Reverse architecting conventional footwear. Towards an A3 Architecture Overview that supports development of alternative footwear architectures.

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Abstract. The architecture of contemporary footwear is the result of a long history of footwear development. In this history, part of the argumentation behind the architecture has been lost, causing footwear developers to make decisions based on habits and badly underpinned assumptions. New insights on the negative influence of most conventional footwear on human (foot) health and the design freedom that arises from modern manufacturing techniques, create the urge to reconsider the common way of developing. By reverse architecting conventional footwear, this paper derives an A3 Architecture Overview of conventional footwear. In the future this overview should provide a tool for enabling product evolution towards healthy footwear, by allowing developers to consciously and purposefully deviate from ‘the standard architecture’ while taking into account the consequences of design decisions they make. The approach that is described in this paper is also applicable to the development of architecture overviews for other product families.

Background

In the Western world, footwear is so commonly used that it has become inherently part of our being in the world. It is via footwear that users are in almost constant contact with different types of environments. While serving as an extension of the human body, the earliest footwear seems to merely have had a protective function (Stewart 1972; Swallow 1987). Nowadays, footwear developers have succeeded to include many more functionalities. These functionalities, however, often partly – or even entirely – show a mismatch with the functions of the human body. Footwear developers mistakenly see the foot as an inflexible lever which is fragile and thus needs to be supported and packaged (Robbins & Hanna 1987). Instead of preserving healthy feet, this can have many adverse short- and long-term effects; the natural shape of the foot can be deformed, loading in the joints can be changed, plantar sensation can be reduced, the foot-strike pattern can be altered, the foot-strength and elastic energy storage can be reduced, evaporation of perspiration can be reduced and the maturation of the foot can be hampered, ultimately resulting in pain, reduced mobility and high societal costs (Buldt & Menz 2018; D’Aoust et al. 2009; Frey 2000; Lieberman et al. 2010; Perl, Daoud & Lieberman 2012; Rose et al. 2011).

Considering those insights, together with the newly obtained design freedom that results from the emergence of modern manufacturing techniques, the common way of developing footwear might unintentionally inhibit footwear developers to use the full potential of knowledge and technology at hand. To support design efforts towards creating product evolutions, first the architecture of present
footwear has to be documented. Reverse architecting using the so-called A3 Architecture Overview (A3AO) – containing a physical view (showing design decisions), a functional view (providing design argumentation) and a quantification view (providing key-drivers) – can be employed for that purpose (Borches 2010). The aim of this paper is, therefore, to derive an A3AO for footwear development by reverse architecting conventional footwear. In the future, this A3AO should provide a tool for enabling product evolution towards healthy footwear by allowing footwear developers to consciously and purposefully deviate from ‘the standard architecture’, while constantly allowing them to consider the consequences of the design decisions they make.

Methods

In reverse architecting, usually three different process phases, being Information Extraction, Abstraction, and Presentation are executed in an iterative manner (Müller, Wong & Tilley 1995). In reverse architecting conventional footwear, also these three phases are executed. The information extraction phase is executed by analyzing descriptions - that are used by academics as well as in industry - in relation to the parts of non-athletic (men’s and women’s) footwear as well as athletic footwear. The phase results in an overview of the components of different types of footwear as well as the functions thereof. By comparing the components and functions and by boiling down to the basic elements during the abstraction phase, both a physical description and a functional description is made that is common for most conventional types of footwear. Together with a shortlist of the key-drivers (Bonnema 2008; Heemels et al. 2006) that represent the high-level requirements of specific footwear (quantification view), these provide the views to be presented in an A3 Architecture overview for conventional footwear (presentation phase).

The physical and functional descriptions are evaluated by analyzing a number of random pictures showing footwear anatomy and by iteratively comparing the represented parts / terms with the results until then. The parts and functions that are still lacking can subsequently be included in the final physical and functional view on the A3 Architecture Overview (see Figure 1).

Figure 1. Schematic representation of research flow.
Physical View

To create a better understanding of the architecture(s) of conventional footwear, first an overview (table) has been made of the terminology related to the functional parts of conventional footwear (Appendix A). The appendix is organized per sub-assembly of the shoe (shaded rows). The parts of each assembly are organized in individual rows; sub-parts are indented. As conventional footwear comes in many different appearances, dependent on the purposes it is used for, the overview makes a distinction between non-athletic footwear (source columns 1 and 3) and athletic footwear (source columns 2 and 4); those types of footwear show a relatively large difference in the materials, components and manufacturing techniques that are used (McPoil Jr 1988). Where athletic footwear is largely the same for both men and women, non-athletic footwear shows some differences in this respect. These differences, however, mainly concern the geometry of parts that are used. Therefore, the overview does not have to make a specific distinction in this respect.

The sources that have been used to create the overview were selected to vary both in academic (source columns 1 and 2) and industrial (source columns 3 and 4) nature. This was done to investigate whether there is any difference in the use of terminology between the two. The distinction is also visible in the columns of the table. An initial number of resources was selected to start with ((Blazer, Jamrog & Schnack 2018; Luximon & Khandual 2018; McPoil Jr 1988; McPoil 2000) that represent the academic viewpoint, and (C&E_Fashions 2019; Motawi 2015) that represent the industry viewpoint). From the sources, quotations were collected in which terminology related to the functional parts of footwear was used. This terminology was underlined, and the citations were structured based on these terms (rows in table Appendix A). When different terms were considered to address a similar part, these terms are presented in the same row. It is important to note that this does not imply that the terms are full synonyms. In the attempt to complement the overview, a number of additional resources (BootMoodFoot 2019; Davis 2014; Kippen 2009; Kurcina 2009; Muzquiz 2017; Pelizzari 2013; Ramsey et al. 2019; Runner'sWorld 2009; ShoeGuide 2019; Wong & Luximon 2013) was added.

Eventually, a number of fields in the table (in appendix A) remained empty. These empty fields can be explained by the different architectures of non-athletic and athletic footwear as well as the lacking need for academics to address the terminology related to specific (sub)parts of an assembly.

The terminology was eventually used to create the physical description of conventional (non-athletic and athletic) footwear presented in Figure 2. When multiple terms were mentioned in the same row of the table, a general term was selected to be used for the physical description. An additional description of a non-athletic women’s pump was added to show the large overlap in terminology with non-athletic men’s footwear while having a complete different appearance; the represented shoe style (‘pump’) merely consists of fewer parts and has only one term (platform) that is specific for this type of shoe. It should be noted that Figure 2 gives a simplified representation of all parts (and corresponding terminology); for a full overview of all terminology, Appendix A should be referred to.

In each quotation presented in the overview in Appendix A, a possible description of the function of the part at hand was made italic. The italic descriptions of functions were used to derive the functions of conventional footwear in the next section.

Functional View

To derive the functions that are general for most types of conventional footwear, the terminology from the physical view was used and the italic function descriptions (see Appendix A) were listed together with these terms. In making Table 1, the function descriptions were rephrased by using terms from the ‘Functional basis reconciled function set’ defined by the National Institute of Standards and Technology, NIST (Hirtz et al. 2002). This was done with the aim to boil down to a limited and uncluttered set of different functions per part, that adheres to accepted terminology.
Figure 2. Physical View: Men’s and women’s non-athletic and athletic footwear
| Component            | Function(s)                                                                 |
|----------------------|-----------------------------------------------------------------------------|
| **Upper**            |                                                                             |
| Upper                | - Enclose top of foot (Khan, Jacobs & Ashbaugh 2013; Runner'sWorld 2009; ShoeGuide 2019) |
|                      | - Enclose sides of the foot (Khan, Jacobs & Ashbaugh 2013; Runner'sWorld 2009; ShoeGuide 2019) |
|                      | - Regulate temperature (BootMoodFoot 2019; Khan, Jacobs & Ashbaugh 2013; Runner'sWorld 2009) |
|                      | - Limit wear (shoe) (Khan, Jacobs & Ashbaugh 2013)                           |
|                      | - Protect foot against moisture (Khan, Jacobs & Ashbaugh 2013)               |
|                      | - Condition cleanliness (Khan, Jacobs & Ashbaugh 2013)                       |
|                      | - Secure to foot (Runner'sWorld 2009)                                       |
|                      | - Protect foot (BootMoodFoot 2019)                                          |
| Vamp                 | - Enclose forefoot (McPoil Jr 1988)                                          |
|                      | - Feel comfortable (to the skin) (McPoil Jr 1988)                            |
|                      | - Limit wear (shoe) (BootMoodFoot 2019)                                     |
|                      | - Regulate/maintain temperature (Motawi 2015)                                |
| Toe-box/toe cap      | - Maintain shape (shoe) (Blazer, Jamrog & Schnack 2018; Luximon & Khandual 2018) |
|                      | - Enclose toes (McPoil Jr 1988)                                              |
|                      | - Display personality (McPoil Jr 1988; Motawi 2015)                          |
|                      | - Protect the foot (ShoeGuide 2019)                                          |
|                      | - Limit wear (shoe) (Muzquiz 2017; ShoeGuide 2019)                           |
| Mudguard             | - Limit wear (shoe) (Kurcina 2017)                                           |
| Throat line          | - Secure to the foot / Detach from the foot (Kippen 2009)                    |
|                      | - Guide foot into shoe (Kippen 2009)                                         |
| Tongue               | - Distribute pressure (Khan, Jacobs & Ashbaugh 2013; Motawi 2015; Muzquiz 2017) |
|                      | - Limit dirt entry (BootMoodFoot 2019)                                       |
| Eye-stay             | - Locate eyelets/webbings for lacing (shoe) (Motawi 2015)                   |
| Laces                | - Secure to the foot / Detach from the foot (BootMoodFoot 2019; McPoil 2000) |
|                      | - Adjust fit (shoe) (BootMoodFoot 2019)                                      |
| Quarter/shaft        | - Enclose back of the foot (BootMoodFoot 2019)                               |
|                      | - Enclose ankles, calf, and leg (BootMoodFoot 2019)                          |
| Overlay/saddle       | - Maintain shape (shoe) (Runner'sWorld 2009)                                |
|                      | - Secure midfoot (Runner'sWorld 2009)                                       |
|                      | - Support arch (Runner'sWorld 2009)                                          |
| Heel counter         | - Stabilize hindfoot / secure heel (Blazer, Jamrog & Schnack 2018; McPoil Jr 1988) |
|                      | - Maintain shape (shoe) (BootMoodFoot 2019; Luximon & Khandual 2018; ShoeGuide 2019) |
|                      | - Stabilize foot (Muzquiz 2017)                                              |
|                      | - Constrain motion (Kippen 2009)                                             |
| Topline/collar       | - Limit dirt entry (McPoil Jr 1988; Runner'sWorld 2009)                     |
|                      | - Feel comfortable (to the skin) (Khan, Jacobs & Ashbaugh 2013)              |
| Eyelets              | - Guide laces (shoe) (Muzquiz 2017)                                          |
| Linings              | - Feel comfortable (to the skin) (Kippen 2009; ShoeGuide 2019)              |
|                      | - Limit wear (shoe) (Kippen 2009; ShoeGuide 2019)                           |
| Welt/feather         | - Join parts (shoe) (BootMoodFoot 2019; Muzquiz 2017; ShoeGuide 2019)        |
| Component       | Function(s)                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| **Lower**       |                                                                             |
| Outsole         | - Protect foot (McPoil Jr 1988)                                             |
|                 | - Protect foot against frictional forces (Blazer, Jamrog & Schnack 2018)   |
|                 | - Protect foot against moisture (Kippen 2009)                               |
|                 | - Transmit force (Blazer, Jamrog & Schnack 2018; Khan, Jacobs & Ashbaugh 2013; Kippen 2009; Motawi 2015) |
|                 | - Reduce shocks (Khan, Jacobs & Ashbaugh 2013; Runner'sWorld 2009)          |
|                 | - Support foot (Runner'sWorld 2009)                                         |
|                 | - Limit wear (shoe) (Khan, Jacobs & Ashbaugh 2013; Kippen 2009)             |
|                 | - Limit torsion (shoe) (Khan, Jacobs & Ashbaugh 2013)                       |
|                 | - Allow flexion (shoe) (Khan, Jacobs & Ashbaugh 2013)                       |
| Tread           | - Transmit force (McPoil Jr 1988; Runner'sWorld 2009)                       |
|                 | - Reduce shocks (McPoil Jr 1988; Runner'sWorld 2009)                        |
| Midsole         | - Protect foot (Davis 2014)                                                 |
|                 | - Reduce shocks (C&E_Fashions 2019; Davis 2014; Khan, Jacobs & Ashbaugh 2013; Motawi 2015) |
|                 | - Stabilize foot (Khan, Jacobs & Ashbaugh 2013)                             |
|                 | - Enclose foot (Motawi 2015)                                                |
|                 | - Feel comfortable (Motawi 2015)                                            |
| Midsole wedge   | - Increase angle (Khan, Jacobs & Ashbaugh 2013; Wong & Luximon 2013)        |
|                 | - Reduce shocks (Khan, Jacobs & Ashbaugh 2013; McPoil Jr 1988)              |
|                 | - Stabilize foot (Khan, Jacobs & Ashbaugh 2013; McPoil Jr 1988)             |
| Insole (board)/foodbed | - Provide template (shoe-fitting) (Blazer, Jamrog & Schnack 2018)             |
|                 | - Maintain shape (shoe) (Motawi 2015)                                       |
|                 | - Reduce shocks (Motawi 2015)                                               |
| Shank/footbridge| - Limit torsion (shoe) (McPoil Jr 1988; Runner'sWorld 2009)                 |
|                 | - Control flexion (shoe) (McPoil Jr 1988; Runner'sWorld 2009)              |
|                 | - Limit flexion zone (shoe) (McPoil Jr 1988)                                |
|                 | - Stabilize foot (Ramsey et al. 2019)                                       |
|                 | - Limit wear (shoe) (C&E_Fashions 2019)                                     |
|                 | - Support foot (C&E_Fashions 2019; Runner'sWorld 2009)                      |
|                 | - Constrain motion (Kippen 2009)                                            |
| Heel            | - Display personality (McPoil Jr 1988)                                     |
|                 | - Reduce shocks (C&E_Fashions 2019)                                         |
|                 | - Increase height / provide heel lift (ShoeGuide 2019)                      |
| Top piece       | - Limit wear (shoe) (Muzquiz 2017)                                          |
| Heel seat       | - Enclose heel (upper shoe) (ShoeGuide 2019)                                |
| Platform        | - Increase height (Wong & Luximon 2013)                                     |
| **Assembly**    |                                                                             |
| Stitching/glue/nails | - Join parts (shoe) (see Evaluation section)                               |
Eventually a general list of possible footwear functions was derived by combining the functions from Table 1 and by removing the duplicates (see Table 2).

Table 2: Functional View: Functions of conventional footwear

| Functions of conventional footwear                                                                 |                              |
|---------------------------------------------------------------------------------------------------|-------------------------------|
| - Secure to foot (secure mid foot, secure heel, …)                                               | - Adjust fit (shoe)           |
| - Detach from the foot                                                                            | - Maintain shape (shoe)       |
| - Protect foot/body (frictional forces, moisture,…                                               | - Support foot (arch, …)      |
| - Enclose foot (optional: ankles, calf and leg)                                                    | - Stabilize foot/body         |
| - Guide foot into shoe                                                                             | - Constrain motion           |
| - Transmit force (foot to ground)                                                                  | - Reduce shocks              |
| - Regulate temperature (foot)                                                                      | - Increase height            |
| - Display personality                                                                            | - Increase angle             |
| - Distribute pressure                                                                            | - Limit torsion (shoe)       |
| - Limit dirt entry                                                                                | - Control flexion / limit flexion zone (shoe) |
| - Feel comfortable (to the skin) (shoe)                                                            | - Locate eyelets / webbings for lacing (shoe) |
| - Limit wear (shoe)                                                                               | - Guide laces (shoe)          |
| - Condition cleanliness (shoe)                                                                     | - Join parts (shoe)           |
| - Provide template (shoe-fitting)                                                                 |                              |

Quantification View

To define the quantification view, again the three reverse architecting phases were executed (Müller, Wong & Tilley 1995). As the quantification view was not really focused on in this phase of the research, this was done in a quick manner. First, information was extracted by reviewing literature on shoe selection criteria (Enke, Laskowski & Thomsen 2009; Goonetilleke & Luximon 2001; Miller 1976). The following shoe-selection criteria were mentioned: Arch type, Shoe design, Color, Appearance, Cost, Brand, Comfort, Fit (Enke, Laskowski & Thomsen 2009); Fashion, Price, Comfort, Fit, Performance, Durability (Miller 1976); Size, Shape, Flexibility, Style, Weight, Inside shoe climate, Materials, Tread, Cushioning (Goonetilleke & Luximon 2001). It is interesting that ‘healthfulness’ is not mentioned by these sources as a selection criteria. Recent insights into the negative influence of most conventional footwear on human (foot) health (Buldt & Menz 2018; D’Août et al. 2009; Frey 2000; Lieberman et al. 2010; Perl, Daoud & Lieberman 2012; Rose et al. 2011), however, might cause healthfulness to become a key-driver. Therefore, this term was also included in the overall list.
Abstraction and merging of the criteria eventually lead to the following shortlist of key-drivers that, for now, establish the quantification view:

- Price
- Comfort
- Appearance
- Durability
- Performance
- *Healthfulness*

Together, these key-drivers represent the interests of the end user. We need to expand and update the set to also include interests of other stakeholders, like the producer and store operator.

**Evaluation**

To evaluate both the physical and functional overviews that were established, first a number of pictures of footwear anatomy was randomly collected via Pinterest (see Figure 3) and the used terminology was compared with the overviews in Appendix A and Figure 3.

The comparison lead to the following list of parts that were not yet described:

- Toe burst panel; A part that is used to reduce wear to the upper caused by the toes/nails. The function of the toe burst panel can also be fulfilled by the toe-box/toe cap or mudguard.
- Mustache; A part with a mustache shaped pattern, added on the outside of the quarter, at the back, above the counter. The function of the mustache is similar to that of the counter and is used in classic sneakers.
- Lace-tip: The strengthened tip(s) of the laces. The tips allowing for easy pushing/pulling the laces through the eyelets.
- Bumper: The rubber strip attached to the forward facing part of a sneaker sole. The function is to decrease wear to the front of the sole.
- Foxing: The term foxing is used for almost any additional piece of leather/fabric attached to the outside of the vamp/quarter to add additional strength or to reduce wear, similar to an ‘overlay’.
- Back-strap/rear-strap: The loop that is attached to the back of the quarter, sometimes as an extension of the back-stay. It can be used for easy shoe-access and prevents the back of the quarter from being suppressed.
- Back-tab: A different word for Achilles tendon protector.
- Air (or gel) Unit: An air (or gel) chamber added to the midsole for additional suspension.
- Insertor support / support insert: An insert in the midsole for additional support / to constrain motion.
- Rearfoot stabilizer: a support insert in the heel part of the midsole, to stabilize the rearfoot.
- Stitching / glue / nails: The materials used to assemble all different parts together.
As most of the parts are used in relation to specific types of footwear only, the terms were added to Appendix A (dashed underline), but like in the first iteration without including them in the physical view (Figure 2) and functional view (Table 2) respectively. The materials used to assemble all different footwear parts together like glue, nails, stitching, however, are essential for any type of shoe. Therefore, these were added to table 1 & 2 and the final presentation in Figure 4 (A3AO overview side) and Figure 5 (A3AO summary side) (for the full size version, see Appendix B: The A3AO of Conventional Footwear).
The established A3 Architecture overview shows the result of the decomposition of conventional footwear in relevant architectural aspects. These aspects form a solid basis to enable future footwear development and support the well thought-through development of new architectures. The overviews provide stakeholders of footwear development with means to easily discuss alternative requirements and/or key-parameters, alternative trade-offs, and to enable them to anticipate the impact thereof. In particular the so far undervalued healthiness of footwear can be improved using this architecture description, without compromising existing requirements.

Future work

The A3AO of Conventional Footwear can only prove its success when it is being used by footwear developers and has the desired results. As the A3AO is developed in the context of a bigger project on tools and guidelines for the development of healthy footwear, this will be the first area of application. In relation to this project, it will be complemented with technical knowledge on e.g. materials and production techniques and in-depth understanding of different stakeholder needs (shoe users, producers, shops, etc.). The use, however, is not limited to this project. It is well imaginable that it can also form a good basis for evolutionary developments in e.g. safety shoes. Moreover, the approach that was used in this paper can be applied to develop architecture overviews for other product families as well.

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Biography

**Winnie Dankers** received her Master’s degree in Industrial Design Engineering from the University of Twente (2009) and continued working as an assistant professor at the Laboratory of Design, Production and Management of the faculty of Engineering Technology. She gained teaching experience in IDE in general, scientific & technical writing and visual communication and her research focused on Information Management. After becoming a mother and shortly focusing on lecturing only, she developed an interest in the field of footwear development. She now researches how footwear developers can be supported in developing footwear that better matches the natural functions of the body.

**(Gerrit) Maarten Bonnema** is an associate professor in systems engineering and multidisciplinary design at the Department of Design, Production and Management of the Faculty of Engineering Technology at the University of Twente. He has worked as a Systems Engineer at ASML. His research aims at supporting system designers, conceptual design and mechatronic design by improving multidisciplinary communication, and systems thinking. An overview of publications can be found at [http://www.tinyurl.com/MaBoPubs](http://www.tinyurl.com/MaBoPubs). Two main application areas are high-tech systems and electric mobility. He has a broad teaching expertise spanning design in general, industrial design, and systems engineering.
**APPENDIX A: TERMINOLOGY RELATED TO THE FUNCTIONAL PARTS OF FOOTWEAR**

Note: The terms that have a dashed underline are added after evaluation of the table.

| Terminology | Acronym & Alternate | Acronym & Alternate | Acronym & Alternate | Acronym & Alternate | Acronym & Alternate |
|-------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Midsole     | -                   | -                   | -                   | -                   | -                   |
| Outsole     | -                   | -                   | -                   | -                   | -                   |
| Shank       | -                   | -                   | -                   | -                   | -                   |
| Footbridge  | -                   | -                   | -                   | -                   | -                   |
| Insole      | -                   | -                   | -                   | -                   | -                   |
| Heel seat   | -                   | -                   | -                   | -                   | -                   |
| Lining      | -                   | -                   | -                   | -                   | -                   |
| Midsole wedge | -               | -                   | -                   | -                   | -                   |
| Heel cup    | -                   | -                   | -                   | -                   | -                   |
| Shank piece | -                   | -                   | -                   | -                   | -                   |
| Heel bridge | -                   | -                   | -                   | -                   | -                   |
| Shank    | -                   | -                   | -                   | -                   | -                   |
| Shank piece | -               | -                   | -                   | -                   | -                   |
| Heel cup | -                   | -                   | -                   | -                   | -                   |
| Shank    | -                   | -                   | -                   | -                   | -                   |
| Shank piece | -               | -                   | -                   | -                   | -                   |
| Heel cup | -                   | -                   | -                   | -                   | -                   |

**Note:** The terms that have a dashed underline are added after evaluation of the table.
**Nomenclature**

**Academic & Non-Athletic**

- The vamp is the top part of the shoe that covers the rear edge of the foot.
- The quarter consists of an inside and outside section of the shoe.
- The lacing systems in sneakers let you adjust the fit to your liking.
- The toe box refers to the area that encases the toes.
- The central part of the vamp just proximal to the toe is referred to as the toe area.
- The central part of the vamp just distal to the toe is referred to as the heel area.
- The part around the lace opening (either eyelet or EYELET) and the front of the vamp is referred to as the face area.
- The part around the eyelets and the front of the vamp is referred to as the face area.

**Vamp**

- The vamp is the top part of the shoe that covers the rear edge of the foot.
- The central part of the vamp just proximal to the toe is referred to as the toe area.
- The central part of the vamp just distal to the toe is referred to as the heel area.
- The part around the lace opening (either eyelet or EYELET) and the front of the vamp is referred to as the face area.
- The part around the eyelets and the front of the vamp is referred to as the face area.

**Quarter**

- The quarter is the part of the shoe between the toe and the heel.
- The part between the toe and the heel that extends to the throat of the vamp is referred to as the quarter.
- The part of the shoe that covers the toes is referred to as the toe cap.
- The part of the shoe that covers the toes is referred to as the toe cap.

**Lacing**

- The lacing system in sneakers is a key feature that allows for easy pushing/pulling the laces through the eyelets.
- The lacing system is often made of nylon or leather and can be held by a tab or a section of leather or plastic.

**Eyelets**

- The eyelets are the openings in the shoe where the laces are inserted.
- The eyelets are often made of metal or plastic and can be inserted into the shoe to allow for lacing.

**Tongue**

- The tongue is the part of the shoe that is connected to the vamp and is used to support the foot.
- The tongue helps to provide cushioning and support for the foot.

**Eye stay**

- The eye stay is a piece of leather or other material that is sewn into the shoe to provide support for the eyelets.
- The eye stay is often made of a single layer of leather or an inch of PU foam.

**Lining**

- The lining is the inner part of the shoe that is in direct contact with the foot.
- The lining is often made of a cotton or synthetic fabric.

**Sole**

- The sole is the bottom part of the shoe that is in contact with the ground.
- The sole is often made of rubber or synthetic materials.

**Upper**

- The upper is the main part of the shoe that is above the sole and is made of leather or synthetic materials.
- The upper is often made of a combination of leather and synthetic materials.

**Midsole**

- The midsole is the cushioning layer between the sole and the upper.
- The midsole is often made of foam or other cushioning materials.

**Outsole**

- The outsole is the outer layer of the shoe that is in direct contact with the ground.
- The outsole is often made of rubber or other durable materials.

**Shaft**

- The shaft is the part of the shoe that covers the ankle.
- The shaft is often made of leather or synthetic materials.

**Quarter**

- The quarter is the part of the shoe that covers the ankle.
- The quarter is often made of leather or synthetic materials.

**Laces**

- The laces are the strings that are used to tie the shoe.
- The laces are often made of nylon or polyester.

**Eyelets**

- The eyelets are the openings in the shoe where the laces are inserted.
- The eyelets are often made of metal or plastic and can be inserted into the shoe to allow for lacing.

**Tongue**

- The tongue is the part of the shoe that is connected to the vamp and is used to support the foot.
- The tongue helps to provide cushioning and support for the foot.

**Eye stay**

- The eye stay is a piece of leather or other material that is sewn into the shoe to provide support for the eyelets.
- The eye stay is often made of a single layer of leather or an inch of PU foam.
**Shoe Terminology**

- **Sole**: The bottom part of the shoe that makes contact with the ground.
- **Welt**: A narrow strip of leather around the edge of the sole and insole.
- **Shank**: A piece of leather or other material between the outsole and the insole that provides support.
- **Quartering**: The insole segment between the sole and the vamp.
- **Tongue**: A piece of leather that is inserted into the shoe to provide cushioning and support.
- **Eyelets**: Circular openings in the shoe upper for lacing.
- **Hook & Loop® Tape**: A fastening system that uses a hook and loop material for closure.
- **Speed Eyelets**: Quick-release eyelets for easy lacing.
- **Back-strap**: The strap that connects the heel counter to the instep.
- **Rear-strap**: A strap that runs behind the heel counter.
- **Collar**: The part of the shoe upper that surrounds the ankle.
- **Heel counter**: A support structure that provides stability and prevents foot rolling.
- **Rearfoot stabilizer**: A device that helps prevent foot rolling.
- **Mid-foot stabilization**: A support structure that stabilizes the mid-foot.
- **Tendon**: A fibrous cord that connects muscle to bone.
- **Achilles tendon**: The largest tendon in the body, located behind the ankle and lower leg.
- **Tendon notch**: The notch in the bone where the Achilles tendon attaches.
- **Ankle**: The joint between the leg and the foot.
- **Bunion**: A bony growth on the side of the big toe.
- **Tarsal coalition**: A congenital abnormality where one or more bones of the ankle are fused together.
- **Tarsal tunnel syndrome**: A condition where the nerves and blood vessels in the instep are compressed.
- **Nerve entrapment**: A condition where a nerve is compressed in a tight space, causing pain and numbness.
- **Nerve block**: An anesthetic technique that blocks pain signals from reaching the brain.
- **Surgical treatment**: A medical procedure to correct a structural malformation or injury.

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APPENDIX B:
THE A3AO OF CONVENTIONAL FOOTWEAR
CONVENTIONAL FOOTWEAR
(SUMMARY)

INTRODUCTION
The architecture of nowadays conventional footwear is the result of a long history of footwear design, manufacturing, and marketing. In this long history, part of the architectural work behind the architecture has been lost, causing footwear developers to make decisions based on beliefs, habits and badly underpinned assumptions.

With new insights on the negative influence of most conventional footwear on human (foot) health in combination with the design freedom created by modern manufacturing techniques, the common way of developing might impede footwear developers in using the full potential of knowledge and technology at hand.

To allow footwear developers to consciously and intentionally deviate from the conventional architecture and work towards product evolutions, this A3 architecture overview shows the basics of conventional footwear. By making footwear developers conscious about the design decisions they make in relation to ‘the standard’ functions, key-parameters, physical appearances, they can purposefully decide to deviate from this while overlooking the consequences, independent of the type of evolution they strive for.

METHODS
The views in this A3AO were created by using the following method (see also [2]):

- Naming the views in this A3AO were created by using the following method (see also [2]):
- **FUNCTIONAL VIEW**
  - The functional view on the other side of this sheet shows a list of the functions that can be fulfilled by conventional footwear. Information for this functional view was collected by analysing descriptions - that are used by academics as well as in industry - in relation to the parts of non-athletic (men’s and women’s) footwear as well as athletic footwear. The analysis resulted in an overview of the components of different types of footwear as well as the functions thereof (see Appendix A).
  - The overview was checked by comparing with a total number of 18 pictures of footwear anatomy from which the terminology was compared and based on which a few additions were made.
  - From the updated overview the function descriptions were rephrased by using terms from the ‘Functional basis reconciled function set’ defined by the National Institute of Standards and Technology, NIST [1]. This was done with the aim to boil down to a limited and uncluttered set of different functions per part, that adheres to accepted terminology (see Table 1 in [2]).
  - Eventually a general list of possible footwear functions was derived by combining the functions from Table 1 in [2] and by removing the duplicates. The list is represented in the FUNCTIONAL VIEW on the other side of this sheet.

- **PHYSICAL VIEW**
  - The terminology that is listed in Appendix A was eventually used to create the physical description of conventional (non-athletic and athletic) footwear presented the physical view. When multiple terms were mentioned in the same row of the table in Appendix A, a general term was selected to be used for the physical description.
  - An additional description of a non-athletic women’s pump was added to show the large overlap in terminology with non-athletic men’s footwear while having a complete different appearance; the represented shoe style (‘pump’) merely consists of less parts and has only one term (platform) that is specific for this type of shoe.
  - It should be noted that the physical view (see PHYSICAL VIEW on the other side of this sheet) merely shows three different types of shoes; many more different types of shoes exist, with different appearances. The terminology of parts, however, largely remains the same for all these different types. For a more complete list of similar terms for parts, the use of Appendix A should be consulted.

- **KEY-PARAMETERS & REQUIREMENTS**
  - Footwear users can have many different criteria for selecting a specific (type of) shoe. Review of literature on shoe selection criteria lead to a list of (sometimes overlapping) criteria that could eventually be summarised in a list of 6 main criteria.
  - For designers, these criteria are the key-drivers that should be reckoned during design. A suitable balance should be found between:

**PRICE**
- comfort
- appearance
- durability
- performance
- healthfulness

Together these criteria establish the quantification view.

**REFERENCES**

- **Experts**
  - Winnie Dankers (w.dankers@utwente.nl)
  - Maarten Bonnema (g.m.bonnema@utwente.nl)

- **Appendices**
  - Appendix A: Terminology related to the functional parts of footwear

- **Literature**
  - [1] Hirtz, J., et al., A functional basis for engineering design: reconciling and evolving previous efforts. Research in Engineering Design, 2002. 13(2): p. 65-82
  - [2] Dankers, W.; Bonnema, G.M. Reverse Architecting Conventional footwear, T.B.P.

**TOP-LEVEL VIEW**
In the Western world, footwear is so commonly used that it has become inherently part of our being in the world. It is via footwear that users are in almost constant contact with different types of environments. While serving as an extension of the human body, the earliest footwear has had both a protective and a symbolic function. Nowadays, footwear developers have succeeded to include many more functions, partly - or sometimes entirely - taking over functions from the human body (see functional view).

In its basis, conventional footwear consists of two major sub-assemblies: the so-called ‘lower’ and ‘upper’. During manufacturing, the upper is moulded around a shoe last (a solid model of the foot) and attached to the lower; the two become inseparable.

The upper has an opening that allows the last to be removed and the foot to enter during use. A closing mechanism secures the last to the foot to enter during use. The upper has an opening that allows the last to be removed and the foot to enter during use. A closing mechanism secures the last to the foot to enter during use.

The upper is moulded around a shoe last (a solid model of the foot) and attached to the lower; the upper is attached to the lower.

Eventually a general list of possible footwear functions was derived by combining the functions from Table 1 in [2] and by removing the duplicates. The list is represented in the FUNCTIONAL VIEW on the other side of this sheet.

- **INFORMATION EXTRACTION PHASE**
  - Result:
    - overview of components of different types of footwear
  - Result:
    - overview of components of different types of footwear
  - Result:
    - overview of components of different types of footwear

- **ABSTRACTION PHASE**
  - Result:
    - abstract and merging of criteria
  - Result:
    - abstract and merging of criteria
  - Result:
    - abstract and merging of criteria

- **PRESENTATION PHASE**
  - Result:
    - physical view in A3AO
  - Result:
    - physical view in A3AO
  - Result:
    - physical view in A3AO

**KNOWLEDGE ISSUES**
* Footwear developers have - for a long time - seen the foot as a fragile body part that needs to be protected, supported and packed. Today, more and more research illustrates the health benefits that are gained by allowing our feet to function in their most natural way. The key-parameter ‘healthfulness’ seems to become increasingly relevant, and as a result, some of the functions that are currently fulfilled by footwear might need to be carefully reconsidered and sometimes even be re-allocated to the human body.

* Due to technology advances and modern manufacturing techniques, new possibilities come within range that can allow footwear developers to reconsider:
  - shoe customisation possibilities,
  - the use of materials,
  - the use of solid and inflexible lasts,
  - the distinction between upper & lower,
  - etc.

**ROADMAP**
In future footwear development, three different scenarios can already be foreseen:

- **Short term**
  - In a first scenario, footwear still has a conventional product architecture and is being produced by using conventional manufacturing techniques and materials.
  - The key-drivers, however, might be quantified differently due to changing trends (e.g. in foot health), leading to changes in the functions of footwear.

- **Mid term**
  - In a second scenario, footwear with a conventional product architecture can be produced by using modern and unconventional manufacturing techniques or materials, e.g. allowing for affordable (mass) customisation. Footwear users are able to customise their footwear based on price / comfort / appearance / durability / performance and healthfulness demands.

- **Long term**
  - In a third and most futuristic scenario the second scenario is supplemented with the possibility to create footwear that has a completely different product architecture.