Modeclix. The additively manufactured adaptable textile.

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Modeclix represents an innovation in the use of 3D Printing to produce a flexible material that is infinitely configurable to meet a range of different demands. The rationale behind the project is to create a fluid 3D Printed textile which could be used to make, in the first instance, clothing.

Modeclix meets current sustainable manufacturing practices, procedures, and definitions through employing the principles of the circular economy. The material can be manufactured on demand and scaled to meet economic requirements. Through repair, re-use and re-purposing the materials life cycle can be extended and adapted to meet changing circumstances. By combining localised manufacture with hand assembly and finishing processes the material encourages social interaction and community growth.

Modeclix is replicable, scalable, sustainable and sets a benchmark for innovation. Modeclix represents a proposition that innovatively changes how both industry and the customer considers materials. The size of the material sheet can be scaled as required and any number of Additive Manufacturing facilities around the world can manufacture to meet demand. The manufactured materials life span is extended through the option for it to be re-configured and re-purposed at any time, thereby ensuring a sustainable future for the material while at the same time encouraging customers to adjust their understanding and approach to how they consume products and services.

Modeclix offers solutions in energy and resources efficiency based on the current status. Through the modularity of the design, energy and resource efficiencies come into play with the materials re-use. As the configuration of the material into useful products is currently a hand process, this encourages a return to local craft based practices which are both scalable and sustainable. Regarding energy and emissions comparisons between AM and conventional textile manufacturing, Modeclix products can be additively manufactured complete and fully assembled once patterns have been devised. This would then offer a reduction in the number of processes and address energy and emissions concerns. For example current textile production requires that yarn is woven into a usable form that then requires cutting and assembly resulting in both an increase in procedures and the potential for waste. Modeclix products could be manufactured fully fashioned using only the material needed to complete the final product. Although Modeclix does not address the wider emissions issues connected with nylon production it does present a use of the raw material which shows how design can be used to create a modular system that can begin to address these issues in the long term. The modularity of Modeclix enables an ecosystem that can efficiently re-use and or re-purpose the material across a variety of different products and services. As the majority of the construction processes are initially undertaken by hand, emission and energy concerns are naturally reduced.

Modeclix demonstrates cost-effectiveness, break-even analyses and life-cycle assessments, and offers a critical comparison to conventional manufacturing practices with clear data to support the same. Within the context of high value manufacturing and bespoke products, Modeclix presents numerous cost effective methods for delivering customised goods and services. The modular linked structure is also workable at different scales and across different product categories, for example, jewellery, bags, garments or interior screening, satisfying a broad cross section of price points and markets. Additional value can be created through the reuse, repair, enhancement or adjustment possibilities that extend the products life cycle enabling it to adapt to future propositions.

Modeclix provides a sustainable method for using resources, through the modelling, design and manufactured demonstration of a final product. The design of Modeclix achieves excellent efficiencies and economies in both the density of build achievable through the AM process and subsequent ease of post processing. Assembly into a range of different product types either by hand or through fully fashioned manufacture via the AM process also contributes to sustainable manufacturing and resource efficiencies particularly when considering the customisation capabilities of the material.

Modeclix presents a new business model fitting into the criteria of environmental sustainability and energy efficiency through its characteristics which encourage the re-use, repair and re-purposing of the material. Buy back, deposit, service design and licensing business models are currently being explored to ensure the future of the materials value is maintained through its adaptability across a range of products and industries.

Methodology.

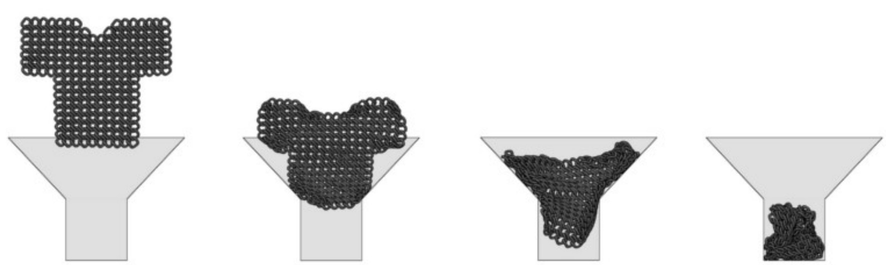
Creating flexible materials using Additive Manufacturing (AM) continues to be a challenge. Consideration has been given to, and includes the variety of AM techniques and materials available, the size of the build chamber of the AM machine, post processing of the final part(s), and successfully being able to utilise CAD to translate ideas which take advantage of the increase in design freedoms offered by AM. A number of significant obstacles needed addressing and resolving. These included how the finished, printed flexible material could be used and applied to wearable garments. Consideration was also given to all these issues as part of this ongoing research project, and provided the constraints within which we created our solution; Modeclix.

Modeclix, a flexible 3D printed textile, addresses the challenges above through combining both traditional construction techniques with advanced manufacturing technologies. The rationale behind the project is to create a fluid textile which could be used to make clothing. Our initial challenge was to overcome the build size restrictions of the AM machines in order to create a full-sized garment.

The AM machine used, in this case a Plastic Laser Sintering System, the **Formiga P 110** from **EOS**, has a total build volume of 200×250×330mm and was selected because of the characteristics of the material; white polyamide PA12-powder (Nylon). Because the Laser sintering process is self-supporting, and rather than the build being supported by a purposely built scaffold that connects the build to the build platform, the powder layer supports each new build layer. This simplifies the cleaning and post-processing of finished parts. In addition, the finished nylon parts can be post processed further, and dyed a range of colours using commercially available dyes used to dye synthetic fabrics.

We initially designed a range of linked configurations using CAD software and produced additively manufactured test pieces to explore the idea. We discovered that the digital designs became complex to create and edit in the CAD software, particularly as we wanted a small link to get maximum fluidity out of the final textile. It also became apparent that advanced CAD skills were required to manipulate the links to get the forms required and to ensure they were going to fit a person. In addition, once you have a full sized garment designed in CAD, a dress for example, which could be made from approximately 10,000 links, it proved difficult to fold it to fit into the available print volume of the AM machine. Another approach we tested included the use of a physics solver to calculate the position of links when using gravity to fill a virtual volume that matches the build area of the AM machine.

Image sequence shows physics test simulation to fill build volume of the additive manufacturing machine.



The complexity of the final CAD mesh makes it computationally challenging, and the physics solver is prone to fail when calculating small distances, typically 0.4mm across 1000's of independently linked parts. If any links fail to remain linked to their neighbour during this process then it's not until the final geometry is manufactured that the problems become evident. The whole garment would then have to be discarded.

The reason for not perusing the physics folding method was not only due to the possibility of the links failing, but also once the garment had been made and it was discovered that it didn't fit the customer or they didn't like it, it would prove to be a wasteful exercise. The garment would then have to be disposed of as it could not be repaired or adjusted. We needed to take a different approach.

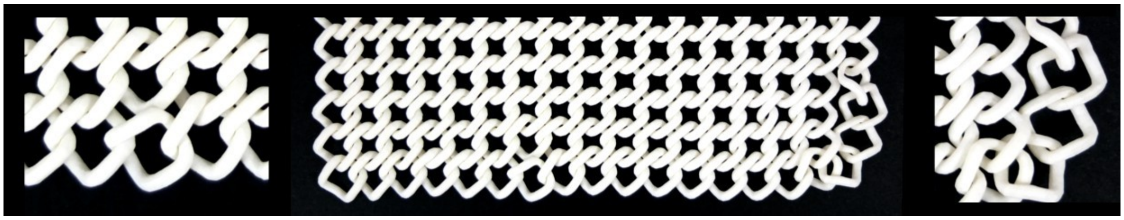
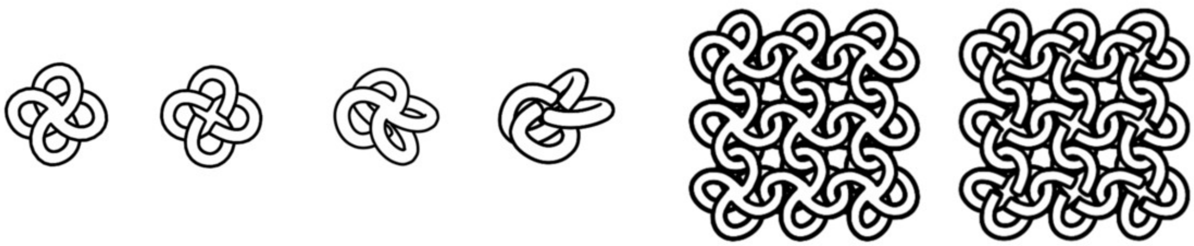


Image shows early AM link experiment where the physics solver has failed resulting in detached links. The problem was not discovered until after the mesh had been built as it's difficult to check link integrity in the CAD file once it's been compressed to fit the build volume.

Based on this initial experimentation we realised that it would be beneficial to create a material that wasn't dependent on CAD expertise and that could be repaired if the AM process failed. This led us to rethink the project. We arrived at a surprising solution which solved the issues we were experiencing.

Modeclix consists of a system of links that can be additively manufactured as linked panels. However, the design of the link allows for the panels to be de-constructed and then reassembled by hand. Linked panels can be connected together and manipulated by hand to create form and shape easily without any CAD expertise. The linking system enables large forms to be constructed. This is crucial as it removes the issue of the size restrictions defined by the model of AM machine used.

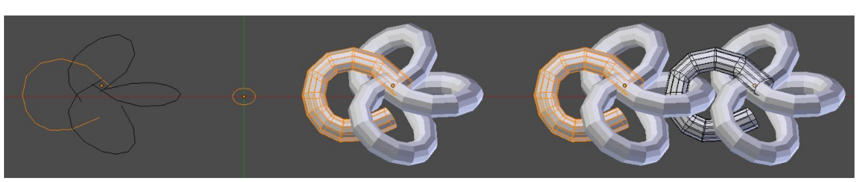


Images of a single link and how they connect together to form a flexible panel. Front & back views.

The smallest link was designed first to work within the machine specific tolerances of the Selective Laser Sintering (SLS) process. The link consists of 4 connected spiral arms. The links are connected across the top face, but left open on the reverse, to allow the links to be disconnected and reconnected as required. The link measures 9.5×9.5×3.6mm. Each arm of the link is 1.4mm diameter and the total size of the link takes into account the need for a 0.4mm gap between links when linked together in the CAD software. This allows sheets of linked material to be manufactured without the links fusing together as they undergo the sintering process.

The sintered nylon link was designed to exhibit the desired properties. The link shape required needed to be flexible as each arm on the link elongates when pulled. It must also be firm enough so that a degree of stretch would be achievable without breaking. The arm of each link also needed to be strong enough to withstand the manual deconstruction and reconstruction process. The link was designed taking into account these desired properties, the quality of the sintered nylon, and the machine specific tolerances of the AM process.

A spiral vector path was generated in CAD software and 4 instance (linked) copies of this path were each rotated 90 degrees. A circular vector section was then attached to each spiral arm to give the desired cross section thickness. As all vector paths are connected in the CAD software as instance copies, any subsequent editing of the paths to adjust and perfect the shape is reflected in all the components simultaneously. This makes the editing process relatively straight forward. Changes to one link will update all links to the new shape. This is a particularly useful work-flow when attempting to ensure the link will function and still have the required distance between links so that the linked panels can be additively manufactured successfully.

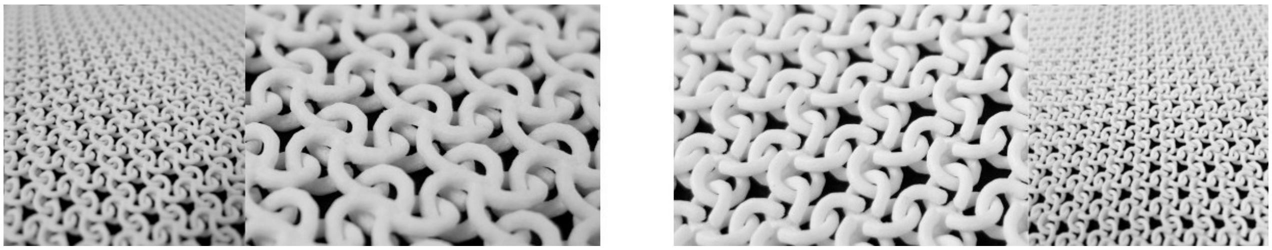


The link is described as a series of curves and a profile in the CAD software.

Panels of links are then laid out in CAD to fill the available build volume of the AM machine used. In our case panels of 22x22 links which equals 484 links per panel are laid out as sheets using an array modifier in the software. 20 duplicate panels are stacked on top of one another in the software to fill the entire build volume available. This 3D digital file is then processed by the AM software. It is sliced into 0.1mm slices and each digital slice is then sent to the AM machine and drawn by the laser into the layer of nylon powder.

Each layer is processed in sequence, one at a time, to build the complete stack. By stacking a close linked mesh in this way we achieve excellent density in the build chamber resulting in a minimal amount of unused powder.

Once the EOS P110 has completed the build cycle (approx 15 hours) and cooled, the build chamber is removed from the machine. The contents are removed from the build chamber and the sintered parts are separated from the unused powder. Excess powder is removed from the parts using a brush and compressed air. Excess powder is collected so that it can be sifted and blended with a % of new virgin powder and re-cycled into the next build.



This image shows the front and back of 484 links, linked as a panel. It has been additively manufactured as a single sheet of connected links. The number of links can be adjusted to take full advantage of the build volume of the AM SLS machine used.

The powder free panels of connected links can be effectively post-processed using a medium drum size vibro-finisher with ceramic media and water. Excellent spiralling rotation is achieved with noticeable smoothing of the AM nylon parts after just 3 hours. This mechanical finishing process burnishes the sintered surface, smoothing it in the process. Once the cycle is complete and the desired finish is obtained, the panels are rinsed in water and allowed to dry.

Modeclix has in the first instance been used to create clothing and fashion accessories to demonstrate the versatility of the linking system. Each item has been made to explore the versatility of Modeclix. All garments have been constructed from small panels and created on a dress making stand in a way similar to traditional dress making. The garments are seamless and do not require the usual pattern making / drafting stage. The material can be manipulated by anyone as they become familiar with the process of connecting the links together by hand. Once familiar with the process, construction can be quick. To link 50 links, typically takes approx 1min once practised with the technique. The links can be connected into an array of different configurations.

Examples of garments, accessories and toys made from Modeclix..

As the panels of links are made of nylon the material responds well to commercially available disperse dyes that are used in the textile industry to dye synthetic fabrics. Depending on the colour required and the volume of textile to be dyed, an amount of the appropriate pigment is dissolved in water and heated to 90-95 degree C. The white linked panels are then immersed in the dye bath for between 15-60 minutes until the desired shade is achieved, the dye in solution can also be reused. The dyed parts are then rinsed and allowed to dry. After dying the textile, patterns and designs can be incorporated into the final item. Because Modeclix is adaptable, different patterns can be created across the textile based on combining different coloured links, each treated as a ‘pixel’ to form designs and decorative detail.

As Modeclix consists of interchangeable links, the repair process is straight forward. The SLS process can sometimes fail as a result of the powder mix not being even, the machine settings being incorrect for the type of object being built, inconsistent heat distribution throughout the build chamber or simply corruption in the 3D data file. This can lead to soft or brittle built parts or parts with anomalies. Once the build is complete and cleaned, it is difficult to check part consistency across 1000's of parts. Modeclix has a break strain of 7kg across a connected panel matrix of 22×22 links, but if pulled with too much force the links will stretch or even break. If there has been an issue with the build then it's evident when the textile is put under stress. Should any of the links fail, the broken or distorted links are simply replaced with new ones, repairing the textile in the process.

Modeclix can also be re-configured. This means garments are completely and fully customisable. For example, garments can be made to fit the customer simply by removing or adding links to adjust the size and shape. This satisfies the emerging, increased demand for bespoke, fully fashioned products. The adaptability of Modeclix allows for it to be configured to fit a range of sizes and different body shapes. Modeclix garments have been worn by a variety of models and individuals all of whom have been enthusiastic and said how easy the garments are to wear and how comfortable they are. Garments are adjusted to fit by simply adding or removing links as part of the fitting consultation. Length can also be adjusted in the same way to reflect the height of the person or their personal preference. Indeed, skirts and dresses can be adjusted from short to long to reflect the customers choice as well as changing fashion trends.

As familiarity with manipulating the material grew, it became apparent that existing garments and items made from Modeclix could be de-constructed and then reconstructed as a different garment. Many of the garments made to test the material and to explore shape making have then been taken apart, and the textile reused in new iterations. This feature means that Modeclix can be continuously re-purposed creating circular economies that renew the products life-cycle. It's a form of recycling but rather than the raw material being processed in order to be remade as something else, it's actually the recycling of a component part. A component part that can be reassembled into other things. Garments have been the initial focus of this research but other items have also been made. This includes bags, jewellery and toys. Modeclix is a design system that inherently incorporates circular economic factors into the products life-cycle.

The potential to develop the system further through new component parts will also ensure the adaptability and future usability of the textile. New AM parts can extend and enhance the life of the textile at a later date and expand the areas of application. Most of the research undertaken to date is based around a single sized link. The 9.5×9.5mm link was established as the smallest link possible. Two additional sizes have been introduced to add to the range and scope of constructed shapes; 10×10mm and 11×11mm. The link cross section diameter remains consistent at 1.4mm to maintain the overall aesthetic and mechanical properties. When these different size of links are used in conjunction with one another it is possible to introduce a scaling across the width and length resulting in a taper or circular arch. Medium sized links have also been modified with the addition of a top panel. Square and circular flat tops create a different visual effect condensing the appearance of the material. The addition of these elements also changes the fluidity of the linked components giving a different tactile feedback enabling more structural forms to be created. Another version of the link incorporates a 4 claw mount for setting acrylic or crystal flat back imitation gem stones. This changes the overall appearance and allows for further customisation of the textile sheet through the use of different colours and finishes of stones. Stones are simply clicked into position and can be removed allowing further changes to be made. Other components that work with the link are also in development including zippers and other forms of fastenings. Promising tests have also been carried out that explore the use of links that have been treated to carry an electrical charge.

Although fashion, accessories and toys have been the starting point of this research project we have only just begun to realise its full potential across a range of different industries and applications. Future development will entail looking at the built environment to explore the use of Modeclix as a screening material, upholstery for furniture and temporary architectural structures. We're also exploring applications in the medical, automotive and defence industries.

Modeclix also addresses the need to reduce resources through localised production, product life extension and demand driven manufacture that's both customisable and scalable. The most widely discussed benefit of Additive Manufacturing (AM) is the idea of localised manufacture. This is enabled through the portability of digital files that instruct the 3D Printer to build the required part and considers the growth of AM centres around the world. Although this idea, in principle, can create a global networked manufacturing facility there is much to be done to realise this ideal, namely with machine configuration, cost and quality control processes that ensure part consistency and price across different facilities. Once these aspects have been resolved then the idea of localised manufacturing can become a reality. The benefits of localised manufacturing include reduced transportation and delivery times, and scalable production across multiple facilities to fulfil high demand periods with the option to scale back when demand drops. Modeclix also reinvents itself with each new application. As new components are introduced that work with the link system, this excites the market through new possibilities that allow all previous Modeclix components to be re-purposed and re-used creating a sustainable future for the material.