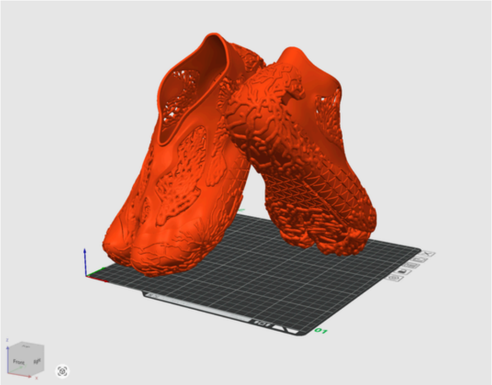
Advanced

Use beam interlocking	☐
Interlocking depth of a segmented region	0 mm

G-code output

Reduce infill retraction	☑

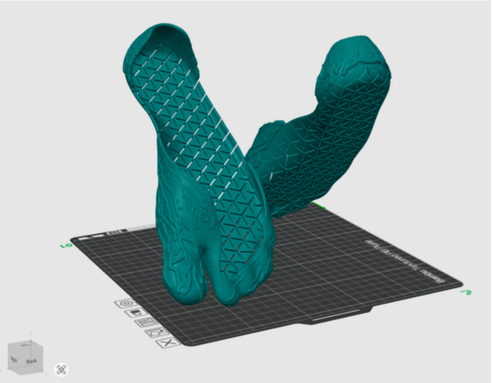
build plate orientation



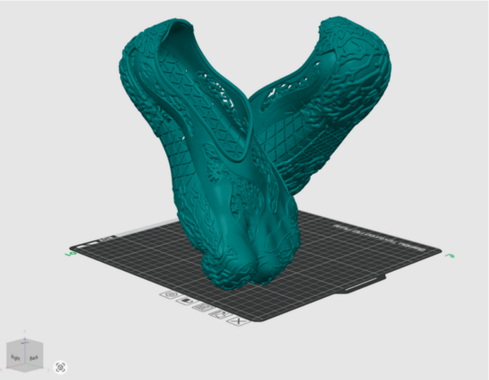
2D 17Hrs

45 degree

1D 8hrs

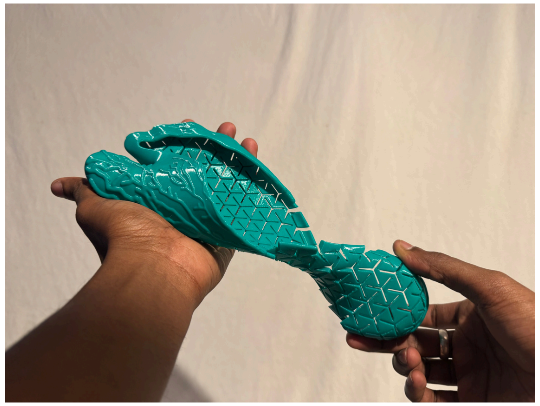


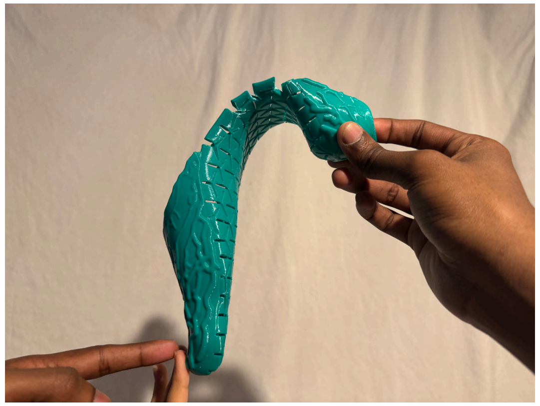
45 degree

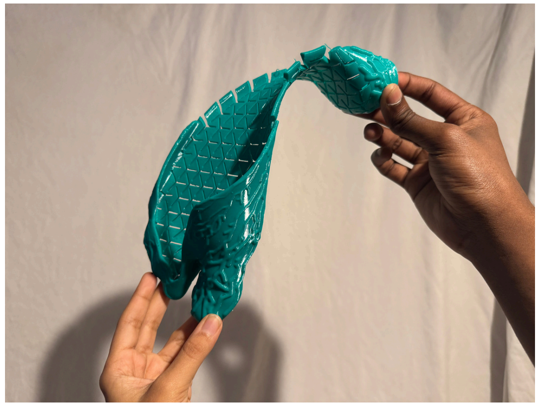


2D 9Hrs

45 degree





business model

1. System Overview: From Product to Footwear Service

UN-IDENTICAL is conceived not just as a shoe brand but as a circular service system. Instead of selling static products in fixed sizes, it offers:

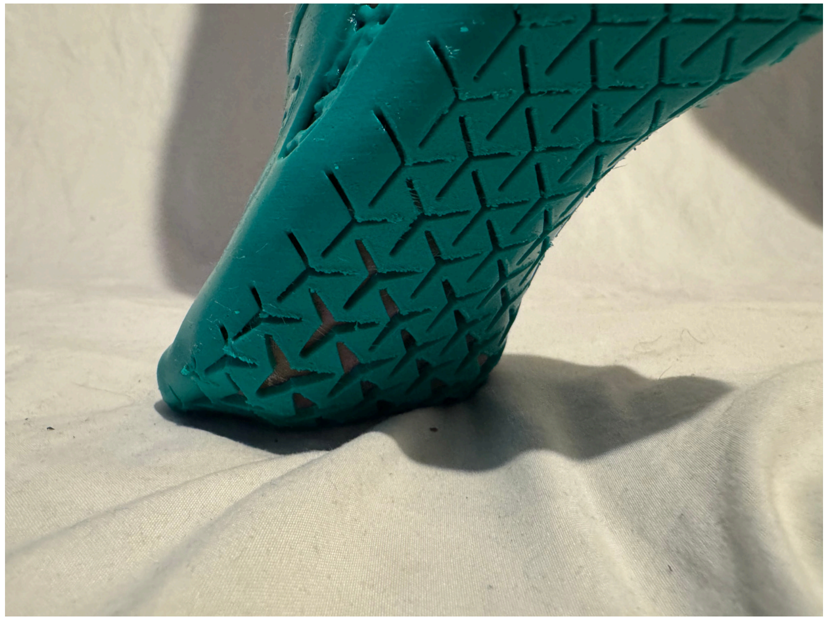
- Data-driven, foot-specific footwear (each pair generated from an individual scan).
- Mono-material, recyclable construction (TPU-based, designed to be shredded and re-extruded).
- A closed loop in which every pair is tracked, recalled, recycled, and reborn as new filament for the next generation of shoes.

The model has three interacting loops:
Data Loop – Foot scans, gait patterns, and wear feedback refine the parametric design library.
Material Loop – Shoes are returned, shredded, reprocessed into filament, and reprinted.
Relationship Loop – The brand maintains an ongoing relationship with each wearer through an app and digital product passport, rather than a one-off purchase.

2. Entry Point: Scanning and Onboarding

UN-IDENTICAL offers multiple, flexible ways to enter the system, to avoid excluding people who don't have access to fancy devices or 3D printers.

At-Home Scanning (App + Web)
UN-IDENTICAL App (core entry)
The user downloads the app, which includes:
Step-by-step scanning tutorials (video overlays, ghost feet showing ideal poses, lighting tips).
Real-time quality feedback: the app checks resolution, blur, angles, and coverage. The scan only uploads if it meets a minimum accuracy threshold (e.g., % surface coverage, pixel density).
Compatibility with third-party scanning apps (e.g., if a user already has a 3D foot scan from a clinic or another service, they can import an STL/OBJ file).



Web Portal
Users can log into the website, upload scans captured elsewhere, and configure their shoes from a desktop interface. This suits users who prefer a bigger screen and more detailed configuration.

In-Store Scanning (Retail Kiosks)
To make the system accessible beyond tech-comfortable users, UN-IDENTICAL partners with:
Independent footwear boutiques
Sports stores

Selected department stores
Each partner location houses a UN-IDENTICAL Scan Station:
A 3D foot scanner (pressure plate + 3D camera) captures shape, pressure distribution, and basic gait parameters in minutes.

Staff assist users who are unfamiliar with digital interfaces.
Orders are placed on an in-store tablet, with the option to:
Link the order to an existing app account, or
Generate a simple profile with email/phone for updates.
This hybrid model makes the system inclusive while still keeping everything digital.

3. Co-Design: Configuring the Shoe

Once a valid scan exists, the user moves into a guided configuration flow. The core logic is:
The geometry adapts to the body first; styling rides on top of that.
Functional Archetypes
The app/web platform offers a set of functional templates, each underpinned by a different parametric script:
Everyday Grounded – focus on comfort and gradual transition to more minimal footwear.
Barefoot+ Trainer – maximum proprioception and flexible toe splay.
Trail / Urban Explorer – higher abrasion resistance, slightly thicker lattice in high-impact zones.
Recovery / Therapeutic – more support under specific regions (e.g., forefoot or medial arch) while still allowing movement.
Each archetype corresponds to a different set of lattice rules (recursion depth, auxetic angles, local stiffness ranges).

Customisation Layers

Within a chosen archetype, users can customise:

Upper language

Options for auxetic pattern families (re-entrant honeycomb, chiral, rotating squares) which all maintain functional behaviour but offer different aesthetics and stretch profiles.

Outsole & midsole lattice profiles

Users can choose between a few “moods”:

Maximum ground feel

Balanced

Higher protection

Behind the scenes, these choices adjust parameters like strut thickness, cell size, and density gradients, not just “thicker / thinner sole” in a traditional sense.

Colourways

Within a limited, recyclable-friendly palette (e.g., natural, carbon, muted colours) to avoid complex pigments that compromise material recovery.

Throughout this process, the interface shows real-time visualisations of:
The user's actual foot scan.
The lattice wrapping and adapting to their exact contours.
Predicted pressure distribution after parametric tuning.
This reinforces the core brand message: your shoe is literally shaped by you.

4. Production Pathways: Physical Pair vs. Digital Pair

UN-IDENTICAL's circular model allows two complementary fulfilment paths.

Central / Regional Micro-Factories (Printed for You)
For most users, the default is to have the shoe printed by UN-IDENTICAL or its certified partners.
Parametric Generation
Once the user confirms their design, the system:
Runs the Grasshopper definition with their scan and pressure profile.
Checks manufacturability (minimum printable feature size, overhang constraints, structural integrity).
Generates a print-ready file (.3MF or STL) and attaches it to the user's digital passport.
Localised Manufacturing
To minimise transport emissions, the file is routed to the nearest certified micro-factory:
This could be a dedicated UN-IDENTICAL facility or a vetted additive manufacturing partner (e.g., local 3D print bureaus with approved TPU materials and machines).
Micro-factories use standardised TPU filament/powder supplied under contract, with strict recycled-content ratios and quality control.
Shipping Options
Home delivery in a minimal flat-pack box.

Store delivery to the original scanning location, which encourages users to bring back worn pairs later.
The app tracks the process transparently:
“Scan received → Geometry generated → In print queue → Printing → Quality check → Out for delivery.”

Licensed Digital Files (Printed by the User)

For advanced or DIY-minded users, there is a “Print Yourself” tier:
For an extra fee, users can:
Receive an encrypted, personalised STL/3MF file of their shoe.
Receive recommended print profiles (layer height, infill, temperature) for TPU.
Optionally purchase official UN-IDENTICAL filament for optimal performance.
Because the file is tightly bound to the user’s unique foot geometry, resale has little value—most other people simply can’t wear that shape comfortably. This keeps the model compatible with circularity and reduces IP abuse.
To keep the material loop intact, the app still nudges self-printers to return worn pairs to UN-IDENTICAL drop points for recycling, regardless of where they printed them.

6. Take-Back, Drop Points, and Incentives

The circular loop depends on frictionless, rewarding returns.

Drop Point Network

UN-IDENTICAL establishes branded Take-Back Dropboxes in:
All retail partners that sell or scan UN-IDENTICAL.
High-footfall grocery chains and convenience stores (e.g., Tesco, Asda, Sainsbury’s, Lidl formats in the UK).
University campuses and sports centres in pilot phases.
Each dropbox is:
Digitally connected (ID + weight sensors).
Equipped with a scanner / touchscreen where the user:
Enters or scans their purchase ID / QR code.
Confirms drop-off with a quick tap.
This creates a traceable link between specific shoes and specific accounts, enabling accurate reward allocation and better material tracking.

Incentive Structure

To encourage responsible returns, the model offers:
Instant digital rewards:
Discount vouchers on the next pair (e.g., £10–£20 off).
Or small cash-back / store credit, processed within a set time window (e.g., 5–7 business days).

5. Use Phase: Digital Passport and Care

Every pair of UN-IDENTICAL shoes comes with a digital passport, accessible via:
QR code or NFC tag on the shoe.
The app / web profile.
The passport includes:
The parametric “recipe” used (lattice family, auxetic type, stiffness mapping).
Material batch (virgin vs. recycled content ratio).
Production location and date.

ecommended transition protocol (especially for users new to minimal footwear, to reduce injury risk).
Wear-tracking prompts: after 3, 6, 12 months, the app asks for simple feedback (comfort, wear, use intensity).
This data feeds back into:
Design refinement (e.g., where users report early wear or discomfort).
Material studies on how recycled content performs over time.
Personal iteration – the next pair can be adjusted based on this real-world data.

6. Take-Back, Drop Points, and Incentives

The circular loop depends on frictionless, rewarding returns.

Drop Point Network

UN-IDENTICAL establishes branded Take-Back Dropboxes in:
All retail partners that sell or scan UN-IDENTICAL.
High-footfall grocery chains and convenience stores (e.g., Tesco, Asda, Sainsbury’s, Lidl formats in the UK).
University campuses and sports centres in pilot phases.
Each dropbox is:
Digitally connected (ID + weight sensors).
Equipped with a scanner / touchscreen where the user:
Enters or scans their purchase ID / QR code.
Confirms drop-off with a quick tap.
This creates a traceable link between specific shoes and specific accounts, enabling accurate reward allocation and better material tracking.

Incentive Structure

To encourage responsible returns, the model offers:
Instant digital rewards:
Discount vouchers on the next pair (e.g., £10–£20 off).
Or small cash-back / store credit, processed within a set time window (e.g., 5–7 business days).

Tiered loyalty:
Users who return multiple pairs enter higher tiers with better benefits (priority production, access to limited “research editions”, or larger discounts).
Transparency on impact:
The app shows “X grams of TPU recovered”, “Y % of your next pair is made from recycled material”, reinforcing a sense of agency and participation.
For self-printed shoes, the same drop-points apply; the digital passport still recognises the shoe and treats it as material to be brought back into the loop.

7. Reverse Logistics and Material Recovery

Once dropboxes are full, shoes are collected and transported to regional material recovery hubs or directly to:
UN-IDENTICAL’s own facility, or
Contracted TPU recyclers.
At these hubs:
Sorting & Verification
Non-UN-IDENTICAL items (if any) are separated.
Shoes are weighed and logged against dropbox data.
Pre-Processing
Basic cleaning (removing dirt, stones).
Granulation: shoes are shredded into chips.
Re-Extrusion into Filament / Powder
TPU chips are melted, filtered, and re-extruded into new filament or powder.
To maintain mechanical performance, a calibrated percentage of virgin material is blended in (e.g., 30–50% recycled content, depending on test results). This balance can evolve as research improves.
Feedback into Supply Chain
Recycled batches are tracked; their use is recorded in the digital passports of new shoes.
Over time, the aim is to increase the recycled fraction without compromising durability or elasticity.

8. Revenue Logic and Circular Value Creation

The business model generates value on several levels:
Primary revenue
Sale of custom-printed shoes (premium pricing justified by custom fit, technology, and sustainability).
Sale/licensing of print-yourself files + official filament.
Secondary revenue
Partnerships with micro-factories (licensing the parametric design engine).
Data insights (anatomical + gait trends) for research partnerships (handled ethically, anonymised).
Circular value
Re-use of materials reduces long-term raw material costs.
Strong brand loyalty via take-back incentives and transparent impact metrics.
Because each shoe is uniquely generated, UN-IDENTICAL competes less on seasonal fashion and more on biological fit + ecological responsibility, building a more stable, long-term customer base.

9. Governance, Ethics, and Practicality

To keep the system achievable rather than speculative:

Phased rollout
Start with a single region (e.g., one country) and a limited number of micro-factories and drop-points.

Gradually expand as logistics and recycling partnerships solidify.

Data ethics
Foot scans and gait data are treated as sensitive biometric information.
Clear consent, anonymisation, and opt-out options are built into the app and web platform.

Education & Transition
Many users' feet are adapted to conventional footwear. The app provides:
Guidance on transitioning gradually to more minimal, high-feedback shoes.
Warnings if they are dramatically changing from very cushioned shoes.

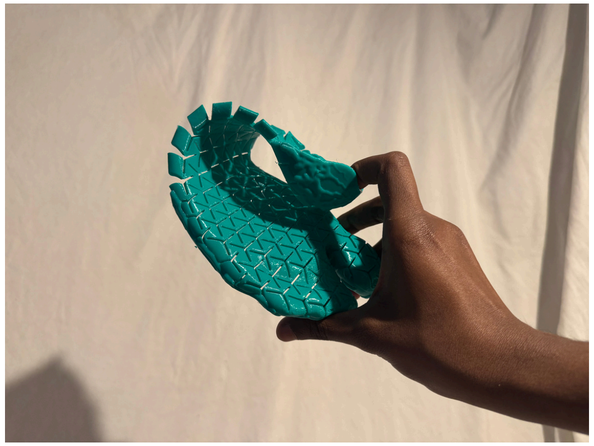
This acknowledges that UN-IDENTICAL is not a magic fix, but part of a long-term, systemic shift in how people relate to footwear, their own bodies, and material cycles.

In this model, your shoe is:
Co-designed with your own anatomy.
Manufactured as close to you as possible.
Used as both interface and instrument for foot health.
Returned not as waste but as raw material.
Reborn as filament and then as someone else's second skin.

That full loop—from scan to shredder to filament and back to foot—is what makes UN-IDENTICAL a genuinely circular proposition, rather than just a "green" shoe sitting on a linear system.

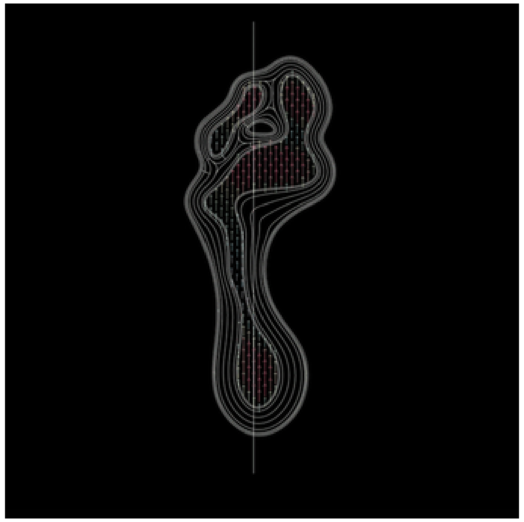
conclusion

The project Footwear as Second Skin: Reconstructing Biotensegrity through Fractal and Parametric Design set out with an ambitious agenda: to rethink footwear from first principles, using biomechanics, biomimicry, and computational design as the foundation for a new physiologically informed and ecologically responsible paradigm. The research demonstrated that the contemporary footwear industry suffers from deeply rooted structural issues—ecological, anatomical, and conceptual—and that alternative design methodologies are urgently needed. While the final prototypes, research methods, and computational systems developed throughout this project do not fully "solve" these challenges, they represent a meaningful shift in how footwear could be imagined, produced, and functionally integrated into the human body's natural mechanics. This conclusion acknowledges the progress made while critically reflecting on the limitations, missed opportunities, methodological gaps, and future trajectories emerging from the work.



A step toward a solution, not the solution itself

First and foremost, the project acknowledges that it does not provide a fixed or definitive solution to the problems it critiques. The global issues of overproduction, non-recyclability, homogenizing design standards, and biomechanical harm cannot be resolved through a single student-led innovation—nor through a single product. Even within the focused context of this project, the prototypes fall short of addressing the complexity and nuance of human gait variability, pathological foot conditions, and long-term biomechanical adaptation.



Rather than positioning the work as a technological breakthrough, the project more realistically stands as a conceptual reorientation: a new lens through which footwear might be designed, used, and understood.

The value of this work lies not in the completeness of its solution, but in its departure from the industry's entrenched assumptions. It reframes footwear as a dynamic, anatomical interface—not a rigid container—and positions geometry, rather than multi-material construction, as the central tool for performance and adaptability. This shift is meaningful, even if unfinished. As seen through the research development, the project effectively opens a direction of inquiry rather than closing it with answers.

Form-fitting fidelity and anatomical accuracy

One area where the project could have pushed further is in the anatomical fidelity of the final prototype. Although pressure mapping and foot scanning informed the parametric platform, the upper and insock regions still lack the nuanced contouring necessary for a truly second-skin product. A deeper integration between foot morphology and the auxetic upper—particularly around areas such as the medial arch, heel cup, and toe splay region—could have produced more meaningful biomechanical compliance.

A next step would be to allow the foot's three-dimensional curvature and muscle pathways to actively shape the auxetic patterns, rather than simply being applied as an offset wrapping surface. This would transform the upper from a "pattern applied to a form" into a "form generated through anatomy," creating more harmonious transitions between zones of stretch, tension, and constraint. Such a system may also allow for micro-differentiation between users with similar foot lengths but different arch profiles, toe orientations, or soft tissue distributions.

Material limitations and lost potential for biomaterial exploration

The project's commitment to mono-materiality—specifically TPU—was n intentional and principled constraint meant to support recyclability and circular production. However, this constraint also introduced significant limitations. TPU, while durable and elastic, cannot mimic the full range of biomechanical behaviours found in human fascia: rapid contraction, graded stiffness, and responsive anisotropy. This became particularly evident when attempting to replicate natural torsion or dynamic load redistribution.

In retrospect, additional material testing with biomaterials, variable-shore elastomers, shear-thickening fluids, or support gels could have enriched the functional capabilities of the prototype. A multi-material system—though more complex to recycle—may have enabled more sophisticated expressions of biotensegrity by controlling contraction and expansion in different regions. The tension between sustainability and functional performance remains unresolved in this project, and future work would benefit from negotiating this balance more flexibly.

The initial non-Newtonian fluid prototype (the “Oobleck shoe”) is a notable example of the type of material innovation that was conceptually promising but ultimately underdeveloped.

The behaviour of shear-thickening fluids maps elegantly onto the idea of pressure-responsive stiffness. Integrating such materials within strategically designed lattice chambers or layered membranes could produce a hybrid system where geometry and chemistry work together, offering a level of responsiveness that TPU alone cannot achieve. Revisiting this avenue could significantly enhance the physiological legitimacy of the design.

Technical skill-growth and its impact on early decision-making

A key reflective insight is the recognition that many early ideation decisions were heavily constrained by the designer’s limited proficiency in Rhino, Grasshopper, lattice generation, and data mapping at the start of the project. As the year progressed, the designer underwent substantial growth in computational modeling, fractal optimization, and structural logic. This growth, however, created an unevenness in the development process: early conceptual directions were shaped more by technical limitations than by theoretical intention.

With the skills now acquired, it is evident that several foundational components of the project could have been executed differently—and more effectively. For example:

the fractal structure could have been developed with higher recursion accuracy,

the auxetic upper could have been computationally tuned to foot-specific tension vectors,

the sock-liner could have been designed as a continuous graded membrane rather than a separate structural zone.

This recognition is not a weakness but a realistic acknowledgement that computational design is iterative, and that mastery often arrives after critical design decisions have already been made. Future evolutions of the project would benefit from revisiting early assumptions with a more advanced computational toolkit, allowing for a more rigorous and cohesive geometric system.

Mono-materiality as both a strength and a hindrance

The mono-material constraint was central to the project’s sustainability claim, and it remains one of its strongest conceptual contributions.

Demonstrating that a single polymer could be manipulated into multiple functional behaviours through geometry alone is a meaningful accomplishment.

However, this same constraint introduced conceptual blind spots. Biotensegrity relies on distributed tension, differentiated stiffness, and complex interaction between compression and tension elements. A purely mono-material substrate may never fully replicate such dynamics. Multi-material 3D printing, or hybrid analog–digital construction, may prove more appropriate for certain biomechanical behaviours, even if this complicates recyclability.

A more nuanced future approach might involve:

- Material zoning with compatible polymers, allowing selective recyclability.
- Embedding non-Newtonian fluids in TPU chambers, achieving true pressure sensitivity.

Introducing a minimal amount of stiffer materials in regions requiring structural reinforcement (e.g., lateral stabilizers).

Balancing sustainability with functional fidelity will remain a key challenge, but not an impossible one.

Reconsidering the rejection of standardization

The project firmly positions itself against the homogenizing logic of standard sizing, mirroring, and mass production. This stance is valid and philosophically grounded. However, the reflection acknowledges that the complete rejection of standardization may have limited opportunities to explore systems that adapt intelligently across diverse bodies.

Standardization, when reconceptualized, does not necessarily imply uniformity. Instead, research into universal adaptive structures—geometries that self-adjust to multiple foot types—could be a powerful extension of this work. Rather than a single bespoke form per individual, one could imagine a material system that behaves as a vessel, conforming in real time to varying foot anatomies. This might involve adaptive auxetics, active materials, fluid-filled channels, or shape-memory technologies.

Had this broader interpretation been embraced earlier, the project might have investigated more universally adaptive geometries rather than purely personalized ones.

Viability as a real-world product

From a commercial and manufacturable standpoint, the project shows promise but also raises critical questions. The prototypes demonstrate functional potential, but several challenges must be acknowledged:

Manufacturing viability

Current TPU FDM and SLS printers struggle with consistent elasticity across large, complex lattices.

Scalability is unclear: printing a full shoe remains time-consuming and costly.

Post-processing, durability, and long-term fatigue performance require extensive testing.

User viability

Questions of long-term comfort, blister resistance, and rubbing remain untested.

Breathability and thermal regulation require additional design interventions.

Slippage, torsion failure, and lattice fatigue must be studied over extended wearing cycles.

Market viability

While the concept fits high-end performance and customization niches, the price point, manufacturing complexity, and durability expectations pose significant barriers.

Thus, the project is viable as research, but not yet viable as a market-ready product without further development, testing, and material exploration.

Reflection on methodology and design process

Several methodological insights emerged during the project:

What the project did well

It built a rigorous biomechanical argument grounded in validated scientific literature.

It introduced a computational design system linking pressure maps to geometry.

It demonstrated credible material experimentation and iterative testing.

It engaged anthropological and historical precedents to contextualize design decisions.

What could have been done differently

More extensive user testing across diverse foot types.

Earlier integration of 3D scanning and pressure mapping.

Greater iteration on midsole geometry before merging upper–sole structures.

Broader material testing beyond TPU.

Earlier exploration of bending, torsion, and fatigue through simulation and physical tests.

The project's broader impact

Despite its limitations, the project succeeds in reframing footwear design as an anatomical, computational, and ecological endeavor. It offers a compelling argument for:

.he obsolescence of traditional shoe lasts,
the feasibility of fully digital, on-demand manufacturing,
the potential for geometry to replace multi-material layering,
the therapeutic possibilities of restoring natural foot mechanics.

In this sense, the project moves the footwear field forward —not by solving its most difficult challenges, but by demonstrating how those challenges might be productively reimagined.

Final Position

In conclusion, the project stands as a speculative yet grounded exploration of what footwear could become when guided by biomechanical intelligence, material restraint, and computational design. It remains an unfinished solution, but a promising one. Its greatest contribution is not the prototype itself but the framework— a new methodology for thinking about footwear through the lens of human anatomy, ecological responsibility, and generative computation.

Future iterations will demand deeper material exploration, larger datasets, more diverse user involvement, and more sophisticated algorithms capable of richer biomechanical tuning. Yet the trajectory set by this research is meaningful: a step toward footwear that partners with the human body rather than constraining it, and toward an industry that values adaptive intelligence over extractive consumption.

The project does not conclude the search for better footwear—it begins it.

Fin.

bibliography

Academic Research Papers

Allen, C., Pinheiro, M., Schoenmaekers, S., D’Août, K. and Willems, C., 2023. Walking with individualized 3D-printed minimal footwear. Royal Society Open Science.

Curtis, D., Willems, C., Paoletti, P. and D’Août, K., 2016. Daily activity in minimal footwear increases foot strength. Scientific Reports (Nature).

Multon, N., D’Août, K., Crompton, R. and Berillon, G., 2014. Anthropometry in bipedal locomotion: the link between anatomy and gait. Journal of Human Evolution.

Ojiambo, R., Gibson, A., Konstabel, K., Lieberman, D., Speakman, J., Reilly, J. and Pitsiladis, Y., 2013. Free-living physical activity and energy expenditure of rural children and adolescents in the Nandi region of Kenya. Annals of Human Biology.

Robbins, S.E., Gouw, G.J. and Hanna, A.M., 1989. Running-related injury prevention through innate impact-moderating behavior. Medicine & Science in Sports & Exercise.

Stoneham, R., Barry, L., Saxby, R., Wilkinson, S. and Waters, K., 2021. Differences in stride length and lower limb moments while barefoot, in minimalist and maximalist running shoes. Footwear Science.

Stoneham, R., Barry, L., Saxby, R. and Wilkinson, S., 2020. The influence of great toe valgus on pronation and frontal plane knee motion during running. The Foot and Ankle Online Journal. Strzalkowski, N., Triano, J., Bent, L. et al., 2015. Thresholds of skin sensitivity are partially influenced by mechanical properties of the skin on the foot sole. Physiological Reports.

Willems, C., Stassijns, G., Cornelis, J. and D’Août, K., 2014. Biomechanical implications of walking with indigenous footwear. Footwear Science.

Willems, C., 2015. The Birth of Feet, The Rebirth of Footwear. PhD thesis. KASK School of Arts.

Books

Bennett, P.J. and Haines, T., 2018. Therapeutic Footwear: A Comprehensive Guide. Amsterdam: Elsevier.

Field, M., 2000. Fractals in Nature: From Characterization to Simulation. Oxford: Oxford University Press.

Frederick, E.C. and Hennig, E.M., 2011. Biomechanics of Running Shoes. Champaign, IL: Human Kinetics.

Kolarevic, B., 2003. Architecture in the Digital Age: Design and Manufacturing. New York: Spon Press.

Mandelbrot, B.B., 1982. The Fractal Geometry of Nature. San Francisco: W.H. Freeman and Company.

Manzini, E., 2015. Design, When Everybody Designs: An Introduction to Design for Social Innovation. Cambridge, MA: MIT Press.

Nigg, B.M. and Segesser, B., 2010. The Science of Footwear. Boca Raton, FL: CRC Press.

Oxman, N., 2018. Material Ecology: The Future of Design. Cambridge, MA: MIT Press.

Oxman, R., 2017. Thinking Through Digital Design: Morphogenesis and Computation in Architecture. London: Routledge.

Pallasmaa, J., 2009. The Thinking Hand: Existential and Embodied Wisdom in Architecture. Chichester: Wiley.

Schön, D.A., 1983. The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.

Design Theory, Systems & Cultural Context

Antonelli, P., 2019. Broken Nature: Design Takes on Human Survival. New York: MoMA Publications.

Oxman, N., 2015. Age of entanglement. Journal of Design and Science (JoDS). MIT Media Lab.

Rittel, H. and Webber, M., 1973. Dilemmas in a general theory of planning. Policy Sciences, 4(2), pp.155–169.

Prosthetics, Skin & Material Studies

Huang, G. et al., 2022. Soft robotics and bioinspired material systems in wearable design. Nature Materials.

Rogers, J.A. et al., 2021. Skin-like electronics for human–machine interfaces. Science Advances.

Wang, X. and Chen, Z., 2020. Smart materials for adaptive wearable systems. Advanced Functional Materials.

Digital Design, Biomimicry & Fabrication

Additive Manufacturing Europe, 2023. Advances in TPU 3D printing for footwear applications. [online] Available at: https://www.additivemanufacturing.media/articles/tpu-footwear [Accessed Day Month Year].

Grasshopper3D, 2022. Kangaroo Physics Plugin Documentation. [online] Available at: https://www.grasshopper3d.com/group/kangaroo [Accessed Day Month Year].

Lovegrove, R., 2015. Beauty and biomorphism in industrial design. Dezeen. [online] Available at: https://www.dezeen.com [Accessed Day Month Year].

Parametric House, 2023. Grasshopper Tutorials: Fractal and Lattice Modelling for Architecture and Footwear. [online] Available at: https://parametrichouse.com [Accessed Day Month Year].

Parametric3D, 2023. Fractal and Lattice Structures in Grasshopper. [online] Available at: https://parametric3d.com [Accessed Day Month Year].

Rhino3D, 2024. Official Rhino and Grasshopper Tutorial Library. [online] Available at: https://www.rhino3d.com/learn/ [Accessed Day Month Year].

All3DP, 2023. Best flexible filaments for 3D printing footwear. [online] Available at: https://all3dp.com [Accessed Day Month Year].

Visual & Inspirational References

MIT Media Lab, 2013. Silk Pavilion Project. Mediated Matter Group. [installation] Massachusetts Institute of Technology, Cambridge, MA.

Oxman, N., 2014. Wanderers Series. Mediated Matter Group, MIT Media Lab. [design collection].

Studio Silo, 2022. Bio-Responsive Materials Research. [research project].

van Herpen, I., 2019. Hypertube Collection. [fashion collection].

Nature’s fractal systems (river deltas, root networks, vascular systems) used throughout as visual and structural analogies in parametric modelling.