F R E Q U E N C Y

DATA-DRIVEN METHODOLOGY FOR PERFORMANCE FOOTWEAR

ALEX HILL

UNIVERSITY OF OREGON

MISSION STATEMENT_

- MY OBJECTIVE IS TO DEVELOP A METHODOLOGY TO TRANSLATE & INCORPORATE BIOMECHANICAL DATA & FOOT PHYSIOLOGY INTO THE CREATIVE PROCESS THROUGH ALGORITHMIC DESIGN TO PRODUCE A NEW METHOD FOR FOOTWEAR DESIGN

Frequency

Alex Hill

University of Oregon

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Business Case

SPD 689

Part I

Current performance footwear is ripe for innovation. Performance footwear today is currently based off of generic lasts taken from an average of samplings that are sport specific silhouettes. A majority of the research and development goes into the tooling of the performance footwear leaving theu pper as a relatively unchanged component. With all of the focus being on the outsole, having various reliable testing protocols to capture information on the plantar side of the foot. Most footwear innovation programs have been mainly focused on improved solutions for areas in impact protection, energy return, supination, pronation etc. This leaves the entire topside of the foot with less research & development improvements even though there is a lot that can be taken away from how the upper portion of the foot is morphing during sport. Why has there not been a well thought-out and executed methodology to qualitatively capture how the dorsal side of the foot is deforming in relation to what is happening on the plantar side during sport? Why is the innovation focus primarily on the smallest surface area of the foot without consideration for the skeletal, muscular, fat, and loose skin structures on the top side of the foot? Another issue with performance footwear today is that most designs are created without the presence of biomechanical data being used as another tool to help inform the best output for a piece of footwear. To add to this issue, as stated above, the footwear is not built around the individual athlete's foot anatomy nor is the footwear based off of the athlete's specific biomechanics of the specific sport they are performing. The mission of the capstone is to develop a methodology to incorporate & translate biomechanical data and foot physiology into the creative process through

generative design to produce a new method for sport specific footwear tailored to the elite athlete.

The data and sport landscape today is vast. Data is constantly being collected during sport, for sport equipment, for injury prevention, and even for entertainment purposes. These main categories can be further broken down into segments of vital sign feedbacks, biomechanical movement capture, sport analytics, and the tools being used that collect and translate the data into product. Predominantly software companies like Strava and Fitbit have created a data ecosystem that collects users running data over time. This includes their distances, running routes, times, and even vital signs such as heart rate. Other fitness tracking companies have equipped sport equipment that use proprietary algorithms to collect vital sign information to provide feedback to the consumers. On the market in 2018, Bose SoundSport wireless sport headphones are engineered to provide the users' heart rate data during physical activity to show feedback overtime about how they are improving. Under Armour's E39 biometric compression shirt first debuted at the 2011 NFL combines. The compression shirt tracks and broadcasts athletic performance. This product took the next evolution of the activity tracker & integrated the technology into athletic performance apparel. With concussions on the rise and a major concern in sports reebok released the Checklight impact sensor cap back in 2013 to help keep athletes safe who participate in impact sports. The CHECKLIGHT is a cap, which can be worn with or without a helmet, that detects impacts to the head and immediately provides a warning to the wearer and

those around. The cap includes a gyroscope, accelerometers, and microprocessor, which are all hooked up using flexible electronics.

Sport analytic companies are partnering with sport teams on both the collegiate and professional levels to collect data regarding individual player performance. The data allows for the coaching staff to qualitatively review how a single athlete is performing to improve their performance output. This resource for sport organization is going to become a common tool to further develop athletes.

Performance footwear powerhouses such as Nike and Adidas have largely invested in technologies that capture both the biomechanics and physical anatomy of athletes to better inform product. 3D body scanning technologies have quickly improved to now have the capability of capturing the athletes movements in real time. This allows for the research and development teams to have a 3D snapshot to give visual feedback of how the athletes body is moving during any given athletic task being performed. Motion capture collection with nodes placed on specific parts of the body can give researchers a detailed description of how the body is performing on a biomechanical level through numerical values. Companies like EA Sports use motion capture nodes to collect the athlete's movements to help inform how the digital avatar version of the athlete moves in game. Generally, motion capture collection is paired with force plate testing. The force plates are measuring instruments that measure the ground reaction force generated by a body standing on or moving across them, to quantify balance, gait and other parameters of biomechanics. Typically force plates are built into testing treadmills or underneath running surfaces. The information can also help to identify

biomechanical corrections to help the athlete improve performance. A more basic technology are pressure mapping tools such as Techscan that capture the pressure distribution of the athlete during gait. This data informs the research and development team about the areas of the athlete's foot that are taking on the highest impact as well as the path of areas of the athlete's foot that are taking on the highest impact as well as the path of areas of the athlete's foot that are taking on the highest impact as well as the path of can also help to identify biomechanical corrections to help the athlete improve performance.

So how are companies translating all of this data into products? In the footwear industry companies have started integrating computational design practices to help translate the data into a visually appealing design based off of data. An example of a biomechanically informed performance footwear is the Nike Rio cleat. Nike developed a proprietary algorithm based off of data collected from track and field athletes to develop specific track spikes tailored to the athlete's running event. Adidas Futurecraft 4D has taken a different approach by developing a unique intrallatice structure based off of pressure mapping that utilizes additive manufacturing on a large scale. New Balance has also used generative design with additive manufacturing informed by biomechanical data to create a unique outsole appearance and improved functionality.

However, currently generative design and additive manufacturing are not being used to their full potential. These are hot buzzwords in the footwear industry today and are mainly being used as market gimmicks that are not grounded in performance innovation. Companies are letting the computational design programs dictate too much

and not allowing for the designers to truely translate the data. There needs to be a balance between the data and the aesthetics to create data-driven beautiful footwear. All of the focus has been placed on the tooling portion of the footwear. There has been no integration of biomechanical data being translated through generative design informing the upper portion of the footwear. The most interesting and new innovation is how the upper and outsole portion of the footwear could weave together and wrap 360 degrees around the foot based off of the athletes 3D scan and biomechanical data.

It is an exciting time in footwear innovation on the material and manufacturing spectrum. Additive manufacturing is becoming faster, with an ever-growing material library. Companies like Carbon help to produce Adidas Futurecraft 4D in under twenty minutes per outsole. Experimentations in the fashion world with textiles has been on the rise. The intersection and integration between textiles and hard goods within the additive manufacturing world opens up a game changing new frontier. Within the next few years the possibility of simultaneously printing drastically different material properties on a single strand of build material could become a reality. This breakthrough in materials and manufacturing engineering would allow for different materials to interweave together creating new structures that could be translated into performance footwear. Footwear that will have specifically printed materials that are constructed based off of the athlete's foot anatomy, biomechanics, and directly tailored to their sport.

Approaching this untapped, unknown area to push footwear a testing protocol must be determined and put into action to help identify the problems that need to be solved. For the purpose of this capstone linear running will be the athletic movement

performed. Areas to improve upon within the footwear piece will be flexibility, stability, and support. Flexibility because current footwear is not constructed based off of individual athlete's foot anatomy or biomechanics to allow for optimal performance. Stability based off of where the individual athlete needs denser material construction to prevent injury. Support to provide the individual athlete with proper amount of material in areas that are sport specific to give them a confident feel in the footwear. To begin the athlete will have their foot 3D scanned in each phase of gait. For this study the terminal stance will be the main focus due to the foot being at its most extreme. The foot is at its longest and skinniest, as well as under a lot of tension preparing to lead into the toe off phase. Once the 3D images are captured in CAD software the initial testing protocol can begin. To test how the pressure is being displaced underneath the foot, the athlete will run barefoot with Techscan insoles. The new methodology of viewing how the foot morphs during gait will be to create a 1-inch anatomical grid system on the dorsal side of the foot. The lines will start by connecting the major metheads of the foot. Once the lines are constructed on the athlete they will run barefoot and be captured with a slow motion camera. Each 1-inch square on the foot will be assigned a numerical value that will be assigned a color based off of how that area is morphing during gait. Once the data is collected from the pressure mapping of the plantar portion and the morphology map of the dorsal portion the ideation process can begin. Through generative design the data can be translated with infinite design solutions quickly. The designs then can be quickly developed and tested again through additive manufacturing. These steps will repeat themselves in a non-linear fashion until a final design is realized.

The use of integration of biomechanically informed data translated through generative design during the design process into creating 360 degree wrapping performance footwear efficiently will create world-changing footwear. Now is the time stop thinking about performance footwear in the traditional sense as an outsole, midsole, and upper. Designers, engineers, material developers, etc. need challenge the traditional ideology to think about footwear with a more holistic approach that is hyper sport specific, pushing the limits of new materials and how they are constructed together, and how all of these elements wrap around the elite athlete's foot to push their athletic abilities beyond.

Part II

Venturing out into the retail market help to validate my hypothesis on where the performance footwear market can innovate in the future. Adidas Futurecraft 4D, Under Armour Architech, and New Balance Zante Generate are all partially made with additive manufacturing utilizing generative design. All of these footwear pieces come with a very expensive price tag ranging for $250 all the way up to $1700+. All of these companies are focused on the outsole portion of the shoe with no innovation in the upper portions utilizing these technologies. Adidas is making giant leaps in terms of quickly mass producing 3D printed structures on a mass scale with their Speed Factories and partnering with Carbon to utilize their printing materials and machines. New Balance has taken a similar direction partnering with Formlabs to develop factories strictly for mass producing 3D printed components for footwear. Nike has taken a different

approach with first using algorithmic design to translate biomechanical data into the Rio track spike plates. But recently launched an upper that is designed integrating biomechanical data into the construction in the VaporFly elite Flyprint. The material is printed out in a pattern specifically designed for a given athlete's needs and attached to the much hyped Zoom X foam midsole from the 4% model. The upper is not a hard-shell 3D-printed material, it's a fabric of sorts. The material is reinforced by the fact that several components of the shoe are still made of FlyKnit including the tongue and collar. Those parts are so similar in chemical composition that there is no glue needed to attach them. Instead, the FlyPrint material is bonded seamlessly with the FlyKnit, making for a one-piece design that is stronger and lighter. In the case of the new FlyPrint upper, the constraints are the properties of the material and the forces that Kipchoge's feet were exerting on that material. With that data, along with the chemical composition of the polymer, a computational model allowed Nike to tweak the design for support, flexibility, reinforcement or relaxation on a much more granular level than they could ever accomplish with FlyKnit. The result of all of this is that the shoe is incredibly light. A 11 gram, or 6% reduction in weight to start. On top of that, one of Kipchoge's big issues with the Vaporfly Elites in Berlin was water retention in the rain. The shoes started out light but water soaked into the FlyKnit and couldn't fully make its way out. The FlyPrint upper is nearly translucent it's so porous, which solves the drainage issue.

As far as the aesthetics are concerned, most of the performance footwear shares the same design aesthetic. The design appears very computational instead of allowing the designer to translate the biomechanical data using generative design as a tool

Instead of letting generative design take complete control of the design outcome. This allows for a lot of exploration into what the infinite design language could be. To not be influenced and distracted by current footwear trends, a new perspective had to be generated. Fashion and architecture have long been playing in the generative design world and more recently with additive manufacturing. Taking design cues from what is happening in these fields of design sparked an entirely new aesthetic and inspiration to which is not being done in the current footwear market. Inspiration driven my suspension architectural structures, linear movement across an organic form, and light neutral colors seem very appropriate to pursue. Especially, in contrast to the over aggressive morphed hexagonal patterns to bright colorways.

Athlete feedback was very intune with the direction of the business case hypothesis. Garnering insights from mostly mid to long distance runners about what there needs are as a runner, their footwear purchasing behaviors, their ideal performance footwear, and the psychological aspect of the runner and footwear connection. After reviewing the insights and feedback, the results reinforced the fact that every runner is different and has hyper specific needs even though they might be running the same distances or events.

After the athlete feedback, professionals in the field of biomechanics, computational design, and footwear design were consulted for insights into the subject matter. The key takeaways from talking to the biomechanists was to be very clear what you are solving for and the why. Once the problems and the reasoning has been identified it is important to develop a reliable protocol to test the hypothesis. More

importantly keep it simple and to not get lost in all of the data. Computational designers had very similar feedback to not get lost in the data and to be very selective on the information you chose to go forward with into developing the design. Stay true to the data but also not to let grasshopper control too much of the design. Keeping a good balance of data and design is key. Senior footwear designers who work in this space alongside the computational designers and biomechanists had a new perspective. The main feedback from the designers was to integrate the data into footwear in a new, interesting way to challenge what performance footwear could be. Don't be afraid to go way out there and to really push the design all while solving the key problem areas that had been identified and staying true to the data collected.

In conclusion to the research and insights gathered, this space of biomechanically driven generative design footwear that considers the athlete's foot in 360 degrees is a very exciting space to innovate. In order to deliver a clear design aesthetic that uses linear running data to transition around the foot smoothly will take many iterations from 3D modeling, 2D sketching, and testing prototypes to land on a final designs that encompass the following:

- solves for flexibility, support, and structure needs
- transitions smoothly 360 degrees around foot
- utilizes correct biomechanical data
- stays within developed aesthetic world

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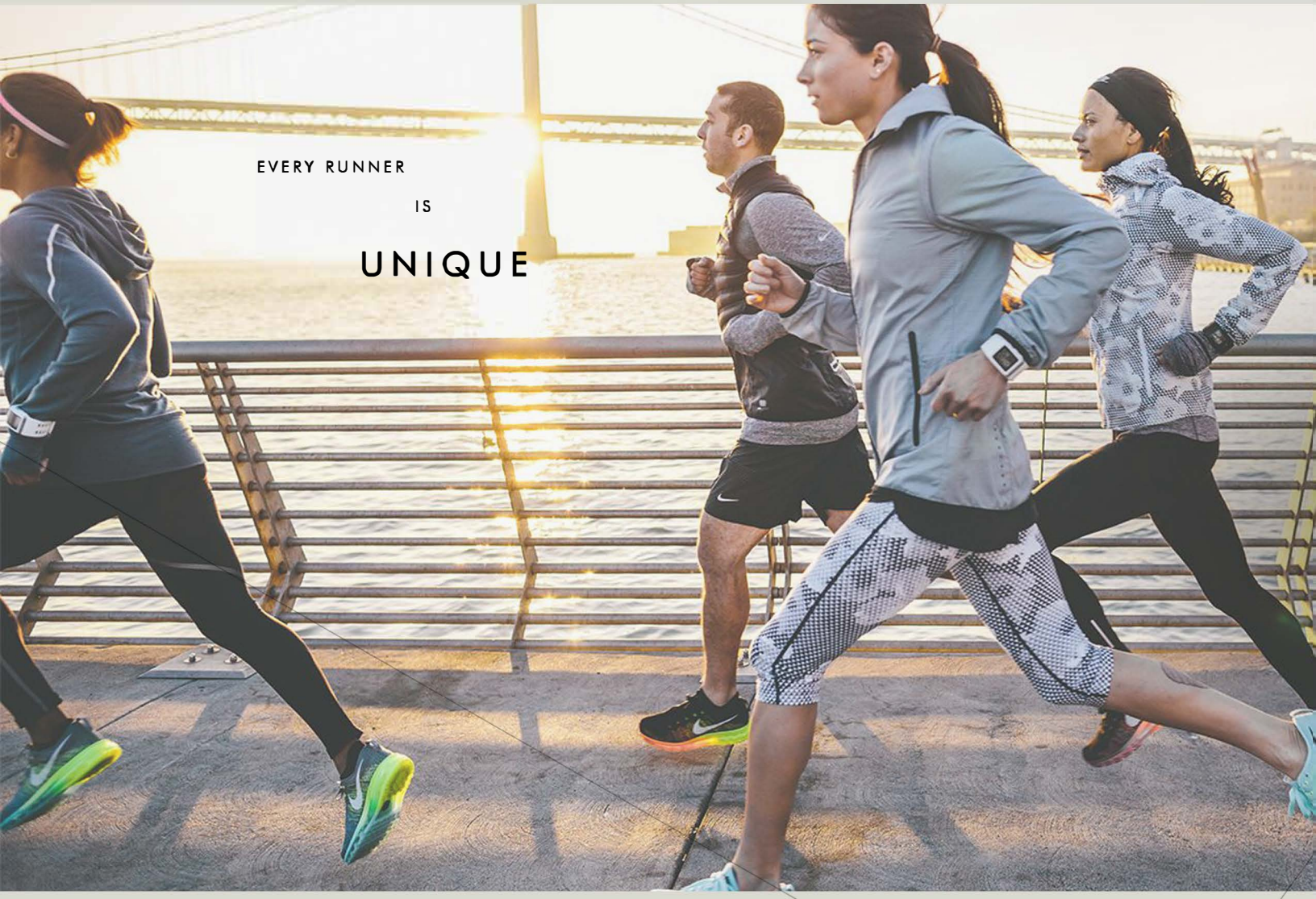

EVERY RUNNER
IS
UNIQUE

WHAT WOULD BIO-MECHANICALLY TAILORED FOOTWEAR BE LIKE?

CURRENT MARKET'S MAIN FOCUS IS ON THE OUTSOLE

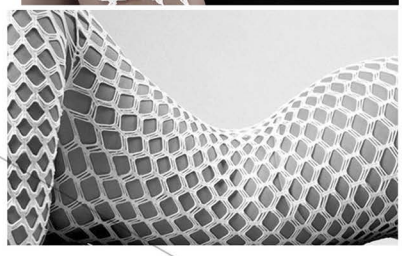
WHAT IF THE UPPER & OUTSOLE WERE INTEGRATED?

DATA IS BEING COLLECTED ALL THE TIME

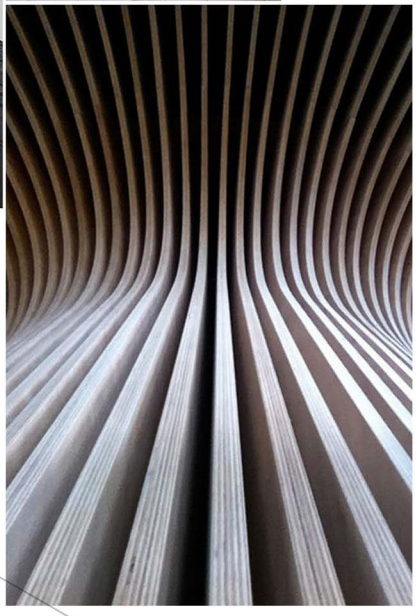
DATA CAN INFORM & DEFINE SPORT PERFORMANCE

MOOD///TREND

- BODY MAPPING
  ADAPTIVE
  ESSENTAIL

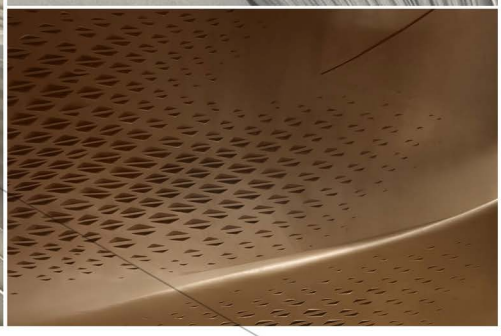


MOOD///TREND

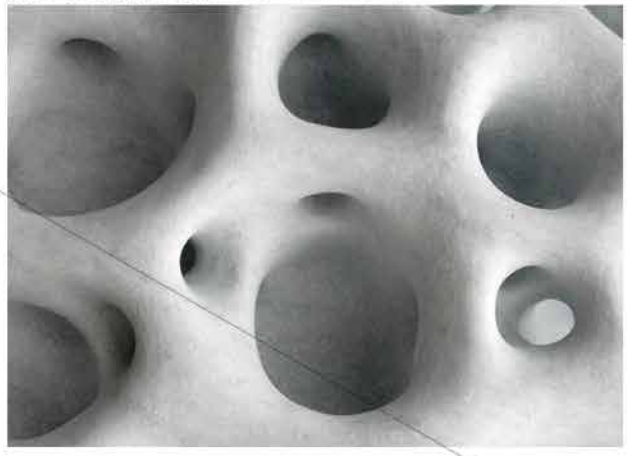


- STRUCTURAL
- GEOMETRIC
- FLUID

MOOD///TREND

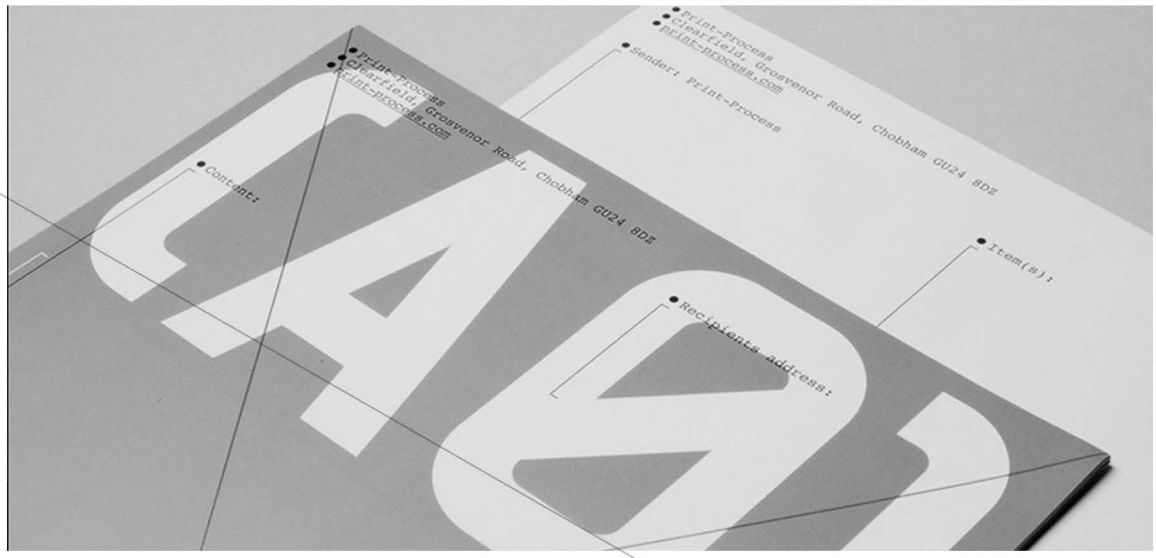


MOOD///COLOR

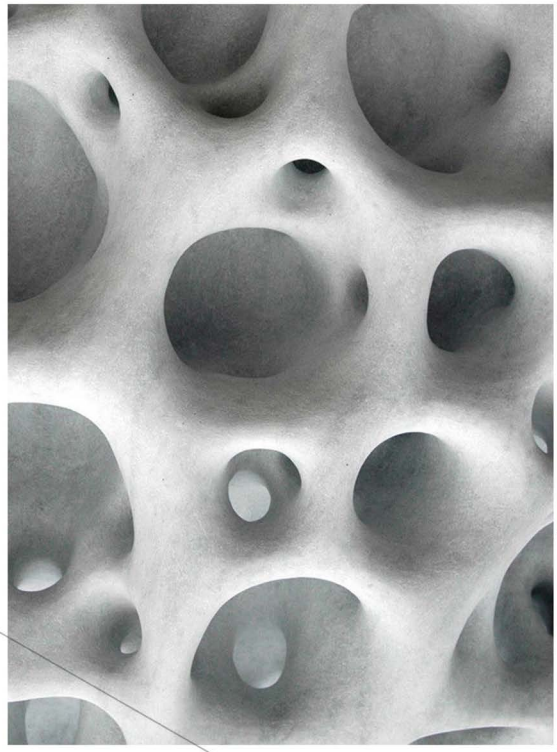


MOOD///TYPOGRAPHY

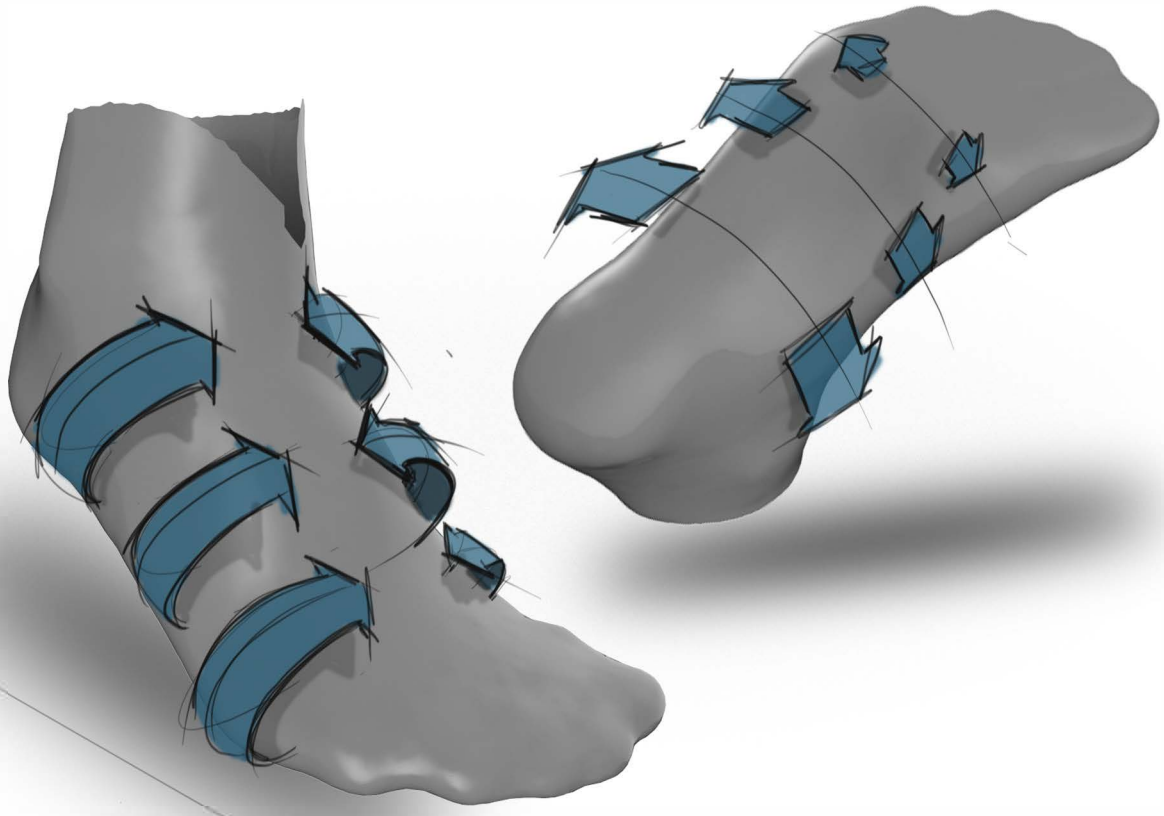
MODERN
SOPHISTICATED
FUTURE



MOOD///COLOR & TRIM



EARTHY
CLEAN
MINIMAL
ESSENTIAL

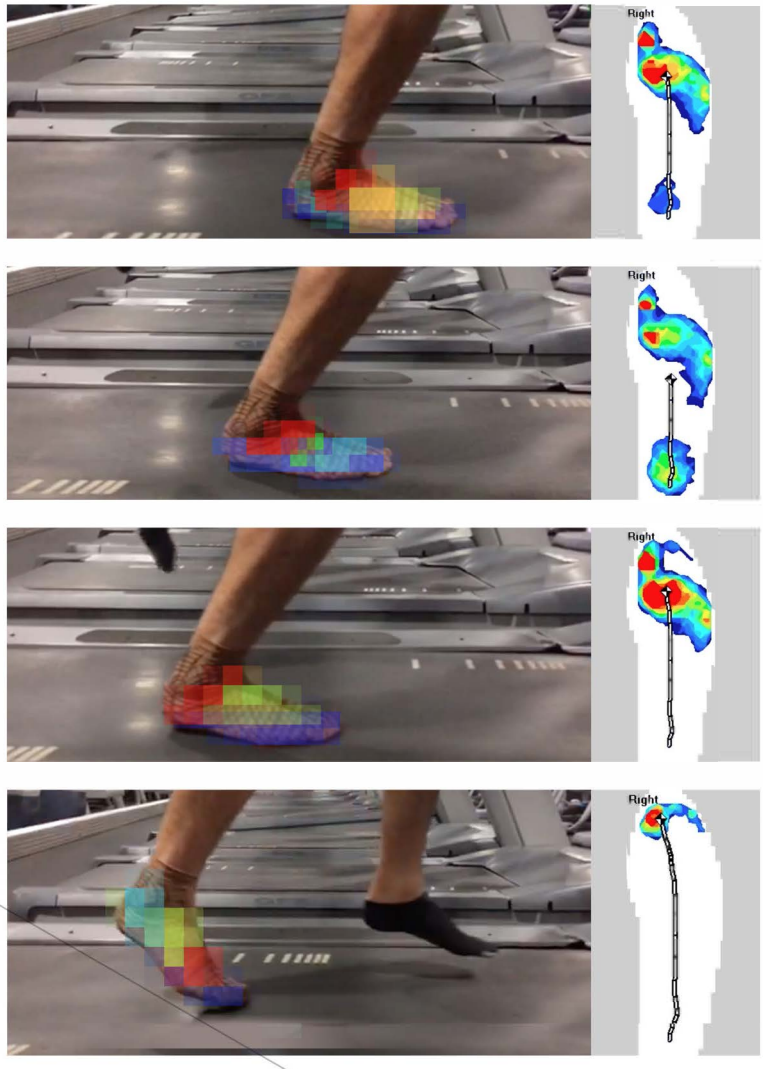


OPPORTUNITY TO DEVELOP A METHODOLOGY THAT WILL LOOK AT THE
FOOT IN 360 DEGREES TO CREATE A SPORT SPECIFIC UNIFIED UPPER & OUTSOLE BASED OFF OF
THE ATHLETE'S BIOMECHANICAL DATA & FOOT SCANS

- I DECIDED TO FOCUS ON THE TOE OFF POSITION DUE TO THE DYNAMICS OF THIS PHASE WHERE THE FOOT IS AT ITS LONGEST & SKINNIEST

- THERE IS A BIG OPPORTUNITY TO CREATE NEW MATERIAL CONSTRUCTION & GEOMETRIES TO DEVELOP HOLLISTIC & INTERCONNECTED PERFORMANCE FOOTWEAR

FOOT MORPHOLOGY MAP VS PRESSURE MAP///

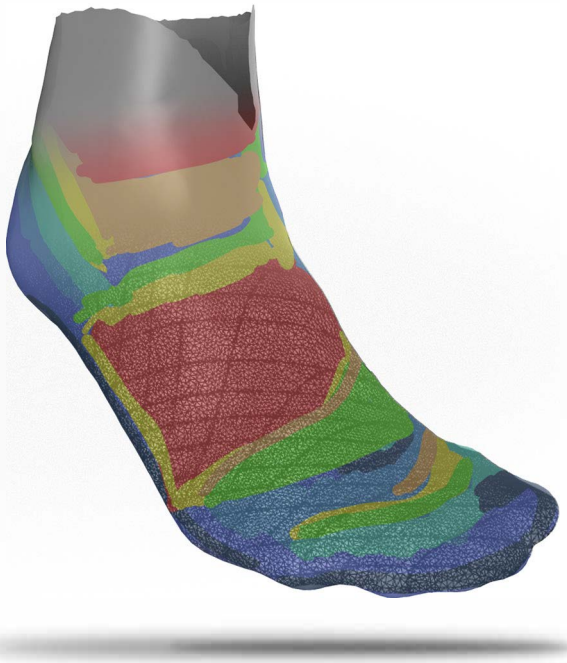


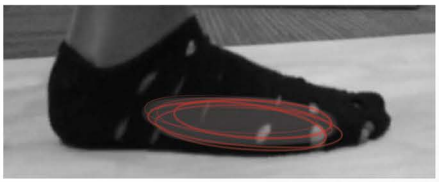
- DEVELOPED A TESTING PROTOCOL TO QUALITATIVELY COLLECT & TRANSLATE THE DATA OF HOW THE THE FOOT'S STRUCTURE CHANGES DURING GAIT

- RED= MOST DRASTIC AREAS OF STRUCTURAL CHANGE

TO

- BLUE= LEAST MOST STRUCTURAL CHANGE

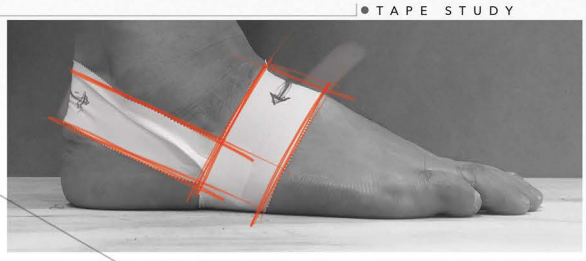


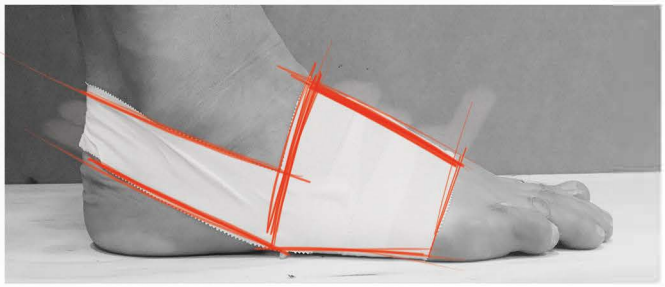


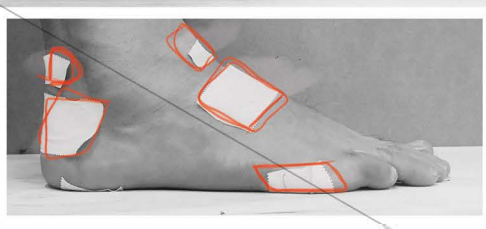
SOCK STUDY

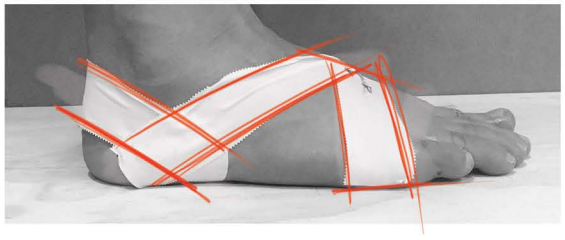
SLOTS WERE CUT HORIZONTALLY & VERTICALLY TO CAPTURE HOW MY FOOT MORPHS DURING GAIT. I STUDIED THE MEDIAL/ LATERAL/ DORSAL VIEWS TO DETERMINE ZONES THAT NEED SUPPORT & AREAS THAT NEED LESS MATERIAL.

TAPE STUDY



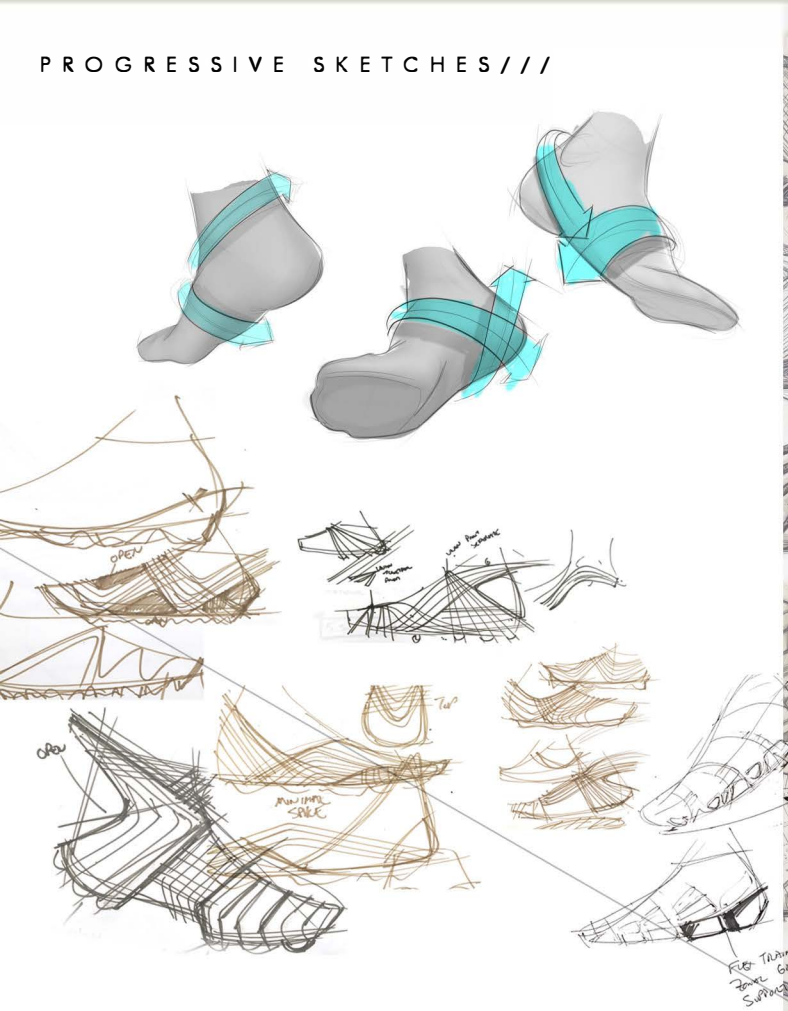


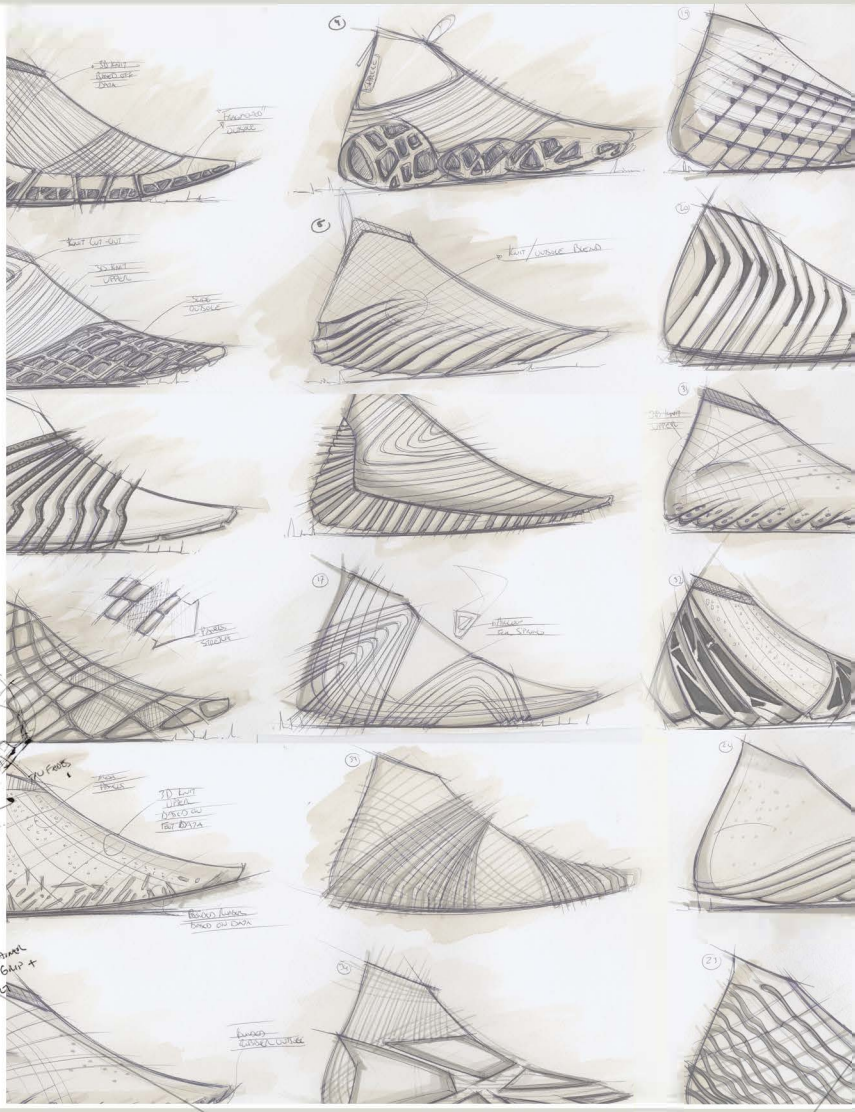




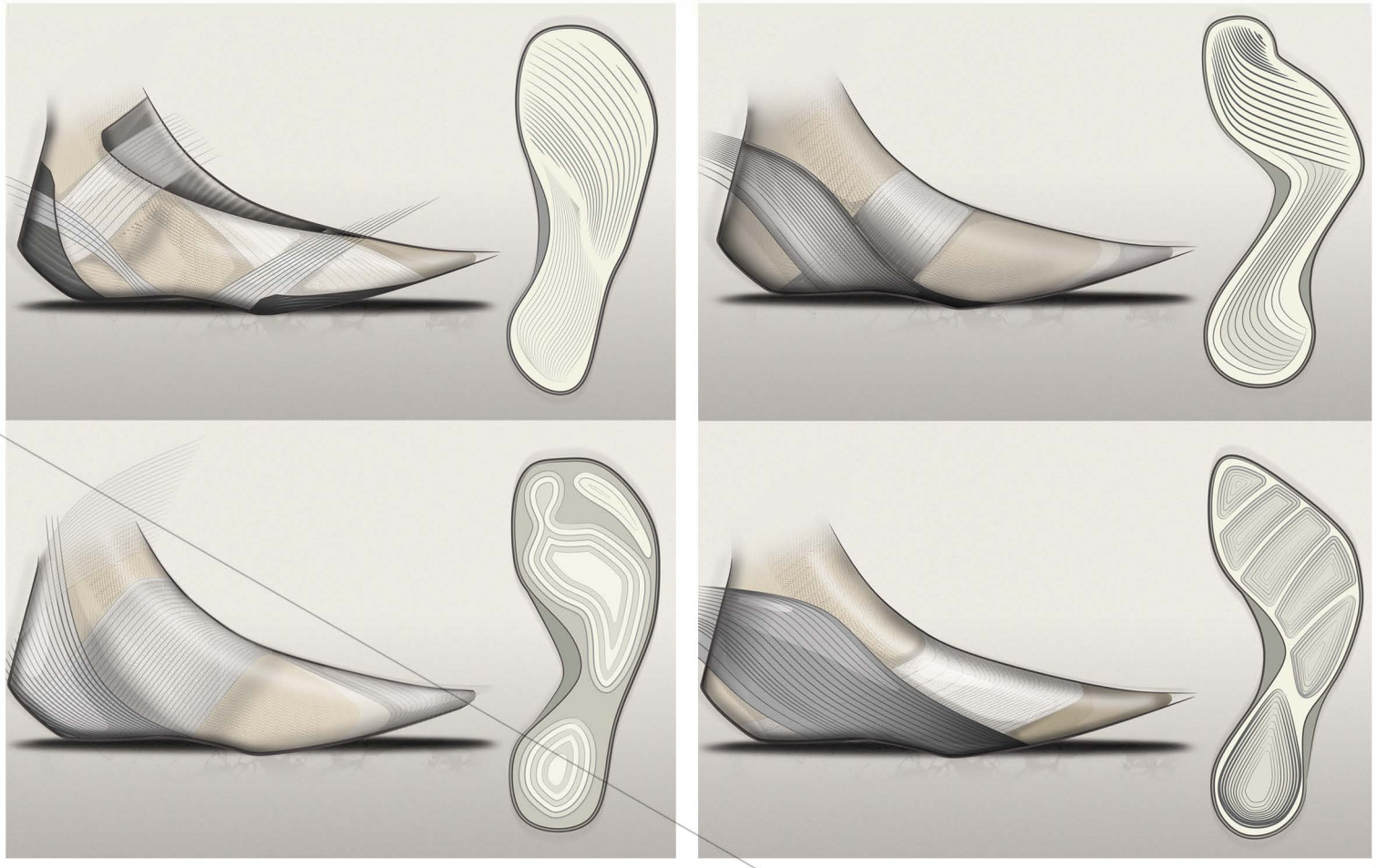
I TAPED MY FOOT TO EXPLORE DIFFERENT SUPPORT/STRUCTURE APPORACHES OF WHAT PROVIDED SUPPORT WHILE ALLOWING FLEXIBILTY TO NOT INTERFERE WITH NATURAL GAIT MOVEMENT.

PROGRESSIVE SKETCHES///



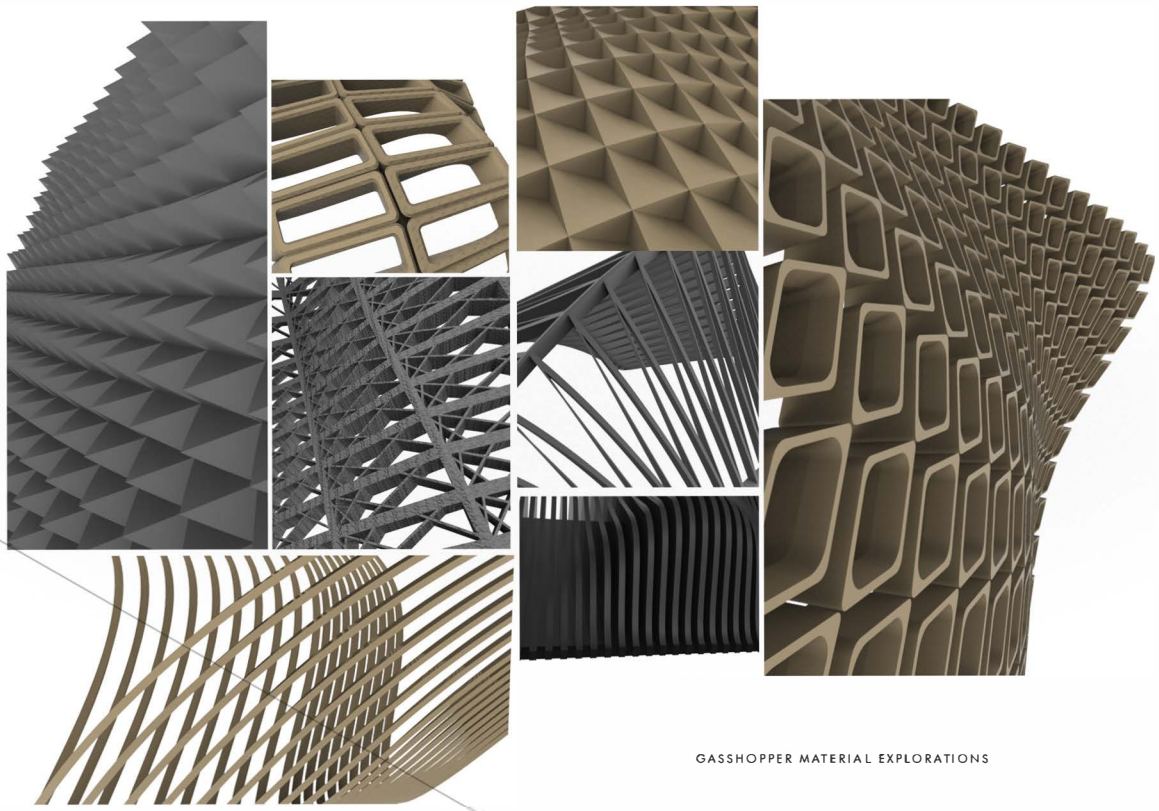


REFINED SKETCHES///



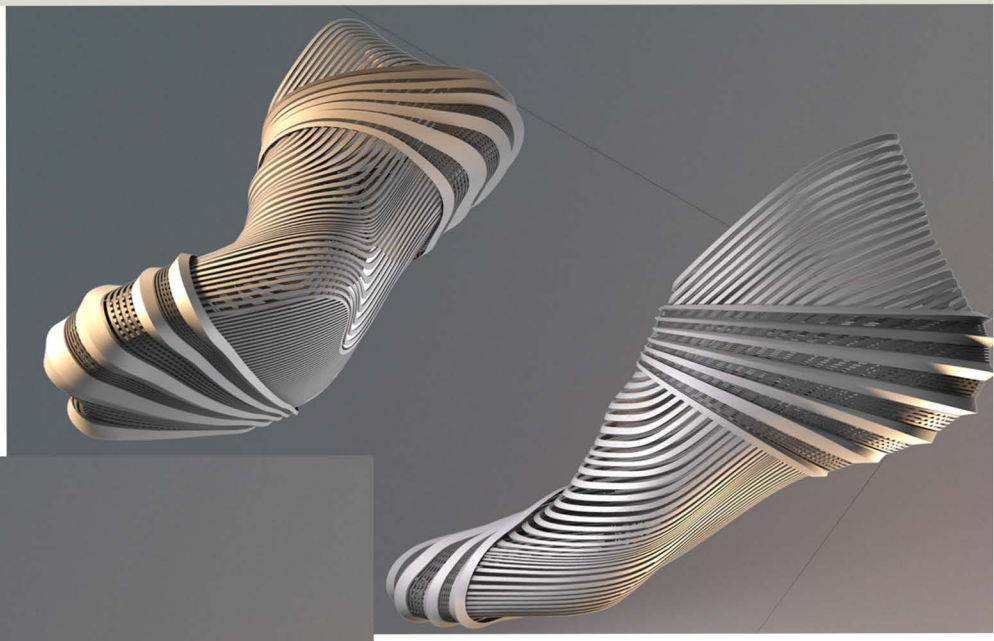
INITIAL TESTING

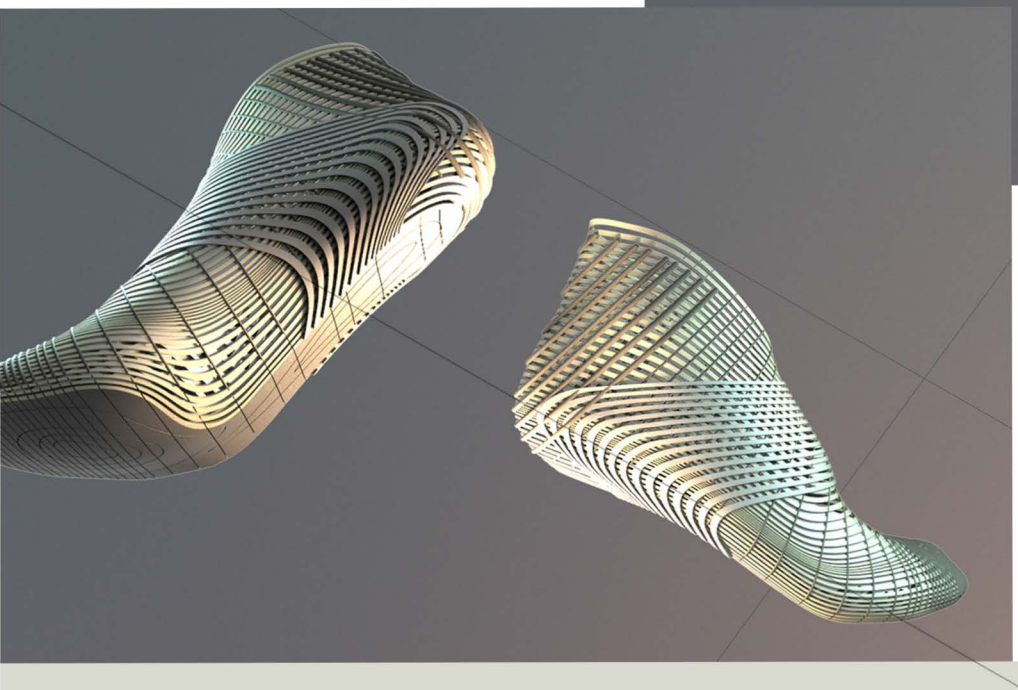
AT THE BOWERMAN SPORTS SCIENCE CLINIC WALKED WITH PRESSURE SENSORS TO CAPTURE WHERE THE FORCES WERE BEING APPLIED ON MY FOOT & HOW THE FORCES WERE BEING DISTRIBUTED.



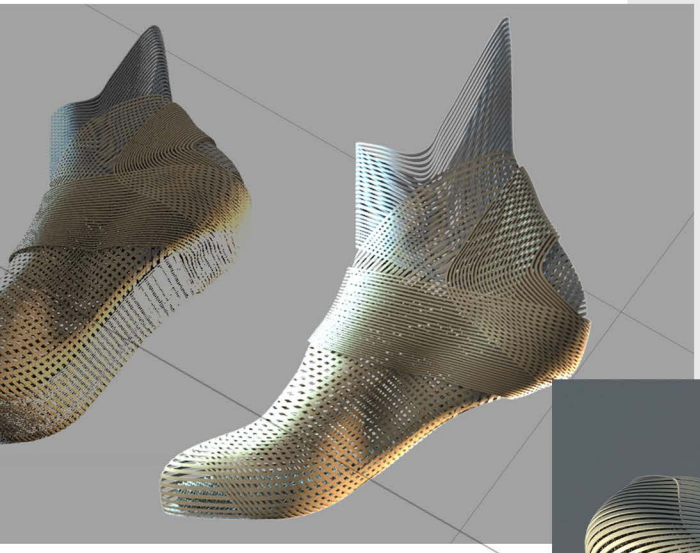
GASSHOPPER MATERIAL EXPLORATIONS

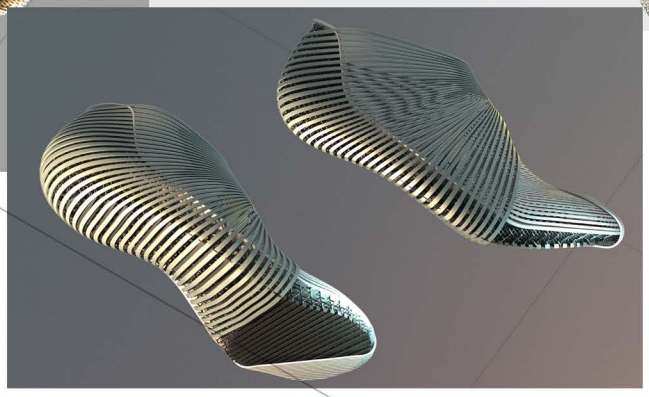
3D EXPLORATION///

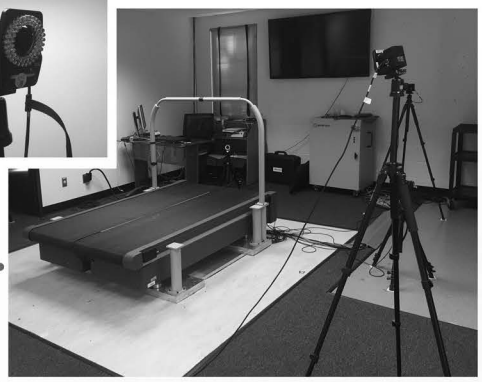


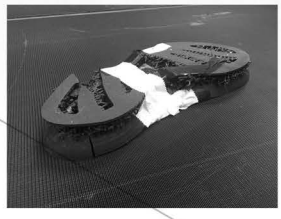


3D EXPLORATION///



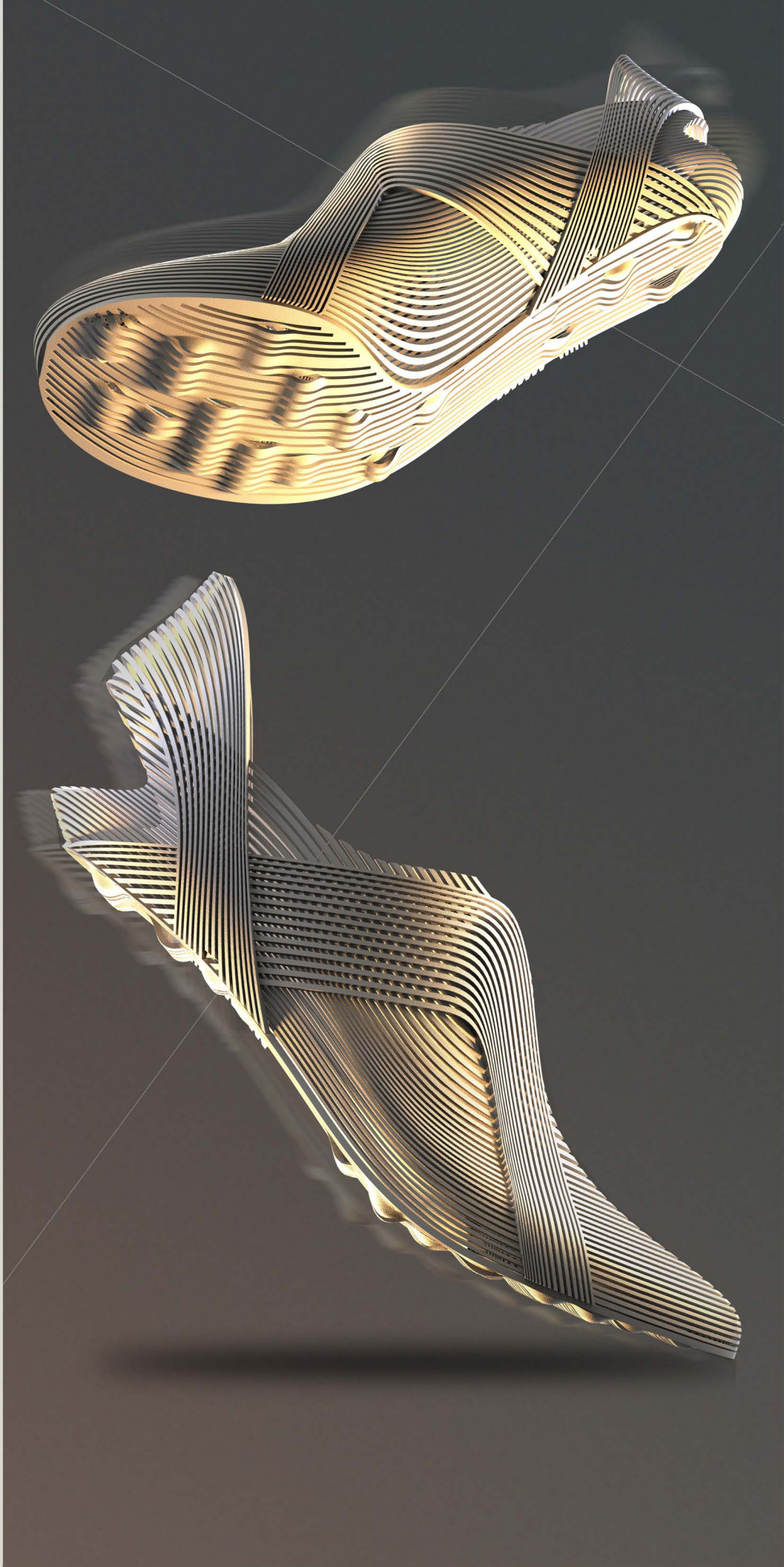






MOTION CAPTURE WITH 3D PRINTED COMPONENTS
THE BOWERMAN SPORTS SCIENCE CLINIC RAN WITH MOTION SENSORS BAREFOOT/ WITH NIKE METCONS/ THEN WITH 3 DIFFERENT 3D PRINTED FOOTWEAR VARIATIONS TO VALIDATE DESIGN DIRECTION

S P I K E

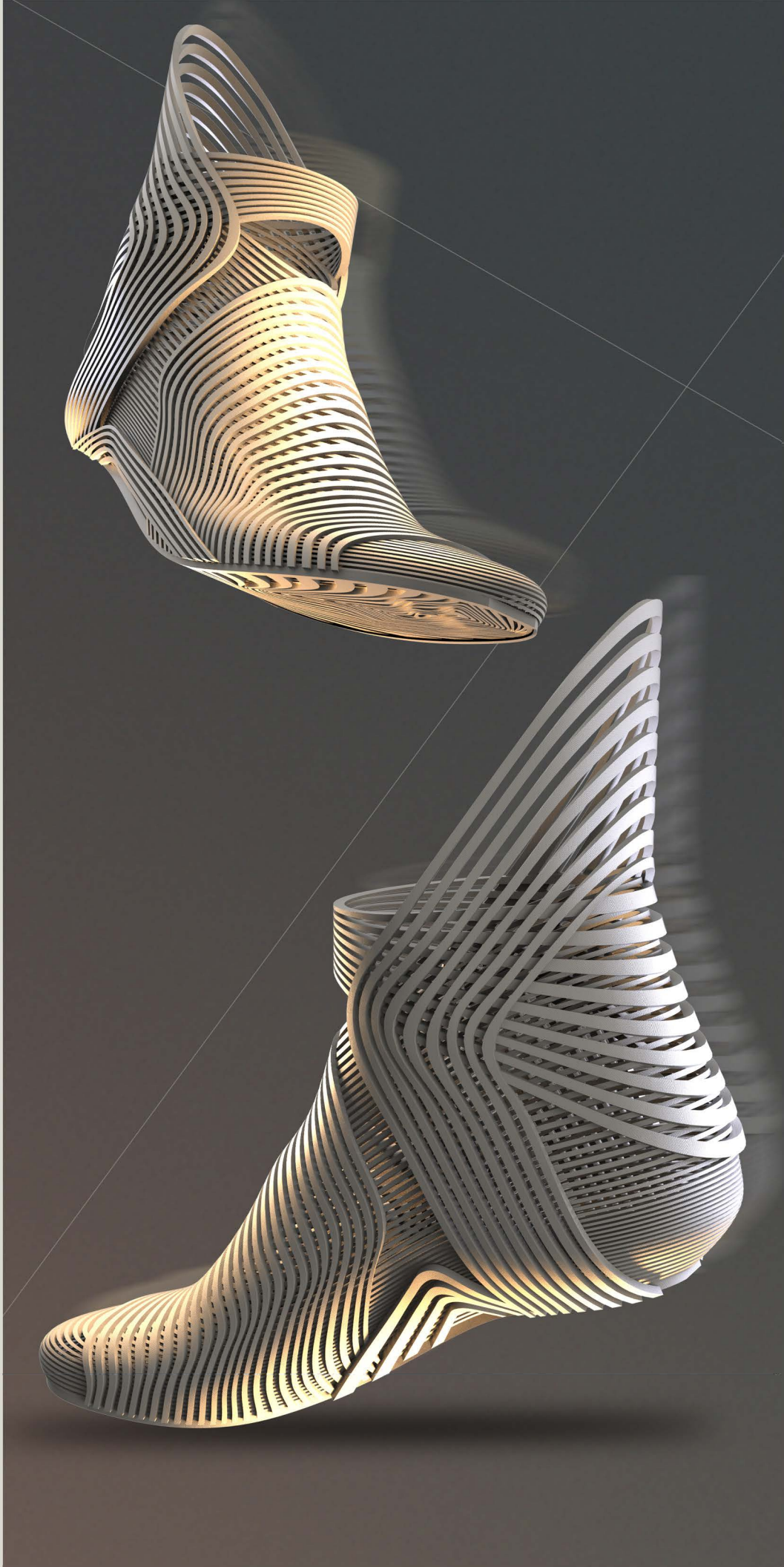


SUPPORT

FLEXIBLITY

STABILITY

F L A T

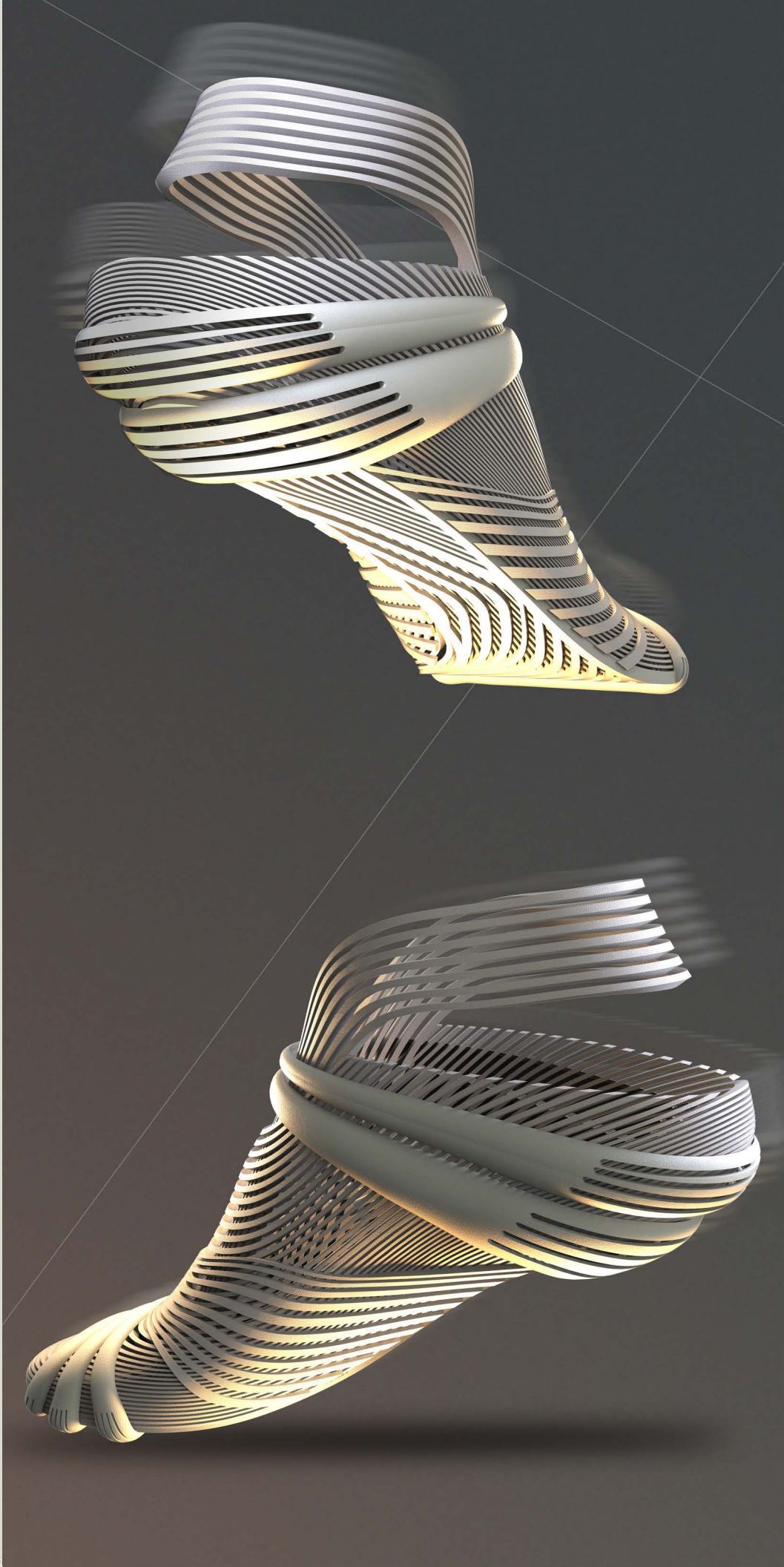


SUPPORT

FLEXIBLITY

STABILITY

CUSHION



SUPPORT

FLEXIBLITY

STABILITY

F R E Q U E N C Y

DATA-DRIVEN METHODOLOGY FOR PERFORMANCE FOOTWEAR