1 Final Publishable Summary Report

1.1 Digital garments as real as reality

Why do fibers need to exist only in the physical realm? Future Fashion Design (FFD) introduces the detail of fibers into the virtual prototyping of garments. Garments that will dominate fashion shows are now designed virtually on the computer to the finest detail, long before the first prototypes are sewn. The time and cost savings are high and will have a tremendous impact on the fashion industry.

Which one is real, which one is virtual? Can you tell the difference?

The FFD research project targeted the garment and textile sectors. It ran over three years and was roughly divided into three sections, covering in-depth architectural planning followed by two development cycles that included end-user acceptance testing.

FFD targeted several business objectives:

- A wider adoption of Virtual Prototyping (VP) by textile and clothing companies,
- The reduction of time to market through a drastic reduction in the time, cost, and manual steps of VP usage by up to 90%,
- The reduction of the necessity for physical prototypes through a close match of VP to physical samples in terms of information fidelity, and
- More flexibility through IT-driven collaboration between roles in the design and development process.

FFD reached these objectives by defining a new, completely virtual and interchangeable production process which consists of four areas. Fabrics are procedurally designed using CAD in the Fabric design area. Additionally, existing fabrics can be analyzed in order to get their procedural structure. In the garment design area, Classic fabric CAD is extended to be able to handle production patterns. In FFD, the additional data of these two areas is now fused into the virtual prototyping area, delivering virtual prototypes of a quality never seen before in the virtual garment design process. Results of these simulation processes can be uploaded to the collaboration area, which allows discussion and management of the whole process.

With this technology, FFD will have a large impact on the garment sector. This is in line with the feedback partners received during dissemination activities and the interest from external companies not involved with the project.

1.2 Project Context and Objectives

Retaining the traditional competitive lead in design and style is a crucial challenge for European fashion firms in the Textile and Clothing Industry (TCI). While the production of goods has moved offshore, significant parts of the process, like styling and pattern design, remain in Europe. Globalization and delocalization of operations along the value chain result in communication and collaboration problems imposed on teams of individuals involved in product development who are located in different places, with different roles, backgrounds, and skills. Product development, using either localized or decentralized teams, represents a significant bottleneck in the clothing industry, both in terms of time (up to five trial and error design-prototyping loops, lasting up to 12 weeks), and cost (up to 7% of the total cost of a fashion product).

Virtual prototyping can significantly reduce the number of physical samples (from five to, potentially, only one final proof sample). 3D garment simulation, the core technology of garment virtual prototyping, has been offered in a number of commercial 3D CAD systems for the past 15 years. Research in this area started 20 years ago and is still ongoing. However, its penetration and efficient use in industry is still low, due to the inherent complexity of simulating flexible materials (fabrics), as well as difficulties in the realistic representation of the fit and appearance of virtually-sewn fabrics (patterns) on virtual human models. Additionally, online collaboration platforms for the participants in the process of garment design and prototyping are currently limited to the sharing of 2D design data and representations. This stands in sharp contrast to the use of 3D collaborative design platforms in other industries, such as construction, engineering, aerospace, etc. The FFD project aimed to remove the main barriers inhibiting the wider adoption of virtual prototyping by the TCI through dramatic improvements in the speed of realistic garment simulations, the accuracy of textile simulation, and functional integration aspects. This new business model offers strong improvements in product development efficiency and services at a low cost, while opening new market opportunities for CAD and PDM/PLM system vendors.

The main business objective of FFD was to enable fashion development teams to unleash their joint creative potential in an open, online, collaborative system featuring rich 3D virtual representations that are close to reality. Before FFD, several steps of the production pipeline did not have any appropriate representation in the virtual prototyping process. A key overall technical objective was, therefore, to define representations of these steps. Now the user retains all of the relevant product information throughout the various engineering stages. This main objective was refined successively throughout the project.

In the following, an overview of the objectives and the reached potential is given:

Higher speed and better quality using multi-core and many-core algorithms plus adaptive meshing of complete garments

Successfully targeting this objective, FFD improved the fidelity of virtual prototyping to such a degree that the number of physical prototypes necessary to be built to assess the design and viability of a product are significantly reduced. Additionally, the setup time for preparing a first virtual prototype was reduced by up to 50% compared to previously existing virtual prototyping systems.

Generation of cloth textures automatically from weaving patterns including supplementary datasets

Getting existing fabrics into the computer for virtual prototyping is an extremely time-consuming process. What took weeks before can now be done in minutes within FFD. By integrating the design process into the virtual production pipeline, FFD successfully built a bridge between fabric and garment design workflows, leading to a much more accurate display of the fabric’s structure than current approaches. Additionally, procedural construction of fabric data for garment visualization avoids the whole acquisition process for textiles. No photographs need be to taken of draped cloth; no digitalization and no manual retouching is required.

Flexible parallel computing software architecture, specially tuned for garment simulation

Garment simulation is special in the way that elements are interconnected. Therefore, finding specialized parallel solutions for existing simulation systems was an important task in this project. FFD can unleash the potential of multi-core machines with a speedup of up to 0.9 per core available.

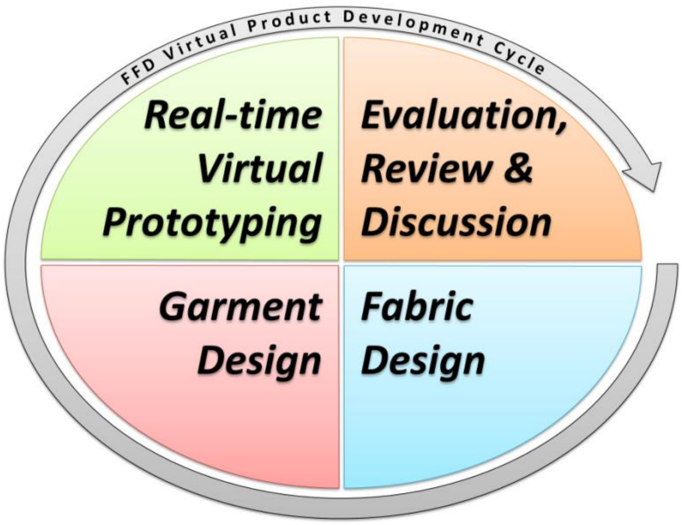
Simulation of the whole textile and clothing production process, from yarn to garment, in virtual prototyping

For FFD to be a success, it was mandatory to cover the whole virtual product development pipeline, starting with virtual fabric generation, in order to reduce the number of manual steps in the simulation preparation phase. It was one of the keys which allow FFD to create a lead time reduction of up to 90%.

Usable project results for the industry, wide dissemination and in-depth evaluation

In FFD, end user testing performed within the project was also implemented through special actions that targeted the reduction of the complexity of working with a virtual prototyping system. The collaborative design platform and the simulation process was optimized in order to bring the abstraction level closer to a real garment and reduce the number of manual preparation steps between CAD and virtual prototyping processes. Overall, a cost reduction of 10 to 25% can be expected when using FFD.

FFD involved partners from the domains of applied research, textile CAD/virtual prototyping development, garment CAD / virtual prototyping development, web collaboration tool development, and end users from the textile and garment industry. This setup of partners allowed FFD to cover the complete development process of garments, from the design of a fabric to complete virtual production.



FFD was split into three phases. The main objective of the first phase was to find a way to convert the vision of FFD into an approach that is capable of handling a fully virtual production workflow, extending beyond classical approaches. Therefore, researchers performed a requirements analysis of existing and future business and production workflows. An overall architecture and business framework was created from this analysis, outlining the FFD solution. The planning of the first architectures of detected must-have features started in parallel. With the development of the project's detailed overall architecture, including a business framework, the first phase was successfully completed.

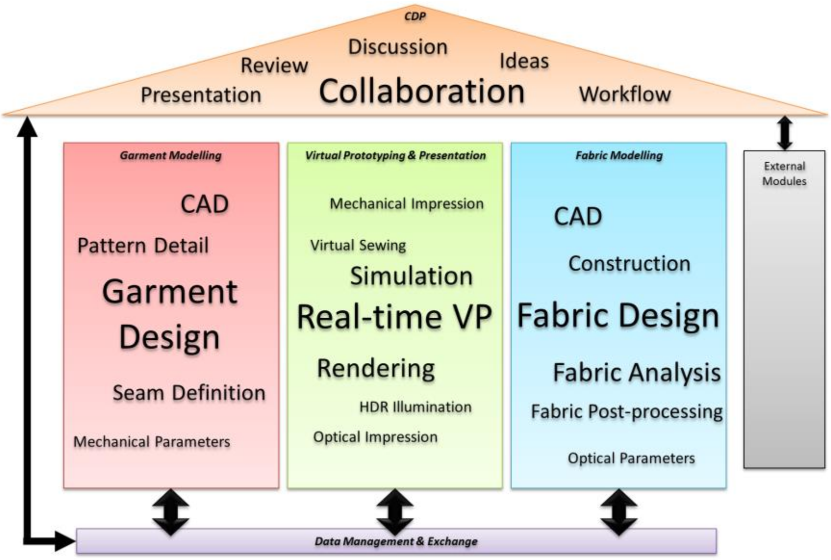
The main goal of the second phase was development and end user evaluation of first demonstrators to test the proposed framework and fill the gaps of existing software systems. At the end of phase two, a summary of the evaluation of the overall structure representing the current state of capabilities was created. At this point, the project started ramping up dissemination activities to make the project and the current results known to the public. The project was first presented successfully at the TexProcess 2013 fair, an important fair for providers of textile design systems, creating a lot of interest.

Based on the evaluation results, Phase three's main goal was to re-factor the demonstrators into final prototypes which can interact together in order to reproduce the whole production process as envisioned at the start of the project. Parallel to this, dissemination was performed to get feedback from external sources and to increase public awareness of the project.

The project has resulted in a new technology, which enables fashion development teams to unleash their joint creativity potential in an open, online, collaborative system featuring rich 3D virtual representations that are closer than ever to reality. Steps which were previously missing are now covered in the virtual prototyping process and the user is able to retain all relevant product information throughout the various engineering stages. Additionally, he has gained a flexibility which allows him to better react to sudden requirement changes and customer requests. In general, the FFD project represents significant 3D simulation progress in the current state of the art of 3D garment simulation systems. Virtual prototypes generated by this innovative technology have achieved a satisfying level of quality. With this technology, virtual prototypes can be adopted in the industry, allowing a reduction of time to market of up to 90%, depending of the way a garment is produced.

1.3 Main S&T Results

1.3.1 Approach



Our approach for realizing FFD splits the development process into four areas, which combined in the complete virtual design process. They can be used independently; however, their main strength is their interconnectivity. This property allows a high flexibility and easy reconfiguration of individual parts within the overall process.

In the **garment modelling** area, the basic sewing patterns of the garments are generated. The importance of adding details like folds, pleats, multiple layers, and seam properties to the pattern definition in order to achieve accurate, reliable, and visually pleasing simulation results, is directly supported in FFD on the pattern level. Thus, a simulation can now reproduce the sewing process of the garment in the virtual world without losing any detail.

In the **textile design** area, FFD allows the generation of high quality fabric textures for the virtual garment prototype. This is based on the procedural description of the fabric, creating a bidirectional link between fabrics and production data, allowing changes on the fly. Additionally, a semiautomatic route is available in order to get fabric producers' fabric samples into the system. A process which previously took weeks can now be performed within minutes.

In the **virtual prototyping and presentation** area, FFD combines the data generated by the two other areas with real time simulation and high quality rendering into a virtual prototype. At this point, high speed meets high quality, creating an interactive representation of the prototype in virtual reality that the designer can now work with as with a real-world prototype.

The system is tied together by the **Collaborative Design Platform (CDP)**. The CDP's purpose is to build a management and discussion tool for the users of the proposed new development process. It implements the underlying workflows, collaboration elements between the different user roles, and flexible usage scenarios to enable previews of prototypes to be discussed, annotated, and used for decisions in the next steps, closing the loop for the next design iteration.

1.3.2 FFD software artefacts

Fabric design and visualization

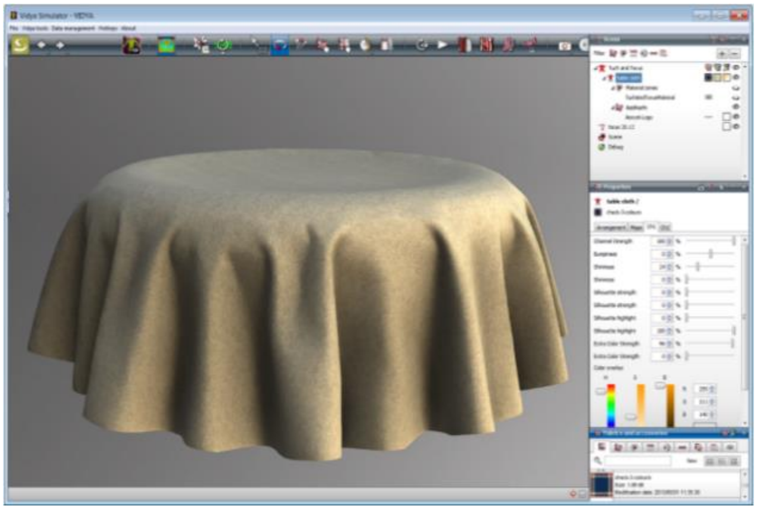
Fabric analysis module

A parametric model for describing fabrics is a reliable source for high quality fabric data for visualization purposes. However, a method is required for capturing existing fabrics and describing them with the model. With FFD, users who have large physical libraries of fabric samples can now quickly convert these for use in the new FFD process.

ScotCAD vidya Plugin

The ScotCAD fabric design CAD system was extended to work in conjunction with the 3D virtual prototyping system. Using the generation subset of the CAD system, small changes to the weaving pattern can be previewed, without the necessity of starting the whole fabric design process. Thus, it is now possible to change designs down to the yarn level while running the garment simulation.

Fabric exporter



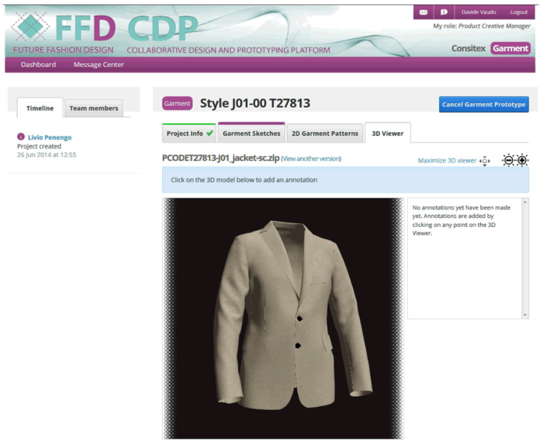
The fabric exporter acts as the glue logic between fabric CAD and the virtual prototyping system. Here, the parameter-based representation of the fabric is converted into a parametric representation, which can be used for real time rendering. The goal of this process was to achieve high resolutions of the fabric in the virtual prototype in order to prevent visible artefacts through regular tiling. A tight integration of the Fabric CAD with the virtual prototyping system removes the time- and resource-consuming processes of early virtual prototyping systems.

High Quality Renderer

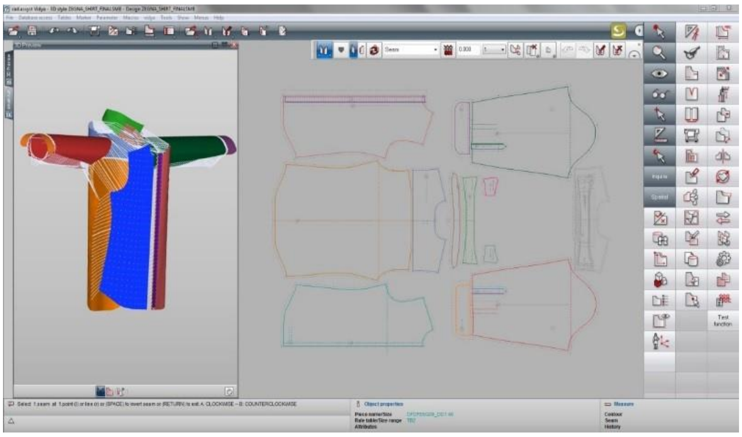
The high quality renderer developed in this project is an add-on to the virtual prototyping system. The challenge was to build a rendering system which interacts in real time with the physical simulation of the virtual prototype. The system also needed to show the garment in a realistic way, including the high quality fabrics from the fabric design process, self-shadowing of the garment, and natural lighting.

Stand Alone Render Framework

The CDP platform uses a stand-alone viewer that was developed for the purpose of viewing simulation results on machines ranging from simple office computers to high-end workstations. The viewer is used to provide 3D previews and enables annotations of simulation results directly generated from the virtual prototyping process. The viewer can be used in several ways, from single stand-alone application, as an app on a tablet, or as an applet plugin in a web frontend.



Garment design application area

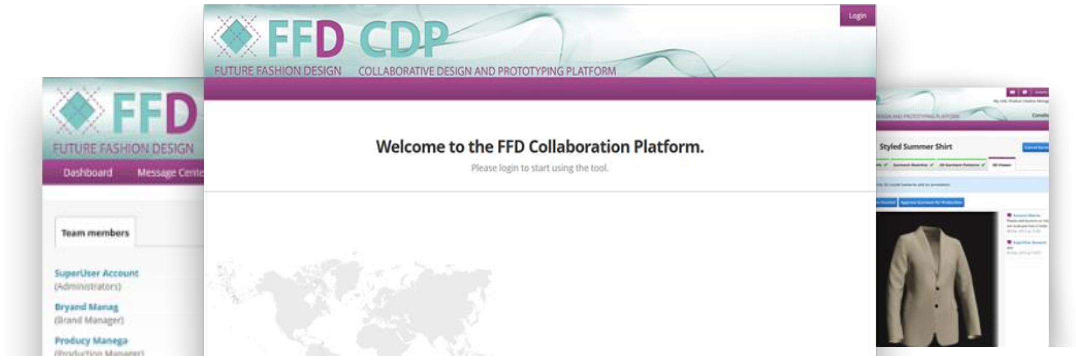


Additional data semantics were developed on the garment CAD side to enable the modelling of all details of the product. This enables simulation based on real production patterns. An increase of design time is countered by introducing automations of some of the preparation processes for the simulation.

Virtual Prototyping application area

The real-time virtual prototyping system performing physical simulation of mechanical and optical effects was extended to achieve a higher simulation resolution by introducing parallel and adaptive simulation techniques. This was done in order to cope with the increase of detail generated by the new design processes. The resulting simulation is visualized by the high-quality rendering system.

Collaborative Design Platform



View of the CDP platform as it is seen by the user.

The web-based collaboration tool *Collaborative Design Prototype* platform (CDP) bundles all communication and management aspects of the production design process to enhance distributed development based on virtual prototyping technologies. CDP seamlessly integrates a bouquet of innovative modules in a unified platform which supports collaboration between users, offering tools for fabric design, garment design, and–for the first time–tools for fabric-to-garment design. All steps in the FFD production design process can be performed in an arbitrary sequence that fits best for the current situation. Now it is possible to discuss, review, and evaluate designs and get feedback from the design team based on a completely virtual process.

1.3.3 FFD scientific results

Within the project, several more complex scientific problems arose, while solving the primary technological questions. These problems were addressed through scientific research that reached beyond the state of the art in science. The results were published at scientific conferences to get feedback from other experts in this area. This way valuable information about the excellent quality on the scientific side of the projects results could be gathered. All results that are introduced found their way into the FFD technologies, mainly for parallel simulation and rendering of garments.

Screen-Space Ambient Occlusion Using A-buffer Techniques

Self-occlusion and transparency are important optical features of a real world garment. For increasing the optical fidelity of the virtual garments a novel approach to the screen spaced ambient occlusion concept was developed by taking advantage of per-pixel fragment lists to store multiple geometric layers of the scene in the G-buffer, thus allowing order-independent transparency (OIT) in combination with high quality, opacity-based ambient occlusion (OITAO). This A-buffer concept is also used to enhance overall ambient occlusion quality by providing stable results for low-frequency details in dynamic scenes.

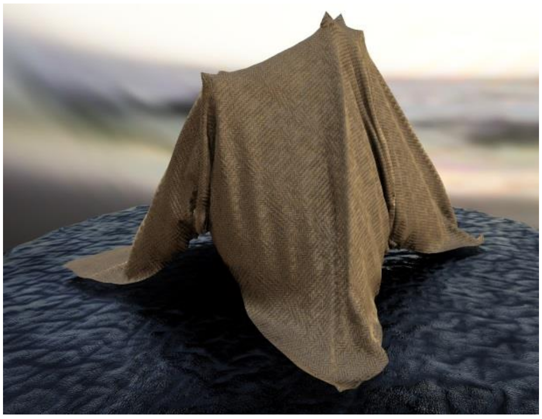
Multilevel Cloth Simulation using GPU Surface Sampling

Garment simulation cannot be fast enough. To efficiently harness the power of graphics hardware a cloth simulation was developed that combines both regular and irregular model types. Both models are coupled by a sampling operation which renders triangle vertex data into a texture and by a corresponding projection of texel data onto a mesh. A CPU-based collision handler and a GPU-based hierarchical constraint solver were implemented to simulate systems with more than 230,000 particles in real-time.

Mesh Partitioning for Parallel Garment Simulation

For the same reason a method for partitioning meshes that allows a simple and efficient parallel implementation of different simulation methods was developed. It is based on a generalization of the concept of independent sets from graph theory to sets of simulation elements. Every simulation method that formerly worked by sequentially processing a set of simulation elements can now be parallelized by partitioning the underlying set, without affecting the behavior of the simulated model.

Efficient Self-Shadowing Using Image-Based Lighting on Glossy Surfaces



For increasing the optical fidelity of the virtual garment a novel natural illumination approach for real-time rasterization-based rendering with environment map-based high-dynamic-range lighting was developed. The approach allows the use of all kinds of glossiness values for surfaces at the same time and in conjunction with directional occlusion. This results in a fast, image-based lookup for the different glossiness values, which gives the technique the high performance that is necessary for real-time rendering.

1.4 Potential Impact

The FFD project addresses the needs of the European textile and clothing industry. The results of the project make it possible for the first time to offer:

- Realistic virtual garments,
- A plausible representation of a physical simulation in a completely virtual prototyping environment, and
- The possibility for all members of the design teams to access design results in an online, collaborative environment.

A dream of the fashion industry is now reality.

The agility introduced by FFD into the garment production process puts production companies in a better position when competing with companies optimized for mass production. More agility in the production process boosts the capability to convert ideas into innovative products and even to incorporate requests from customers or changes on the fly.

The European garment industry is a market that is focused on flexibility and response to customer requests. Most of the designers are located in Europe, while the majority of production is done in Asia. Thus, The main impact of FFD is on the European market, since its target is enhancing the flexibility of designers, which is not a key aspect in mass production.

The project results show a strong reduction effect (between 10% and 25%) on a significant portion of the product development costs in the garment sector. This is an important step for SMEs and large companies in the strained European market. The results of the project have shown their potential to strengthen the competitiveness and competencies of fashion companies in Europe. This potential is generated by the elements of the project which now allow virtual development tools to work in an integrated way, creating a benefit through the smooth transition between the individual development steps and the flexible management mechanisms of the collaboration platform. Altogether, it creates a lead time reduction of between 50% and 90%.

The importance of these properties were repeatedly underlined by the user communities we met in the course of our dissemination throughout the project. This confirmed the main objectives of this project and provided important evidence for the direction of our development and the methods used.

More information can be found on our website:
www.future-fashion-design.eu