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Report 2: Optimizing the product of e-VOLuTion - Concept and approach

In order to connect to the last report, an in-depth literature review is conducted in the areas of mixed reality, visual analysis and ultimately the connection to a new way of life cycle assessment or rather life cycle engineering. This provides the background for the Indo-German consulting team to develop a concept for the visualization of environmental data as well as product data for process optimization in terms of increased sustainability for the company e-VOLuTion. This is followed by a subsection containing a description of the concept and one explaining the approach to implementing the concept.

Literature research

In Augmented Reality, through the use of holographic technology, digital visual components, noises, and other sensory stimulation are combined to create an improved, interactive image of the actual world.
Three elements make up augmented reality (AR):

- a fusion of the digital and physical worlds
- in-the-moment interactions and
- precise 3D object recognition.

By superimposing digital material in actual working situations, augmented reality provides a more effective method of creating, curating, and delivering digestible instructions. There are two types of augmented reality: marker-based and marker-less. Example use of AR in Retail: A retail store's internet app allows customers to utilize augmented reality to see how things, such as furniture, would appear in their homes before making a purchase [1-2].
Virtual reality is the use of computer technology to create simulated environments. The user is immersed in a three-dimensional experience thanks to virtual reality. Users engage with 3D worlds instead of just seeing a screen in front of them. A computer becomes a portal into other realms when all five human senses are simulated. The availability of content and computational power are the only constraints for a fantastic VR experience. Non-Immersive Virtual Reality, Semi-Immersive Virtual Reality, and Fully Immersive Virtual Reality are the three basic subcategories of VR.
Example use of VR in Real Estate: Beyond 3D models, developers may experience living within their brand-new property. VR might be used in both residential and business settings. Additionally, co-working spaces may employ virtual reality to place a potential renter inside the facility before they sign up [3-4].
Combining the physical and digital realms allows for more natural and intuitive 3D interactions between people, machines, and their surroundings. This is called Mixed Reality. The development of computer vision, graphics processing, display technologies, input methods, and cloud computing are the foundation of this new world [7].
True mixed reality experiences can only be made possible by combining three key factors:

- Cloud computing powered computer processes.

- Advanced input techniques and
- Impressions of the environment

The worlds of physical and digital are combined in mixed reality. The virtuality continuum is a spectrum with these two worlds at each end. The mixed reality spectrum is how we refer to this range of realities. We have the physical truth that people exist on one end of the range. We have the matching digital reality at the other end of the spectrum. Example of MR in Engineering: Engineers could be able to work remotely, perform 3D modelling before any money is spent on labour and materials, and more with the use of mixed reality gadgets. This technique would speed up design and development while also reducing costs [5-6].
Difference between AR, VR, MR, and XR: In the recent growth of types of virtual realities, it can be challenging to keep up because of their subtle differences. The types of digital realities are [2]:

- Augmented reality (AR)— designed to add digital elements over real-world views with limited interaction.
- Virtual reality (VR)— immersive experiences helping to isolate users from the real world, usually via a headset device and headphones designed for such activities.
- Mixed reality (MR)— combining AR and VR elements so that digital objects can interact with the real world, which means elements can be designed and anchored within a real environment.
- Extended reality (XR)— covering all types of technologies that enhance our senses, including the three types previously mentioned.

Visual Analytics

LCA data is complex to understand and is, therefore, subject to misunderstanding by various parties in the industrial field with different expertise [8, 12]. It is required to have expert knowledge to interpret the results [11] and thus rarely provides suitable decision support [12]. Adding to this, a communication deficit between a number of levels of the workforce complicates the outcomes [11]. Product designers for example need as early as possible in the process of a new product the LCA results in order to minimise consequences later on because of the design choices made in earlier stages. These results are often presented in 2D through vertical bars charts which are easily comparable by the length equalling the value [8]. A great disadvantage is the inadequate visualization technique that hinders the interpretation and the decision making [11]. Over the last decade, the data collected for product development has increased drastically [10, 11] but our ability to analyse the data remains modest [10]. Many times, large data sets for energy and resource flows of a product are stored and presented over its entire life cycle from the manufacturing process within the facilities to the end when it is disposed of [11]. The relevant information of these data sets has to be extracted quickly since the investment of time and money are squandered because of limited proper use of the data [10].

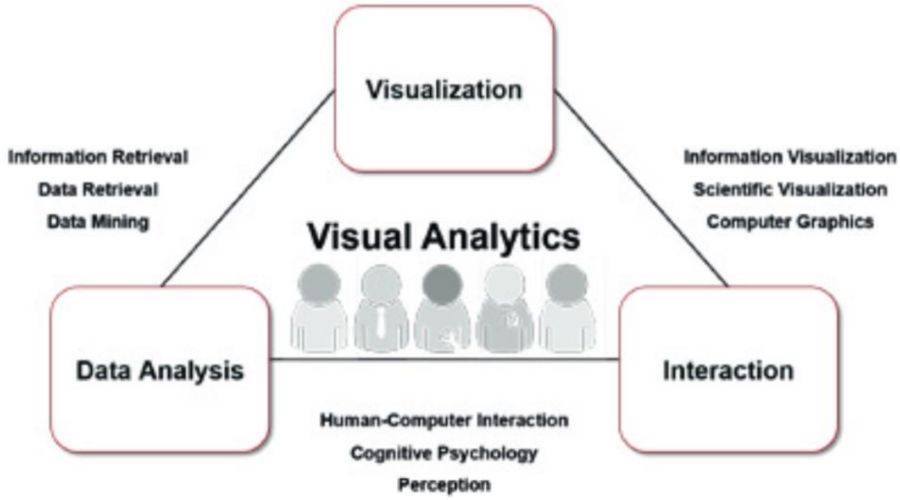

Figure 1: Visual analytics combining data analysis, interaction and visualisation [11]

For this reason, Visual Analytics (VA) decreases the time spent for interpretation of the data, making it easier to visualise and targets the involvement of stakeholders and decision-makers as well as the reduction of the complex cognitive work [10, 11]. It is an approach to combine and facilitate the data analysis, human interaction and visualisation as shown in figure 1 [8, 10, 11, 12]. It aims at visually representing information as a human-centred approach to make better decisions by delivering the direct interaction with the data [10, 12]. The user can handle life data sets, meaning “massive, multi-dimensional, multi-source, time-varying information streams” [10], through VA methods and, in this way, react flexibly, creatively and fast to different events by using their background knowledge [10, 11]. VA is to be used in an iterative process by collecting data, processing and presenting it, and making decisions [10]. This feedback loop uses the three terms as shown in figure 1 to visualise, interpret and prototype LCA results by constantly changing the parameters or limitations [11]. The user is solely responsible for the appropriate visualisation and the efficient and effective communication of the results which is a non-trivial task [10]. The human perceptual system limits visualised multidimensional data in regard to the number of dimensions [9]. Because of this, the best option is a 3D spatial layout since it is the natural human way of perception [9]. Nonetheless, increasing the amount of data to some extent, there will be a data overload and at that given point the user can be expected to misinterpret the relations presented [9]. Employing two variables, the surface patch in 3D for three ordinal levels has one of the nine shapes in figure 2. This is for real applications often insufficient and thus more than two variables are necessary per cell [9].

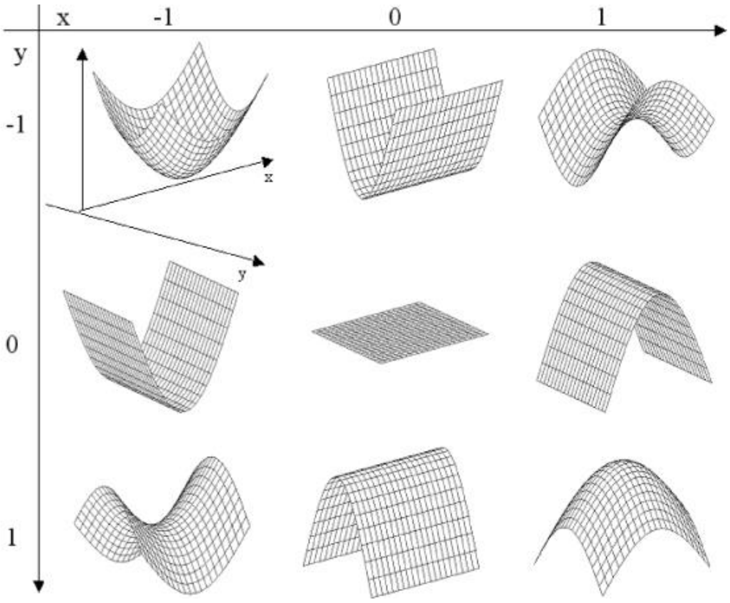

Figure 2: the nine shapes when using two variables [9]

VA comes with major benefits but also has challenges some of which are shortly introduced. The visual scalability defines the capability of displaying and processing large data sets with the appropriate techniques [10]. The key challenge here is to compress the dataset and maintain the highest possible amount of detail since the accuracy is decreasing by this method [10]. Following the interpretability which generates the right conclusions out of the data stating it the biggest challenge of all [10]. Another challenge of VA is giving the right data at the right time with the suitable methods and tools highlighting hotspots and trade-offs in different charts while providing the level of accuracy [11]. Modelling tools are a limiting factor since they restrict human interaction which is counterproductive to the model shown in figure 1 [11]. However, tools for exchanging data efficiently with a high degree of automation are crucial to raise the potential of VA methods and approaches [11]. One approach can be realised in Mixed reality (MR) [11, 12]. It has become a powerful tool to increase the productiveness and significantly improve processes [12]. As shown in figure 3 the conventional way of forwarding LCA data in the upper part of the image yields poor results; however, by implementing MR technology the process can achieve larger outcomes. Yet, due to the very limited tools MR technologies have been used in few case studies [12].

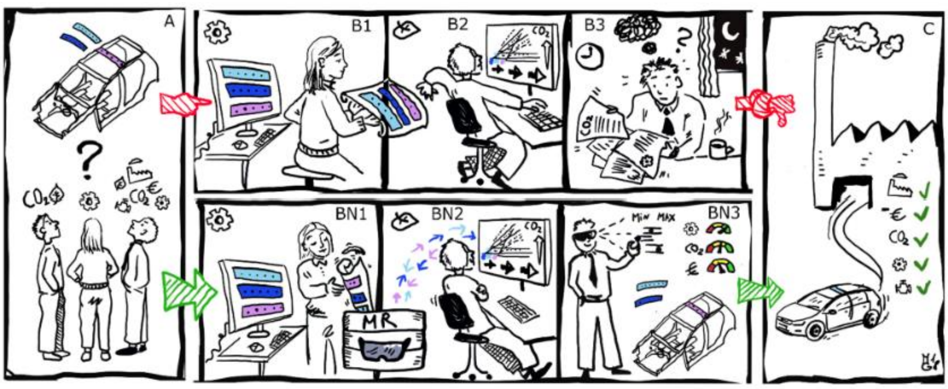

Figure 3: the conventional way to forward LCA data and an MR approach [12]

The following steps may help by finding a solution to the visualisation problem on VA in MR [10]:

1. Problem characterization
2. Identification of MR software
3. Coding, interaction, design and implementation
4. Validating the prototype

Development tools available for Mixed Reality

Choosing appropriate AR Development tools is essential to create a user-friendly AR application. When it comes to choosing an AR development tool, we must consider some important factors such as support for the platform (Android, iOS, web), Its cost, performance factor, Development engine (Unity, Unreal, flutter, react native, native android/iOS, etc.) support, tracking support (Plane, Image, face, body tracking), GPS support, OpenSceneGraph (3D graphics) support and much more.

Platform (Android/iOS)

ARKit is Apple's development kit for AR-based iOS applications. It is fully integrated into Apple's Hardware, this streamlines development work, allowing coders to focus on creating the best product possible. It consists of Apple's reality composer tools which make it easier to convert 3d models into fully manipulable AR objects. It performs better than AR Core in terms of image tracking and recognition. It has been used to develop many famous applications like IKEA Place, Stavia, and Labster. The drawback of ARKit is that it is only compatible with IOS devices
AR Core is Google's development kit for building AR applications. Initially, it only had support for android, but the recent iterations of the kit cater for iOS as well. It has superior graphical capabilities. It matches ARKit in terms of colour intensity and temperature but adds a few extra features that help craft immersive AR experiences. With AR Core, coders can use shaders and manage pixel intensities – opening up new visual possibilities for virtual objects. It is also capable of handling light estimation. This applies ambient lighting based on your camera image, making virtual items seem much more realistic. It has been used for creating applications such as streem, Beer Pong, AR navigation, etc.
WebAr is a new technology using which we can view AR content without having to download mobile applications. Using web AR, we can embed interactive content wherever we want by sharing an AR-enabled URL. 8th Wall is one of such frameworks released by Niantic. It lets users view realistic 3D objects and volumetric videos in their local area without waving their phones or resizing content.

Development Engine

There is a variety of Development Engines that are available for developing AR applications (such as Unity, Unreal, flutter, React Native, native android, iOS, etc). To choose the appropriate development engine we need to consider factors such as rendering support, Asset store, performance, and developer's community support.
AR Software Development Kits
SDK is a set of software tools and programs that include documentation, application programming interfaces (APIs), code samples, libraries and processes, as well as guides that developers can use and integrate into their apps. Developers can use SDKs to build and maintain applications without having to write everything from scratch.
There are a variety of SDKs that are available for developing AR applications, each having its advantages and disadvantages. A few of them are as follows

1. Lightship ARDK
2. Vuphoria

3. AR foundation
4. MRTK

Our Concept

The background research now enables a concept for a possible application to optimize the product of e-VOLuTion. The main conclusions are the complexity of LCA data, the importance of linking LCA data with other technical data and the lack of knowledge about LCA of the stakeholders. Therefore, an application should be created, which supports the individual user in their field of decisions and directly forward these to other decision makers with the help of the application. This is because this application is supposed to work interactively with each other. That means, it is possible for a user to cause restrictions in other areas by means of their decision. For example, a developer in the area of a single component can determine that production only makes sense with a certain material, and this leads to the fact that the material is no longer displayed for other stakeholders. Thus, experts from the individual areas have a direct influence on the decision as a whole.

In figure 4, a general illustration of the application is shown. In order to describe this in more detail, it is necessary to look from the perspective of a user. The user selects (point 2) whether the user is, for example, a product developer or a process developer. In this way, the relevant information and application controllers can be displayed immediately for the respective user. The following concept focuses on the product developer. This is because, as previously described, the integration of LCA data at an early stage within product development is gaining in importance. At point 1, the user can select the location where the final product is going to be used. Which is relevant since the location matters in various considerations or analysis and with the selection the correct data can be accessed. For example, the mix of electricity or even the climate depends on the location and can have influences on the final decision. After selecting the location and the user, the interface is built accordingly.

Here the different parts of the product are shown as in the figure (point 5), with the help of the arrows the user can reach the other components. Thereby the different parts of the product are displayed as shown in the picture below (point 5), by means of the arrows the user can reach the further components.

At each individual component (point 4), the user can now select different scenarios. An example would be different material compositions of a partial product. Either the user can either select one specific case or all alternatives at the same time. In the second case, a diagram as shown (point 3) would appear. This now illustrates the CO2 emissions of the different options over time, i.e., the lifetime of the product. The emissions can be caused during the production of the product alone, as well as during the replacement, but also over time. As a result, the surface shown in the diagram will build up in a different way. By means of the colours the user can determine now, at which time and also in which case the component is optimal. Further information, which the user needs additionally, can be seen in the picture at point 6. Here, for example, assumptions or certain conditions can be listed.

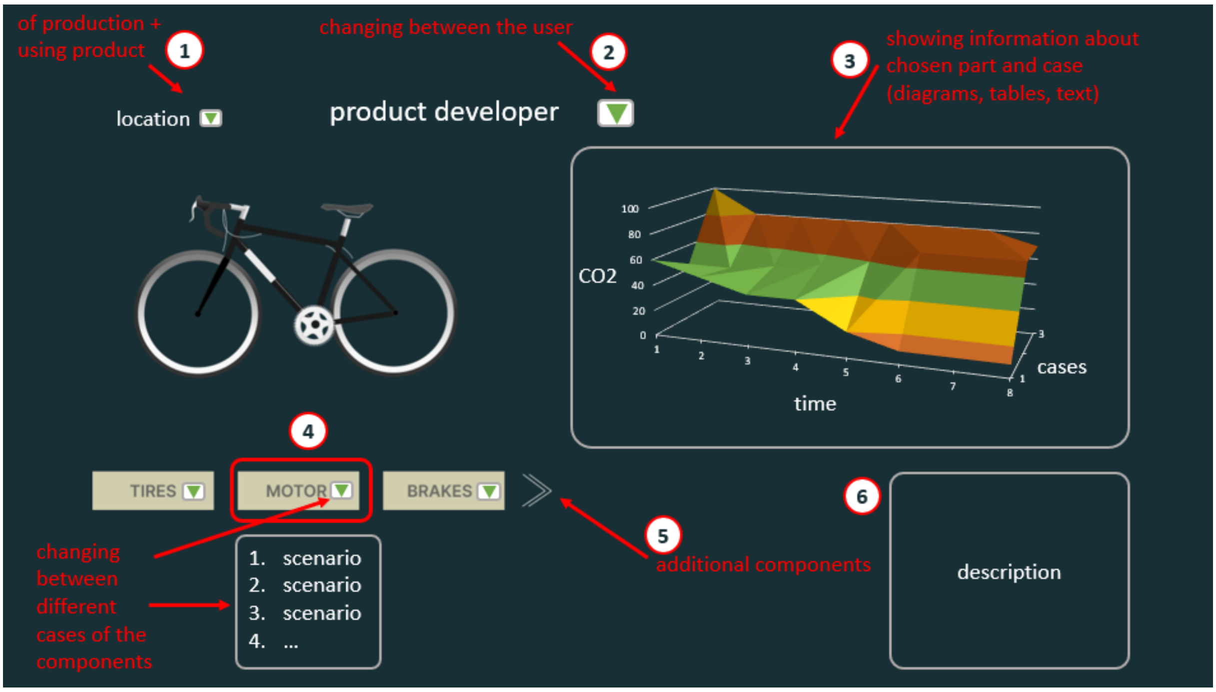

Figure 4: General illustration of our application with descriptions (in red)

After a rough description of the application, here is some more information about what is not visible in the picture. The diagrams are mostly shown in three dimensions to make it easy for the user to visually see in which case/scenario the best results can be achieved. The e-bicycle is shown in three dimensions in the prototypes. This allows users to take a closer look at it. In addition, the individual components can then be placed in focus so that critical parts of them can be identified.

In addition, the environmental effects can be directly identified in the whole, or which part has the greatest influence. For this these are colored in different colors, in order to identify that and information about the values/data and/or diagram in the provided fields (see in picture 3 & 6).

Our Approach

In the next steps, the representation shown above will be transferred to the application using the MRTK software.

For this purpose, the interface with the individual functions such as the product itself, pop-up menus and also the various buttons will be implemented initially. In addition, first diagrams will be generated using test data. Thereby it will be considered which data or information is most relevant for the particular stakeholder.

Currently, the application is completely represented in virtual reality. It is now necessary to check whether this is the right way to present it or if a mixed reality application would make more sense.

Ultimately, it is important to create real added value with the application. Therefore, we put ourselves in the position of individual stakeholders during development and testing, and record this accordingly in the results.

References

[1] https://www.techtarget.com/whatis/definition/augmented-reality-AR

[2]https://dynamics.microsoft.com/en-us/mixed-reality/guides/what-is-augmented-reality-ar/
[3] https://sopa.tulane.edu/blog/whats-difference-between-ar-and-vr
[4] https://www.marxentlabs.com/what-is-virtual-reality/
[5] https://guides.library.utoronto.ca/c.php?g=607624&p=4938314
[6] https://bernardmarr.com/the-most-amazing-real-world-examples-of-mixed-reality/
[7] P. Milgram, F. Kishino, A Taxonomy of Mixed Reality Visual Displays, IEICE Transactions on Information Systems, Vol E77-D, No.12 December 1994(https://cs.gmu.edu/~zduric/cs499/Readings/r76JBo-Milgram_IEICE_1994.pdf)

[8] Maud Rio, Florent Blondin, Peggy Zwolinski, Investigating Product Designer LCA Preferred Logics and Visualisations, Procedia CIRP, Volume 84, 2019, Pages 191-196, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2019.04.293

[9] C. Forsell, S. Seipel and M. Lind, "Simple 3D glyphs for spatial multivariate data," IEEE Symposium on Information Visualization, 2005. INFOVIS 2005., 2005, pp. 119-124, doi: 10.1109/INFVIS.2005.1532137

[10] D. A. Keim, F. Mansmann, J. Schneidewind and H. Ziegler, "Challenges in Visual Data Analysis," Tenth International Conference on Information Visualisation (IV'06), 2006, pp. 9-16, doi: 10.1109/IV.2006.31

[11] Alexander Kaluza, Sebastian Gellrich, Felipe Cerdas, Sebastian Thiede, Christoph Herrmann, Life Cycle Engineering Based on Visual Analytics, Procedia CIRP, Volume 69, 2018, Pages 37-42, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2017.11.128

[12] Alexander Kaluza, Max Juraschek, Lennart Büth, Felipe Cerdas, Christoph Herrmann, Implementing mixed reality in automotive life cycle engineering: A visual analytics based approach, Procedia CIRP, Volume 80, 2019, Pages 717-722, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2019.01.078