

TOBIAS KAPPELER

VDK - Virtual Design Kit

**Designing sheet
metal constructions
in virtual reality.**

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«Virtual reality is inevitably going to become mainstream - it is only a question of how good it needs to be before the mainstream is willing to use it.»

PALMER LUCKY



Introduction

Constructing with metal

Over the last 5000 years, the art of constructing with metal has evolved. The Industrial Revolution redefined the process of production, characterised by the increased integration of machinery in the workforce.

In the late 1950s, the first Computer Numerically Controlled (CNC) machines were invented. They can autonomously produce complex shapes with high precision. Since then, the focus of human work has shifted towards generating files to produce with CNC machines.

Computer-Aided Design (CAD) software are able to simulate a construction, test its functionality, and generate the files for CNC machines. Because of advancements in CNC machines, CAD software have become invaluable. CAD software, however, are very complex because of their endless functionalities, thus have a steep learning curve.

Virtual Reality in Design

Virtual Reality (VR) is, “a medium composed of interactive computer simulations that sense the participant’s position and actions, providing synthetic feedback to one or more senses, giving the feeling of being immersed or being present in the simulation”¹

VR allows you to be immersed in any three-dimensional (3D) space you desire. For instance,

cardiologists can analyse a heart from within,² archaeologists can transport themselves into ancient graves³ and designers can visualise and interact with an object in virtual space.⁴ VR also offers new ways of executing commands, interacting with virtual objects and additional ways for communication. An interface can be replaced by an interactive object, which results in intuitive approaches to operating software. Being able to receive visual, audio and haptic feedback⁵ makes it easier to grasp the consequences of your actions.

“Software simulation can help bypass the many layers between sketch and final product”⁶ Therefore, it only seems logical that virtual reality is the next step in simulation. VR provides an innovative approach to design in which each step of the process can be simulated and reconstructed accordingly. This method sustainably uses resources and reduces, if not eliminates, potential errors in the final product.

“People love immersive and 3D interactive experiences. Tracking sensors as Wii Remote from Nintendo and Kinect from Microsoft are experiencing significant success.”⁷ In the last decade, the use of VR in design has become increasingly popular and we have seen an increase in the

2 Universität Basel: <https://www.unibas.ch/de/Aktuell/News/Uni-Research/Virtual-Reality-in-der-Medizin-Neue-Chancen-fuer-Diagnostik-und-Operationsplanung.html>

3 Lithodemosvr: www.lithodemosvr.com

4 Gravity Sketch: www.gravitysketch.com

5 Haptic feedback: Rumbling of the controller

6 Sherry Turkle, Simulation and its discontents. Yanni A. Loukissas; Keepers of Geometry P. 165

7 New Trends in Interaction, Virtual Reality and Modeling, Ernestor de la Rubia and Antonia Diaz- Estrella, P. 47

availability of VR modelling, sculpting and drawing software, some of which are multi-user accessible. These VR software can import and export files for further use with desktop software and to take pictures of your work. Some desktop software have a VR version while others have seamless VR integration.

VR is being used in the education field mainly as teaching tools for training and simulations; from chemistry,⁸ to mixing cocktails⁹ or learning how to operate trains.¹⁰ In addition, VR can be used to review bigger projects and constructions,¹¹ manage workflow and operations¹² and configuration software exist that showcase products in VR.¹³

Virtual Reality and sheet metal constructions

Since an early age, I’ve been interested in designing and building physical objects, especially when it ensures practicality. I did an apprenticeship as a metal worker and afterwards specialised in sheet metal construction. I’ve worked on the construction site as an assembly fitter as well as a project manager.

As such, I’m interested in the future implications of VR in craftsmanship, specifically metal work. During my Bachelor, I developed a VR software called ‘VDK’, which I have been using to understand: How can VR be made available as a design aid for sheet metal construction, particularly for people with no knowledge of craftsmanship?

8 Mel Science: www.melscience.com/vr

9 Bartender VR: www.bartendervrsimulator.com

10 Derail Valley: www.derailvalley.com

11 Iris VR: www.irisvr.com

12 Revit: www.autodesk.com/products/revit-live

13 Brio VR: www.briovr.com



Figure 1: Hanging lamp, made from 1mm steel raw.

1 New Trends in Interaction, Virtual Reality and Modeling, Ernestor de la Rubia and Antonia Diaz- Estrella, P. 46

VDK – Virtual Design Kit

Introduction

VDK – Virtual Design Kit – has been developed as a prototype VR software to explore how VR can be used to design sheet metal constructions. With the method of a virtual design kit from predefined elements the user can create their design, which can be exported as a .dxf file and cut by a laser.

The project shines a light on future design methods in VR and how virtual space can be used to create physical products. The project provides an innovative approach to data creation for CNC machines.

VDK was developed in collaboration with the HumanTech Institute at the University for Architecture and Engineering in Fribourg.¹ VDK advanced through the partnership with Meyer Blechtechnik,² Regent Lighting³ and Virtual Valley,⁴ the Research Society for Draft Design and received funding from Blaser Metallau AG.⁵

Scope

In developing VDK - we examined different interaction design approaches to create constructions and guide the user through their VR experience. We explored different

1 HumanTech: www.humantech.heia-fr.ch/EN/presentation/Pages/core-competences.aspx

2 Meyer Blechtechnik: www.meyer-blechtechnik.ch

3 Regent Lighting: www.regent.ch

4 Virtual Valley: www.virtualvalley.ch

5 Blaser Metallbau: www.blaser.net

communication approaches, which included: a project video, a website, and a physical representation of the software in the form of a physical kit with a manual and sheet metal constructions. *senduci dusanihil maximen ditiam, nobis volorro essed et pro dolenda consequa volora voluptassum ra vel experibusci officim olorum sam lat.*

Evolution of VDK

At HyperWerk, I learnt to create 3D models with Blender⁶ and texture these models using Substance Painter.⁷ To design and program VR experiences, I used Unreal Engine 4⁸ and its visual scripting language “Blueprints”.⁹

In 2017, I developed Virtual Craftsmanship¹⁰ to create constructions in VR by using virtually simulated machines: a hand lever circular saw and a column drill. The project was developed in collaboration with the institute for Interactive Technology from the FHNW in Brugg. The software enables four users to work simultaneously, where they can learn how to operate the

6 Blender: www.blender.org

7 Substance Painter: www.substance3d.com/products/substance-painter

8 Unreal Engine 4: www.unrealengine.com

9 Blueprints: <https://docs.unrealengine.com/en-US/Engine/Blueprints/index.html>

10 Virtual Craftsmanship: www.vistom.ch/virtual-craftmanship/
FHNW Computer Science: Vistom Bachelorthesis

machines, as well as learn of potential dangers when using these machines

I realised that cutting virtual objects or subtracting from a whole requires experienced graphic programming skills and is very calculation intensive, especially at runtime.¹¹ Since I did not have the knowledge or resources available, a different approach to create constructions had to be found.

During the usability tests, I found that a lot of users prefer to “play around” in the virtual environment rather than “doing tasks”. The setup shouldn’t be too serious; designed in a way that encourages trying new approaches and should enable the user to quickly visualise their design. “Virtual Craftsmanship” was too close to a second reality which some users found repulsive and operating the machines was very limited and only allowed the user to create simple constructions. Since CNC machines are the industry standard, it made sense to create a software that was designed for CNC machines. The VR software “CRAFT”¹² simulated a lathe and designing an object by operating it. The user can export their design, send it to a company and they return the design after the production. This process of exporting and sending the file to a production company is also applicable to metal construction.

Process

Having realised the advantages and pitfalls of “Virtual Craftsmanship”, VDK evolved. The idea is to have a kit of predefined, 3D pieces of sheet metal that snap together when overlapping. Simultaneously while designing, a flat projection of the design is generated. This can be exported as the stencil for laser cutting. After the cut action, the sheet metal is sent back to the user in its flat state, ready to be folded up. The folding can be done by hand due to perforated bending edges.

11 Runtime: In computer science, runtime or execution time is the time during which a program is running (executing)

12 Craft: https://store.steampowered.com/app/558740/CRAFT_Work_VR_Shop/

This method allows a more playful approach while designing and is easier to program. The design method is intuitive and allows anyone without prior knowledge of metal construction or CAD software to design objects.

I formed a team consisting of HyperWerk students interested in the project and with a shared enthusiasm for the technology.

To program the framework for attaching and detaching objects I collaborated with the HumanTech Institute at the University for Architecture and Engineering in Fribourg.

Before “Virtual Craftsmanship” was finished and VDK established, I wrote a second collaboration project with the Institute for Interactive Technology at the FHNW in Brugg, which had the goal to find an intuitive way to assemble elements in VR.¹³ Unfortunately, the workload was too intense to continue both projects, so I did not work on it further, but a lot of code and knowledge contributed to the development of VDK.

In November 2018 I realised that the programming was much harder than anticipated and that I underestimated the work behind programming my own framework. I worried that if I couldn’t understand the code myself, it would be difficult to lead and develop the project further, as it was quickly getting complex. As such, I set out to learn how to program with Blueprints. I focused on several components including: user interaction; taking photos and videos from within VR for the VDK website; and creating tutorials that explained the VDK software. We were learning to program, while at the same time developing the software. This proved to be very challenging and time consuming. As such, we made the informed decision to prioritise functionality and interactions, instead of the design and aesthetics of the virtual environment.

We developed the first prototype in January 2019, which we showcased at the Open House. Though there were many glitches in the software, user feedback was largely positive and it motivated us to make further improvements.

13 FHNW Computer Science: Vistom 2 Bachelorthesis

In March 2019, I received an offer for the MA/MSc Innovation Design Engineering¹⁴ degree, jointly offered by the Royal College of Art and Imperial College in London .

To communicate the project and to find industrial partners, we decided to make a short video that sets the project into context and explains the design method.

VDK can be used for a broad range of objects which is hard to communicate and difficult to understand. Therefore, I decided to use lamps as an exemplary use case, since their functionality can be simulated in VR and they can be found in almost every household.

For our corporate identity, we designed a logo and decided on three colours and a font that we would use throughout all of our communication, physically and virtually.

To reference our partners, have an online appearance that can be shared and show that the project existed, we created a website.¹⁵

“Focus on making interfaces intuitive - that is, design interfaces that can quickly be understood, accurately predicted and easily understood”.¹⁶ I tried to design the interactions based on these principles, with a clear visual language and to reach a larger user group. Doing a lot of usability tests with different people was helpful. Linking the corporate Identity with the interaction design was a necessary step in improving both the identity and the usability of VDK.

To produce first prototypes of lamps we partnered with Meyer Blechtechnik for the metal constructions and Regent Lighting for the light source. Both companies were interested in partnering to explore how they could integrate the project into their business.

To reach people not familiar or fond of the technology we decided to create a physical kit with a catalogue of the elements for demonstrating our software. The kit is designed the same way as constructions made with VDK and it opens in three steps, so the user has an uplifting unboxing experience.

¹⁴ Innovation Design Engineering: <https://www.rca.ac.uk/schools/school-of-design/innovation-design-engineering/>

¹⁵ VDK: www.virtualdesignkit.ch

¹⁶ The VR Book, Jerald P.355

The outlook of postgraduate studies in September brought a shift in the focus of the project – rather than trying to set up a government funded research project¹⁷ with the Institute HumanTech and industrial partners, I decided to expand my skills in programming.

Reflection

A lot of time was invested at the start in encouraging team spirit and getting people excited about the project by talking about it and envisioning its implications. Looking back, what created a good team spirit and got people on board was working and developing the idea from concept to prototype together.

When leading a team, it is important to integrate all members and give them responsibility and freedom, remaining fair and objective but at the same time being assertive to deadlines and consequent when work is not done as discussed or on time. All team members had their ups and downs which was mainly due to not seeing or realising progress. Having functional, visual or physical progress is important to stay motivated, therefore defining achievable goals is essential, while at the same time keeping the bigger picture in mind.

To successfully lead an interdisciplinary project, you need to understand the basics of all the disciplines to make a reasonable decision. Learning and understanding the basics of programming was necessary to understand the complexity of the issues we faced and steer the project accordingly.

I had underestimated programming and thus the first project description for the collaboration between VDK and HumanTech got split into three projects¹⁸ which were developed until July 19.

“Nicht nur die Form der Produkte, sondern die Regeln, welche die Benutzbarkeit beherrschen, müssen also zum Gegenstand der Untersuchung gemacht werden.”¹⁹ Programming has taught me to not only to think of the “action”

¹⁷ Innosuisse: <https://www.innosuisse.ch/inno/en/home.html>

¹⁸ HumanTech: Semesterproject 5 MeccanoLego 2.0

HumanTech: Semesterproject 6 MecannoLego Sharing Platform

HumanTech: Bachelorproject MeccanoLego

¹⁹ Design ist Unsichtbar, Lucius Burckhardt, P.30

I want to achieve, but rather the bigger framework it sits in and relies on. What could the potential effects of my new action be and what could evolve from it?

Looking back, we thought too early about what the virtual environment should look and feel like before we had the functionality. The important part is functionality and when this is achieved, form and aesthetics follow to improve its usability. Functionality cannot be thought of alone, but a proof of concept has to be achieved to evaluate further action.

Communicating your project in a way that it is understood correctly is very difficult, especially with new technology involved since people are not familiar with its implications. I learned this throughout all communication approaches I’ve taken. Corporate identity can improve not only the visual communication but also the usability and associations with the project. Having enough time to develop this and thinking about it at the right stage of the process is essential. Restricting yourself to a certain look, colours and style, plus paying attention to details can help achieve the desired goal.

Our website was helpful to be found and shared on the web but it also gave the idea behind VDK away. Next time I will not create a website until the project is market-ready and fully developed. For a very technology-heavy project, it was a good idea to create a physical representation of the software. People can relate with the physical kit and understand what the project is about without having to try the headset. This allowed us to reach a wider audience, especially people not familiar with VR or technology in general.

The collaboration with industrial partners gave us a valuable insight into how VDK could be implemented in the market. Both partners see the value of VDK in them using the software rather than end users. For Meyer Blechtechnik the software was not yet advanced enough to be used commercially. They were worried that they would receive a lot of small orders from many users creating a substantial amount of administrative work which would only be profitable if specialised on this. Regent saw a big advantage of VDK in the fact that their clients could design their own lamps with the components from the

company and approach them with a finished design. This lowers their efforts to visualise the customers idea and integrates them into the design process.

Being able to create a variety of sheet metal prototypes showed the potential as well as the flaws of our design process. Folding the construction together by hand is convenient but only stable enough to a certain extent of size and does not allow the construction to be disassembled. Furthermore, as everything is lasered and folded together from one piece, this requires the construction to be produced from one metal sheet and doesn’t allow to optimize the construction for the laser cutter and save material. A future approach could be bending support angles which are then screwed together with loose pieces.

Working with predefined pieces seems a good approach to get started, but to create constructions with specific dimensions or shapes, requires a kit with many different elements, which in turn need a bigger menu or interaction area. A forthcoming strategy could be to have a set of predefined pieces which can be modified in size or shape. This way, the user is not overwhelmed by too many possibilities and does not have to search through a huge catalogue of pieces.

I realised that having a first functional prototype is essential when developing something new to evaluate further action. An interdisciplinary team and collaboration with other professionals and industrial partners can excel a project and ensure quality. However, it is important to choose the right timing for further actions and getting partners involved, to stay focused and not get overwhelmed. While developing something innovative, remaining agile and flexible towards the outcome is essential. The hardest thing in this project was balancing a vision and ideas with what can be developed with the skills and resources available. By looking at the issues from the perspective of an engineer as well as a designer I was able to create something functional and usable which at the same time is aesthetically pleasing and user-friendly.

PROCESS

TIME

PROCESS STAGES

ACTIONS TAKEN

Nov 17
2nd year HyperWerk

Concept for Virtual Craftsmanship (VC)

Collaboration with Institute for Interactive Technology

Feb 18
2nd year HyperWerk

Research for VC

Software evaluation and learning

Jul 18
2nd year HyperWerk

Start of collaboration and work on VC

Modelling, texturing and programming of VC

Sep 18
3rd year HyperWerk

Reflection of VC

New design approach needed to create construction

Nov 18
3rd year HyperWerk

Concept for VDK
Start follow up project of VC

Teambuilding HyperWerk, Collaboration HumanTech and Inst. Inter. Technology

Jan 19
3rd year HyperWerk

Programming

Learning Blueprints for user interaction

Mar 19
3rd year HyperWerk

Openhouse exhibition presenting current stage of VDK

First contact with enduser and presenting idea of VDK

Apr 19
3rd year HyperWerk

Project Video

Video to communicate project and find partners

May 19
3rd year HyperWerk

Acceptance to master degree

Shift in focus on personal development of technical skills

Jun 19
3rd year HyperWerk

Concept for communication approaches and funding

Planning of Physical box, website, tutorials and prototypes

Jul 19
3rd year HyperWerk

Partnership with Meyer Blechtechnik and Regent Lighting

Industrial partners to produce prototypes

Corporate identity and VR menu design

Linking corporate identity with interaction design

Communication to reach people not familiar with VR

Production of physical box and catalogue of pieces

Hyper Festival

Showcasing VDK Software and lamp prototypes

Reflection

Reflection with partners on future implications

INSTITUTE FOR INTERACTIVE TECHNOLOGIES

FHNW
BRUGG

INSTITUTE HUMAN-TECH

SCHOOL OF ENGINEERING AND ARCHITECTURE
FRIBOURG

VDK

REGENT
LIGHTING
LED LIGHTS
BASEL

MEYER BLECH-
TECHNIK
LASER CUTTING
BRITTNAU

BLASER
METALLBAU
SPONSORING
ANDELFINGEN

ACADEMIC INSTITUTIONS

INDUSTRIAL PARTNERS

VIRTUAL VALLEY
RESEARCH SOCIETY FOR DRAFT DESIGN
BASEL

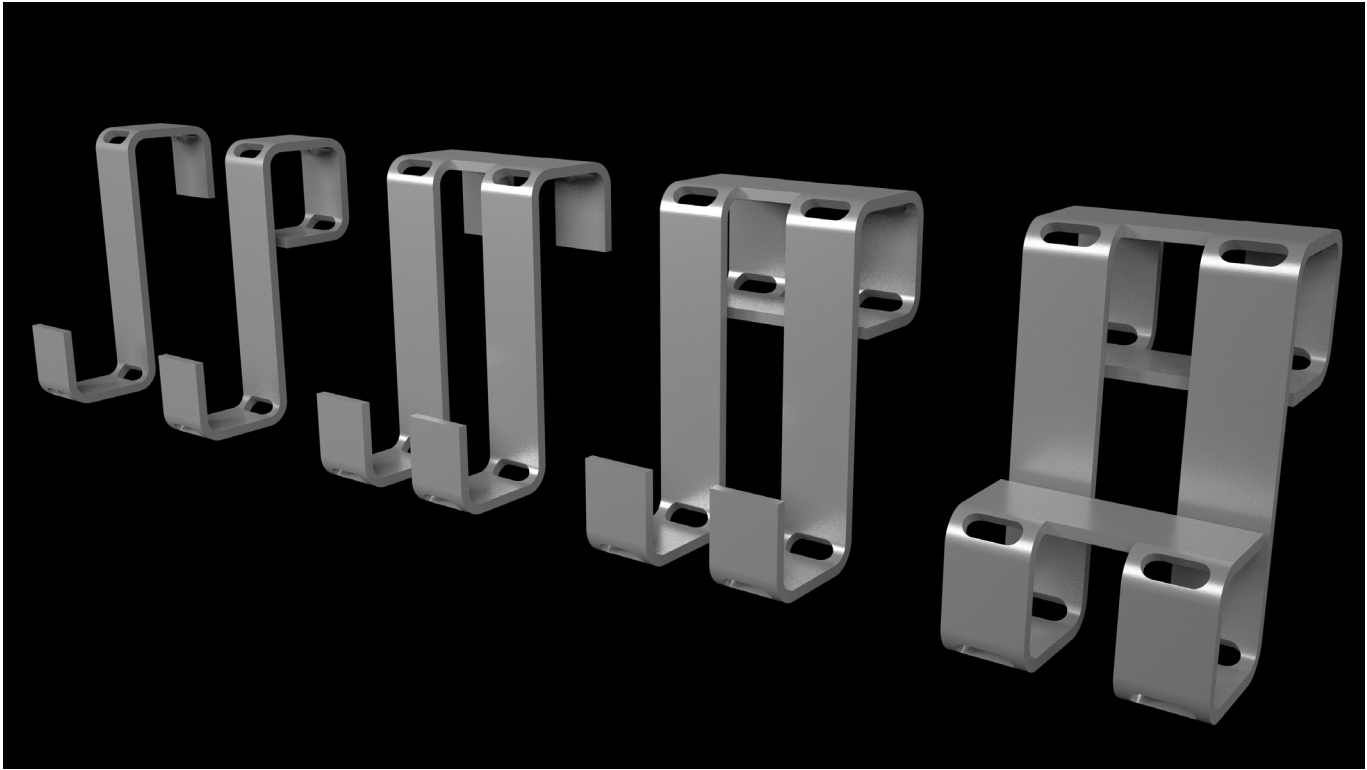


Figure 1: Renderings of sheetmetal construction with three pieces.



Figure 1: second prototype of the menu and the controller.

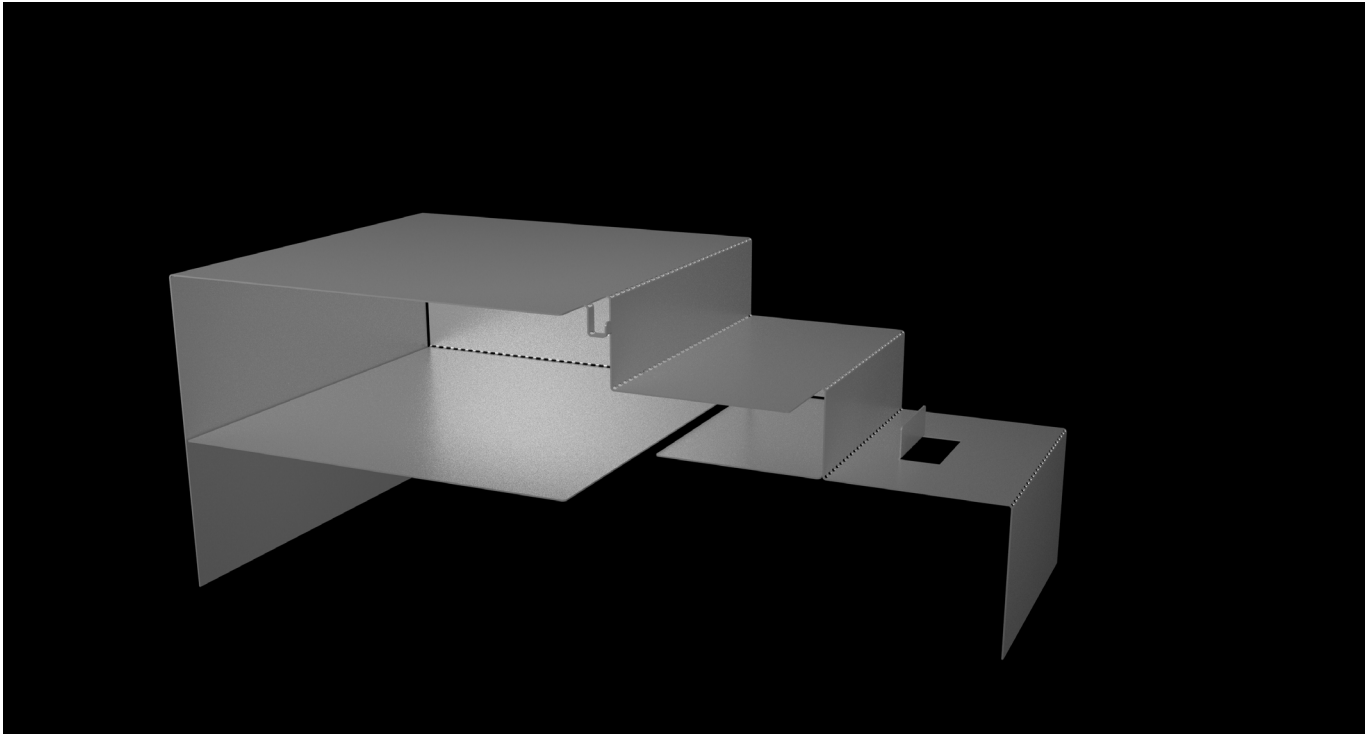


Figure 2: Rendering of sheet metal construction with four pieces.



Figure 2: Experimenting with three virtual cameras and their navigation to take images and videos.

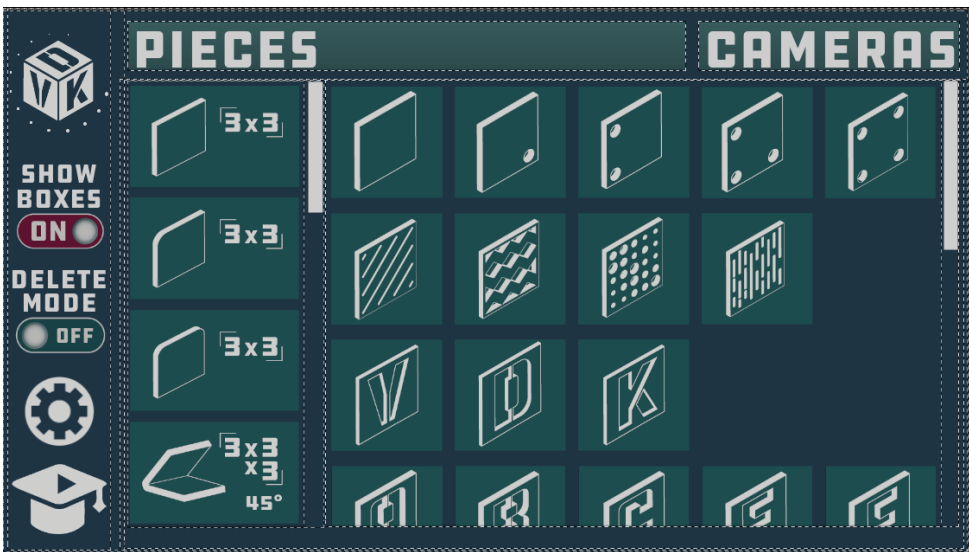
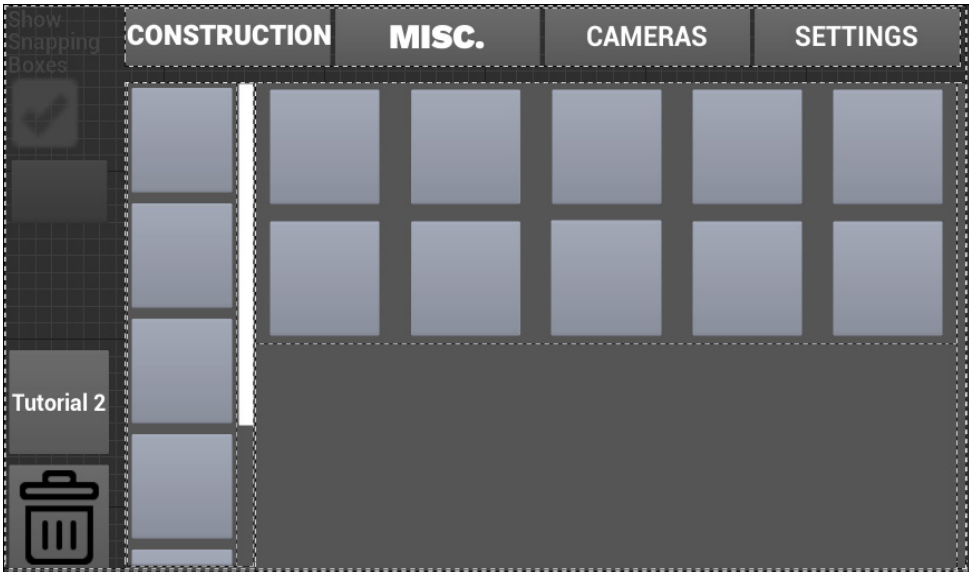
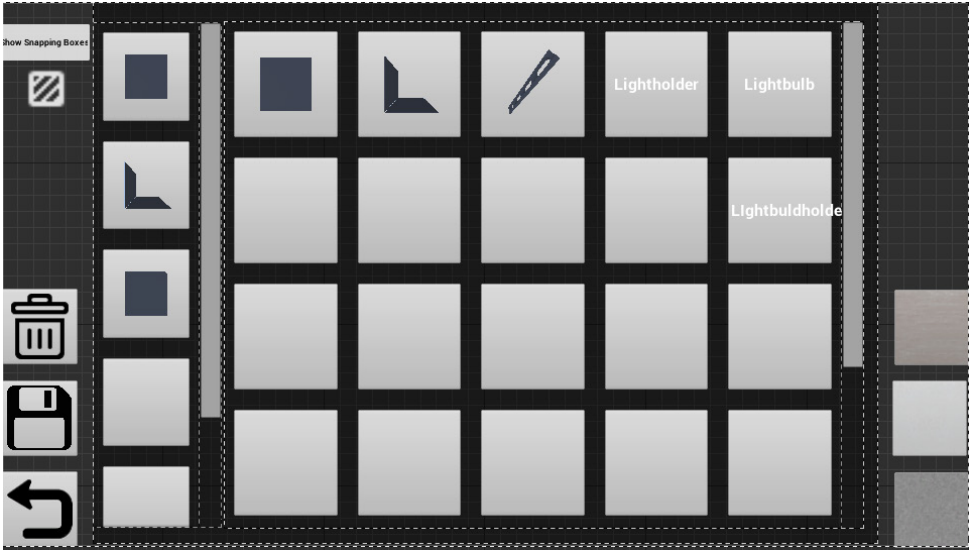


Figure top: First VR menu

Figure middle: Second VR menu after first experiences with potential users

Figure bottom: designed menu after usability tests and corporate identity design.

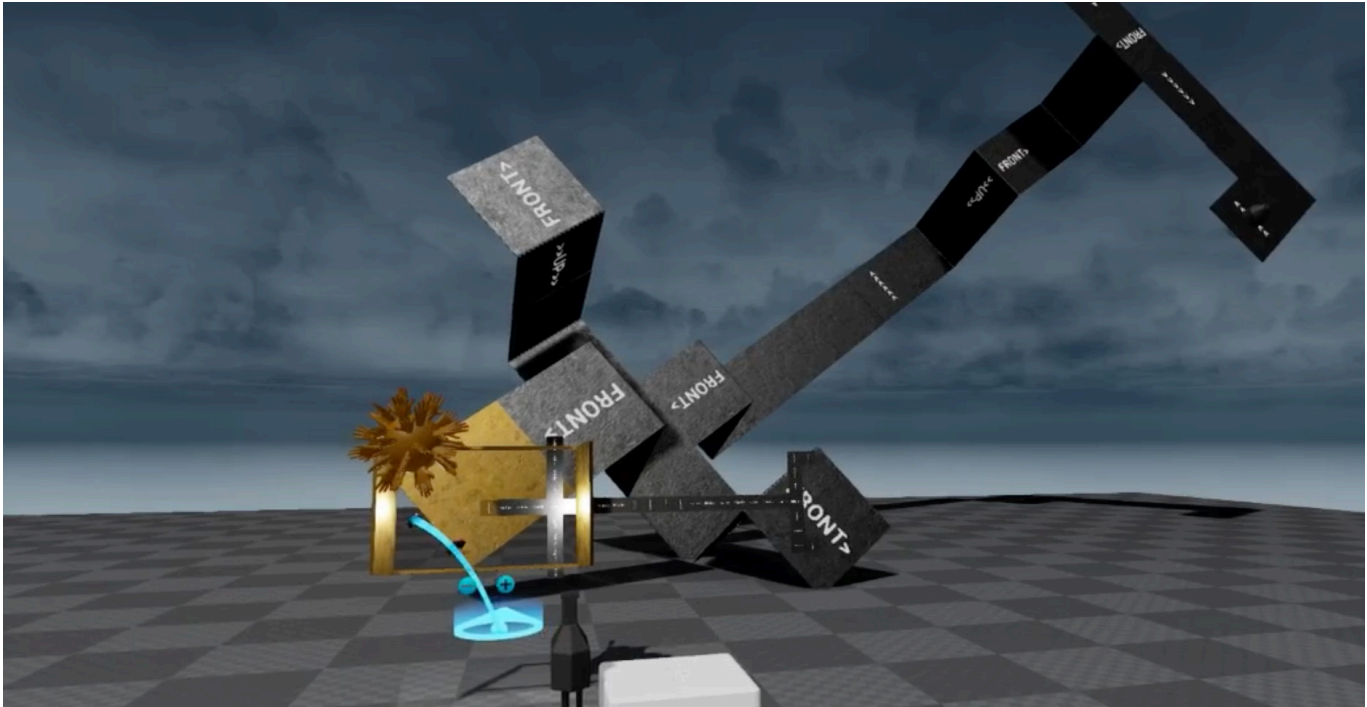


Figure 1: Screenshot after the snapping of 90° angles and the flat projection of the construction was developed.

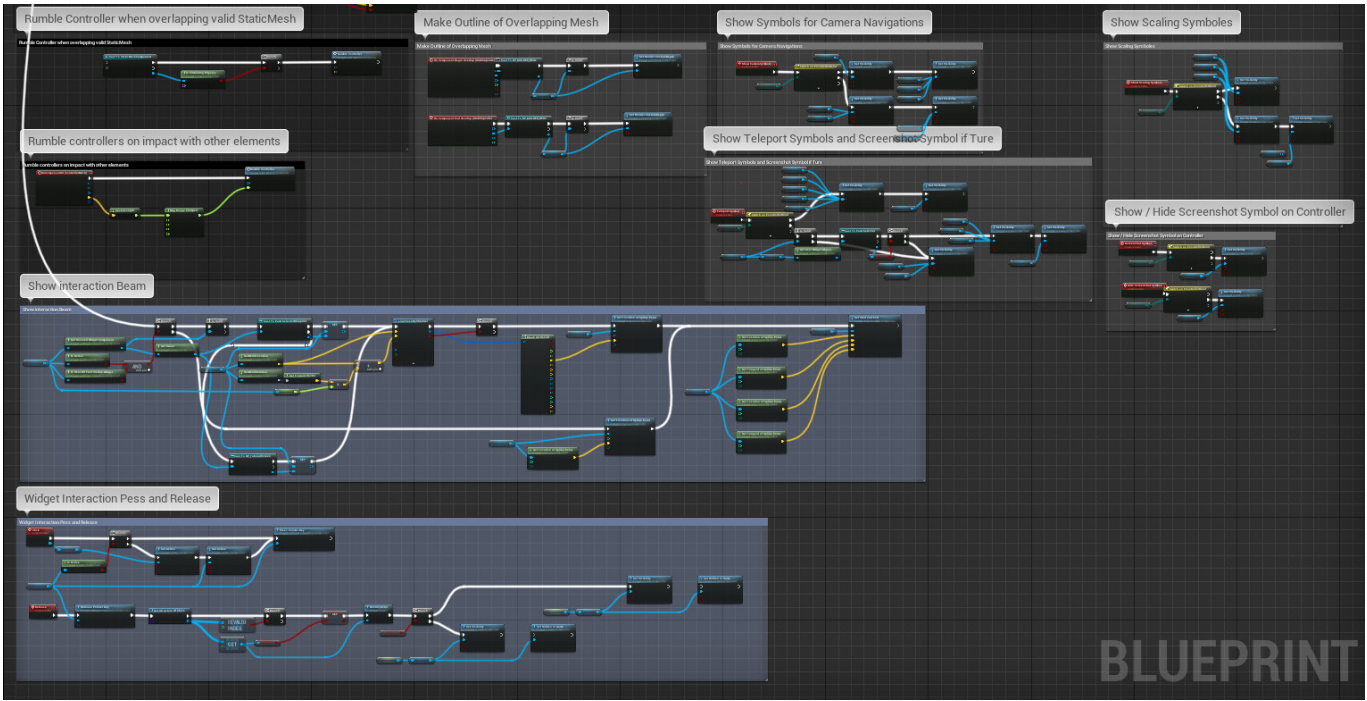


Figure 2: Blueprints: The visual scripting system of Unreal Engines 4 with which we developed VDK.

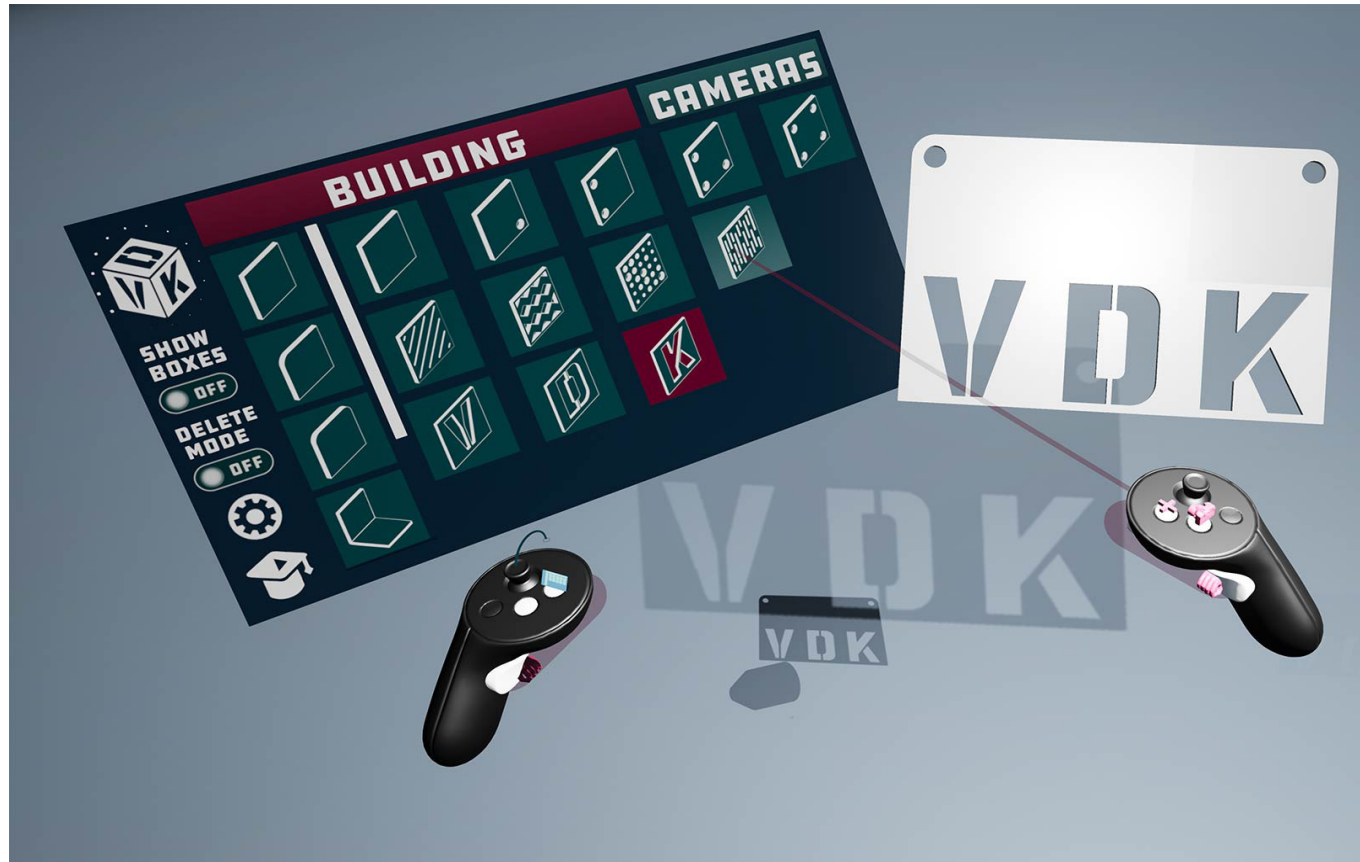


Figure 1: Controllers with laserbeam to navigate the menu.

«It is impossible to work in information technology without also engaging in social engineering».

JARON LANIER



Figure 2: The symbols on the controllers indicate the underlying action of the button and help to guide the user.



Figure 3: The red outline around pieces indicates when and which piece can be picked up.

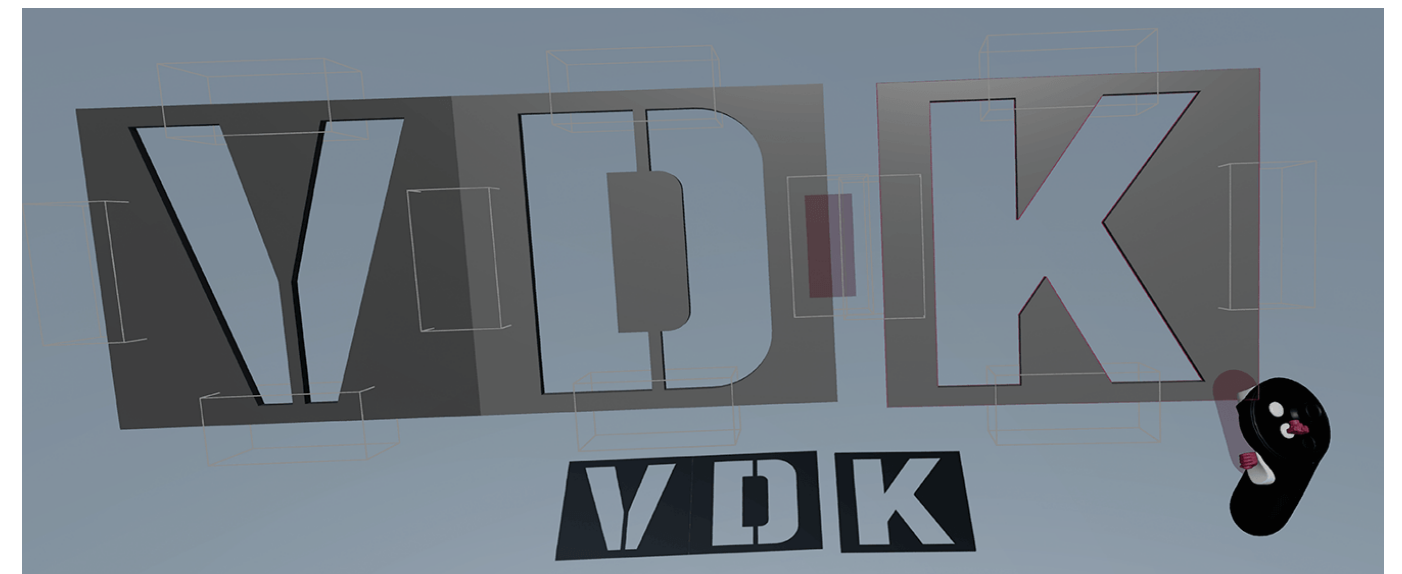


Figure 4: When two white boxes overlap, a red cube indicates that the pieces snap together.

Discussion

Years theme - Connecting the dots - doing care.

With VDK I connect the virtual with the physical world, end-users with CNC machines, craftsmanship and technology, bridge between engineering and design and provide an intuitive platform for creation. For a VR Software multiple “dots” have to be connected to ensure a satisfying experience; 3D modelling, texturing, interaction design and usability, game design and object-oriented programming.

The current environmental situation is alarming and therefore sustainability needs to be considered for every step of a design process. The prototypes made with VDK are easily recyclable since they're only from one material and produced locally with a laser cutter that runs on solar energy.

Through the users involvement in the design process, I hope to achieve a more sustainable and emotional relationship between the user and products.

Future implications

With the invitation to the “Light and Building” Exhibition in Frankfurt¹ by the company Regent and the interest of Meyer Blechtechnik, there is a clear potential for the technology as well as the design method within the manufacturing industry. VDK can also be applied to other production methods such as milling, bending or waterjet cutting, and can be used for different materials such as wood, textiles, plastic, stone, cardboard etc.

I chose the name VDK - Virtual Design Kit - because it is not specific to material, production method or a design, because I envision a future where projects, complex constructions and buildings are developed with VDK. Next to further functionality that supports and enhances the design process, I also see VDK as a work environment for transdisciplinary collaboration where multiple people have access to a shared space from different locations. In the future, BIM (Building Information Modelling) should be integrated to retain model intelligence from concept to construction, provide an accurate cost prediction and increase efficiency and effectiveness with multiple entities involved. The increasing development of hardware within the mixed reality field provides a promising future but also asks the question of what the future medium will be. Having VDK on an augmented reality headset would be extremely interesting since it would allow to design constructions directly at the desired location and thus provide an even better insight on the finished design.

VDK lowers the threshold of creating goods that can be sent directly to your doorstep. This might increase the consumption and the production of goods. This does not only apply to individuals but also to companies and mass production. I would like to see a future where disruptive technologies such as Mixed Realities are used sustainably, and I plan to design VDK in an educative way regarding this issue.

Diversity inclusion

Traditionally craftsmanship and construction are very male-dominated industries and I hope that VDK can give people with no background knowledge, other genders and disabled people the chance to play an active part in this field. I would like to see the virtual space bridging the gaps between different nationalities, races and ability-levels to bring people together and ensure a more diverse and equal future

Team

All the work in VDK has been initiated, coordinated and supervised and by me.

HyperWerk:

Christoph Schneider, Venti.

Christoph helped on the:

- Environment Design of VDK for the Openhouse exhibition in January 2019
- Physical kit: Design and production.
- 3D Modelling of the kit elements.

«I was able to learn a lot from Tobias. His vision for the project and project management approaches guided us from concept to product. At the same time, we were free to integrate ourselves and lead the project in new directions and discovering new aspects of the tool.»

Nicolas Dubied, Venti.

Nicolas helped on the:

- Physical kit catalogue: Design and production
- VDK menu: Design of buttons and symbols

«It was a pleasure working with Tobias, visionary of VDK, great team player and a good project leader. His ambitions and his technical capabilities always provided fresh inputs and motivated me to go further. By working on VDK I was able to explore new fields and improve various skills.»

Brianna Deepprose, Venti.

Brianna helped on the:

- Project video: Storyboard

HumanTech:

Alessandro Silacci, Project Coordinator

- Supervising VDK

«Tobias had a clear idea of the projects' results and always provided the required support to the students in order to attain the objectives. Tobias has been very pedagogical with the students and showed a great mastery of the tools used. Furthermore, he has always been there to support the students, provided good feedbacks and never lost motivation for the project. We are truly satisfied with the work and are looking forward to collaborating again in the future.»

Conclusion

We have reached our goal of designing a prototype of a virtual reality design software that allows anyone, with minimal effort, to create sheet metal constructions. I also see my personal goal of building a foundation for my future as achieved, with the acceptance to the master's degree “Innovation Design Engineering”. The feedback of our partners and users has shown that VDK can be used within industry and is beneficial for a design process. This last year at HyperWerk has been extremely enriching and allowed me to progress educationally and personally. I'm looking forward to further explore the implications of mixed realities in the field of construction with VDK in my master's degree.

¹ Light and Building: <https://light-building.messefrankfurt.com/frankfurt/de.html>



Figure top: Physical Kit closed.

Figure middle: Physical kit with open lids.

Figure bottom: Physical kit fully open with manual snappable pieces, led light, light holder, electricity plug, switch, Arduino board, cable, screws & nuts, wrench and Allen key inside.

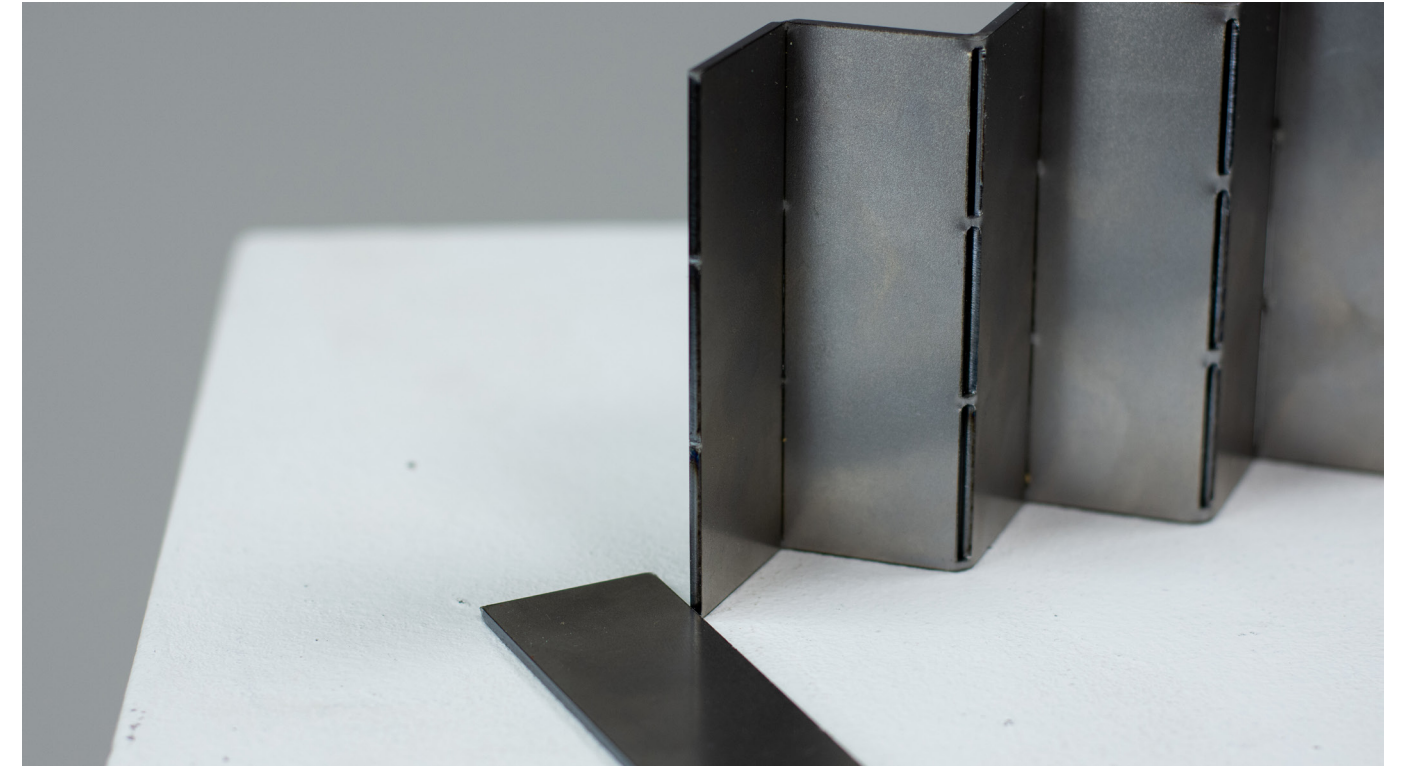


Figure 1: Lasered examples of perforated bending edges.

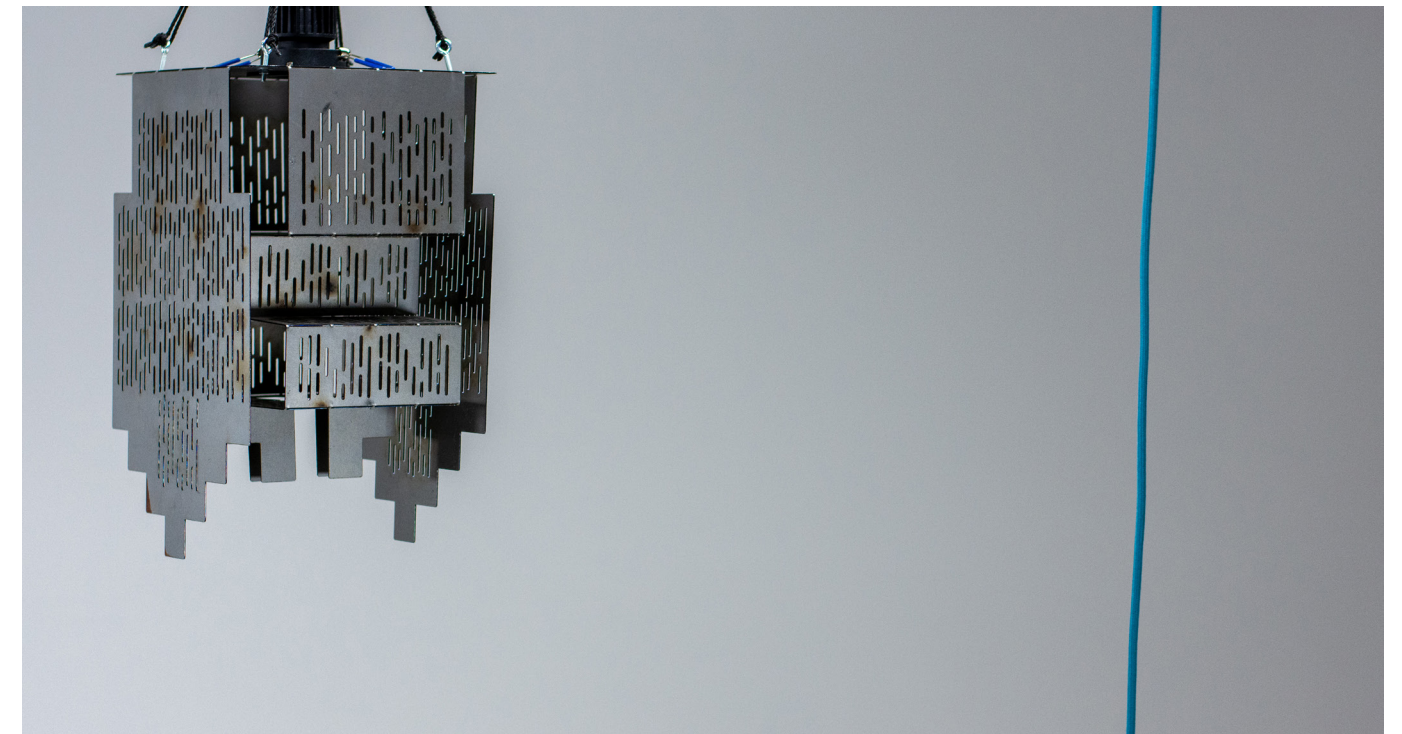


Figure 2: Hanging lamp made from 1mm steel raw and folded together.

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- IDE: <https://www.rca.ac.uk/schools/school-of-design/innovation-design-engineering/>
- Innosuisse: <https://www.innosuisse.ch/inno/en/home.html>
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- Spectator Screen: <https://www.youtube.com/watch?v=1l15Ryz4Ce8>
- Navigation Mesh: https://www.youtube.com/watch?v=PPOCYDPOnK0&list=PLsP3MXv9-PLT30hc1xt0z0Qbv7lLqQ_Eh

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Figure 1: Team, physical kit and sheet metal lamps.

Abstract:

Virtual Design Kit uses virtual reality as a platform to design sheet metal constructions. Users can attach predefined elements to each other to create their design. While designing a flat projection of the design is generated, which can be exported and cut by a laser. The design is sent back to the user ready to be folded up at perforated bending edges. VDK allows anyone without prior knowledge of craftsmanship or CAD software to create sheet metal constructions. VDK is an innovative approach to lower the threshold in generating files to produce with CNC machines.