Augmented Reality Enabling Disassembly Sequence Planning

Daniela Francia, Leonardo Frizziero, Alfredo Liverani, Giampiero Donnici, Nicoletta Dalledonne
Department of Industrial Engineering
Alma Mater Studiorum University of Bologna
Bologna, v.le Risorgimento,2 - 40136, Italy
d.francia@unibo.it, leonardo.frizziero@unibo.it, alfredo.liverani@unibo.it, giampiero.donnici@unibo.it, nicoletta.dalledonne@studio.unibo.it

Abstract

Nowadays, the importance of the concept of "Urban Mining" is growing even more, which consists in searching for raw materials inside objects that have reached the end of their life, instead of "inside nature". It can be commonly found especially in mechanical and electronic equipment valuable materials, which can be extracted and reused as secondary raw materials.
The importance of Design for Disassembly (DfD), that is the central topic of this paper, is increasing because of it brings great advantages in terms of disassembly times of components that have reached the end of life.
According to the Disassembly Sequence Planning (DSP), this paper presents an application of several methods derived from literature to a two-way valve, to find optimal disassembly sequences. Different sequences have been compared in terms of disassembly time consuming, by the conversion of operations into disassembly time using accredited methods found in literature.
Finally, an application in Augmented Reality is proposed to simulate a practical evaluation of what has been theorised so far.

Keywords
Design for Disassembly, CAD modelling, Sequence Planning, Augmented Reality

1. Introduction

Inside the cities, large quantities of secondary resources (waste) are produced that can be used to produce raw materials and, at the same time, cities need energy. The coupling of the waste supply chain with the energy one could constitute a new way of understanding the industrialization process, more virtuous and sustainable. Furthermore, considering the variability of prices, the limited availability, and high environmental costs of many raw materials, it becomes necessary to use resources already available in the area. The term that today encodes this new approach is Urban Mining. This is an attempt to shut down the production processes, but the operating methods are not. If some, in fact, consider landfills as mines (urban miners are those who go looking for metals in waste), others consider the set of treatment processes aimed at recovering raw materials. In fact, there are many aspects to consider, therefore the only possible interpretation concerns the definition of a "system" that facilitates recovery and recycling. This awareness leads, in recent years, to focus worldwide the reuse and recycling, since resources are running out and consumption is at its highest. Hence, some strategic methods have been investigated to enhance the design on the basis of the life cycle of the product in order to improve the quality and reduce the costs and lead times of a project. This is in general well known as Design for X (DfX), but in particular in this paper we want to focus on the Design for Disassembly (DfD). The design made in the perspective of the DFD is the basis of Design For Environment (DFE), that is, a design with the purpose of making products and processes compatible with the environment. Furthermore, it brings numerous advantages within the analysis of the End Of cycle Life (EoL), since it proposes techniques which are intended to facilitate maintenance and speed up the total disassembly of the products. DFD has also purposes common to those of the Global Goals For Sustainable Development, i.e. the Global Goals for one Sustainable Development.
The DFD itself pursues in particular to the development of infrastructures and industrial productions that are in balance with the environment and use resources in a sustainable manner and to individuals and businesses alike must strive to

halve waste through reduction, reuse and recycling, as discussed in Francia et al. (2016), Francia et al. (2019), Francia et al. (2020), Liverani et al. (2019).

In the industrial context, the benefits of DfD are observed with cost reductions both from the point of view of the manufacturing company during manufacturing, and of the user in the life cycle and in the recovery of the product. Many concepts underlying the Design for Assembly (DfA) agree with those of the DfD. From this it follows that one design geared towards assembly improvement may result also advantageous for disassembly. For example, reducing the number of different materials used within a project, a fundamental element in DfA, also plays an important role in the DfD, not only from the point of view of recovery of secondary raw materials, but also to obtain a decrease of the separation time of the different materials. For this purpose, they are given indications on the best ways to combine materials of different nature within a project.

Another important aspect of the DfD is the calculation of the “depth of disassembly”, i.e. the total number of phases in the sequence of disassembly. It has been proven that the cost of disassembly has a trend directly proportional to the depth, instead the revenue is characterized by a rapid initial increase, which then tends to diminish and to have a course much less than proportional to the depth, (Desai and Mital, 2003).

In this context, Disassembly Sequence Planning (DSP) is a discipline that is used frequently: it consists of the formulation of a disassembly sequence that is in accordance with the basic principles of the Df D.

As regards disassembly, two types can be considered: complete, if all the components that are part of the assembly come disassembled or selective, if the aim is to reach a specific component, called Target, without necessarily having to completely disassemble.

Also, disassembly can turn out to be destructive, if to achieve disassembly of some components is it is necessary to break others or non-destructive, if all the components of the assembly can be removed without being broken and can consequently be recycled or even reused.

The DSP must consider all the existing constraints between the different components of the assembly and the direction in which these have the possibility of being removed, in addition to the overall structure of the product at the end of its life. To make the sequence obtained is significant, it is necessary to choose materials that are recyclable and compatible with each other, as well as avoiding the use of materials that may be toxic to the environment and / or to the operators themselves, minimize and standardize fasteners (for example choose screws all with the same diameter nominal) and avoid permanent connections (i.e. gluing, welding, etc.).

To facilitate the process of finding the optimal disassembly sequence, the useful algorithms, which are used, can be characterized by:

• Graphic approach: determination of the possible sequences through observation of the graphic representation of the assembly;
• Approach with CAD: determination through the analysis of the CAD model (i.e. precedence matrix);
• Geometric approach: determination by graphs (i.e. disassembly wave).

Three disassembly research method, derived from literature, were explained, and applied to a case study to perform a comparison in terms of disassembly time and to choose an optimal sequence for disassembly operations. The simulation of the disassembly has been then performed by Augmented Reality (AR) tools, in order to make virtual assembly and disassembly simulations of CAD models proved to be useful both for making considerations regarding the Design for Disassembly, but also for the Design for Assembly, since the real physical relationships between a component and the other can be tested.

For the simulation was used PTC CREO CAD software, for creating the configurations representing the different steps of disassembly of the assembly, according to the four different sequences in exam. After that, the environment used was that of 'Animation' within the 'Applications' section of the software. Corresponding videos in MPG format were created, to virtually observe through a screen how the disassembly’s operations would be compared.

Augmented Reality (AG) consists of the overlapping of multimedia information to the reality that is being observed, through the interposition, between the observer and reality itself, of the display of a mobile device or of a wearable device, which are equipped with a video camera and have installed a AR software, equipped with tracing and rendering systems. Indeed, the principle on which Augmented Reality is based is called Overlay. What is usually observed is the frame of the object of interest through the device (i.e. tablet, smartphone, etc.): the system will recognize it, analysing the flow of images it receives from reality, and will activate the new additional level of information that will overlap and integrate in real time adequately with reality, so such as to provide new additional data, following all the movements that occur in the environment thanks to the identification of reference points in real space.

Augmented Reality exploits SLAM (Simultaneous Localization and Mapping) for depth detection; cameras and sensors, to get data regarding user interactions; processors, to play different measurements.

It is possible to identify different types of Augmented Reality, which have been developed and are exploited in different sectors nowadays. In this paper the simulation followed the Marker/Recognition based method.

The following paragraphs describe the staring method adopted for the disassembly sequences formulation and then a deep explanation on a real assembly, that is then virtually reproduced.

2. Literature Review

The optimal disassembly sequence has derived from the sequence identification by different research methods discussed in literature.
More in particular, three methods have been selected in order to be applied to the proposed case study.
The fist method is: Research on the selectable disassembly strategy of mechanical parts based on the generalized CAD model (Jianjun, Y. et al 2003).
This method aims to achieve, through disassembly, a specific selected component of the assembly, called Cx, and, in general, it consists of two phases: first of all, acquire all possible sequences disassembly that lead to the target component to be removed; then identify among all the sequences obtained which is the optimal one. It is defined as Objective Function (OF), the one that optimizes the disassembly sequence. According to the different purposes of the disassembly, there are different methods to define the OF, for example the minimum time of disassembly, the minimum cost of disassembly or the maximum rate of recycling, etc. Often, the one that can be used as the Objective Function minimize the number of components to be disassembled to reach the component Cx. This type of disassembly sequence is defined as Optimal Sequence (OS).
The second method is: time-based disassembly method: how to assess the best disassembly sequence and time of target components in complex products (Favi et al. 2019, Mandolini et al. 2018).
This method aims to identify which is the best disassembly sequence considering, not only the geometry of the components involved, but also their state of wear, any deformations created during the year and the type of tool used. It is based on 5 steps:
1) Identification of the target components of the internal disassembly of the assembly. It is based on several aspects, such as compliance with the maintenance and with the service to be provided, both provided during the use phase, compliance with the directives provided by EoL (End of Life), possibility of creating new business models.
2) Analysis of the product structure starting from the virtual model _ Yes it can take advantage of the CAD model or the Bill of Materials, both useful for extract important information, such as quantity and name of components, their geometries, general arrangement, any physical obstructions, dimensions, weight, and material.
3) Construction of the level matrix and analysis of the types of connections. The purpose is to identify the levels of disassembly and relationships precedence and connection between the different components involved.
4) Calculation of the possible disassembly sequences. Through the defining the levels of disassembly it is possible to discard some sequences from computational computation. Considering a generic level n, only components belonging to level (n) itself or to the next level (n + 1) will be considered for the calculation of the possible sequences. Therefore, after removing a component at level (n), the removal of components belonging to level (n-1) is not considered in the calculation. This rule generates an important advantage in the search for optimal sequence, drastically reducing computational time, maintaining the quality and accuracy of the results.
5) Calculation of the best disassembly sequence. The optimization of the problem exploits a simple mathematical model with the purpose of minimize the disassembly time to reach the component identified as a target. There may indeed be cases where the path more short (minimum number of operations) is not the fastest. The sequence with the lowest disassembly time value is the one that will be selected, as reported in the following equation:
BDSTx = min (Seq_1Tx; Seq_2Tx; Seq_3Tx;… Seq_iTx;… Seq_nTx)
BDSTx represents the Best Disassembly Sequence to achieve the target component Tx. Seq_iTx is the i-th possible sequence of disassembly to reach Tx. Finally, n is the total number of possible disassembly sequences for Tx.
The main step is 3, which first of all involves building a type matrix NxN, where N is the total number of components of the assembly to be disassembled, each of which will then be represented by a column and a row. One level Disassembly is defined as the level at which one or more components are connected to other components, they can be disassembled without any obstruction physics. This definition allows you to limit the number of possible paths for reach the selected target component, avoiding calculations to achieve non-optimal disassembly sequences.
The third method is: selective disassembly sequence generation based on lowest level disassembly graph method (Mitrouchev et al. 2015).
This method is based on a detailed study of the structure and the spatial arrangement of components. It is based on the construction of a Disassembly Geometry Contacting Graph (DGCG), scheme within which all the components to be disassembled placed on different levels are shown, in based on their possibility of disassembly. What distinguishes this method from others it is precisely the fact that you do not simply get the levels of disassembly of all the elements of the assembly, but also the reasons why a component cannot be disassembled at a higher level.

When considering a component to be disassembled, they can identify:
• Set of Directions of Removal (SDR), i.e. the possible directions of removing the part in an assembly;
• Collision Direction (CD), i.e. the directions in which it is not possible remove the component;
• Geometric Feasibility, or the condition in which two elements can be assembled or disassembled so as not to have interference or bumps each with the other.
To reduce the complexity of selective disassembly, this method takes advantage of the concept of a Gaussian sphere to determine the necessary SDRs. To move the objective element of a product, you must first check each contact for understand what its possible SDRs are. If a component is free in space, its SDR in the Gaussian sphere it will be represented by a sphere whole. If, on the other hand, there is a contact, for flat example, between two figures, the affected surface will restrict the number of directions along which the component can be removed, and the sphere will be halved. Self instead there should be two contact surfaces with a body, then the sphere would be reduced to a quarter. Once the SDRs have been identified, collisions must be detected. One of the most used methods is the method of the projection calculation proposed by Jimenez (Jimenez et al. 2001).
These methods were useful to perform the sequences for the disassembly operation, but, among the sequences, the most promising was chosen in order to minimize the time for completing the procedure of disassembly. The best sequence found was then reproduced virtually by a simulation of operations that was implemented through the adoption of VR techniques, as suggested in literature by Osti et al. (2017), Bajana et al. (2016) and De Amicis et al. (2018).

3. Methods
In order to get a better understanding of the design methods of previously exposed disassembly sequences, they have been applied to the case study of a 2-way valve. So, the first necessary step was to model the individual components of the assembly in 3D, through use of the PTC CREO software, starting from the construction drawings taken from Straneo et al. (1972).

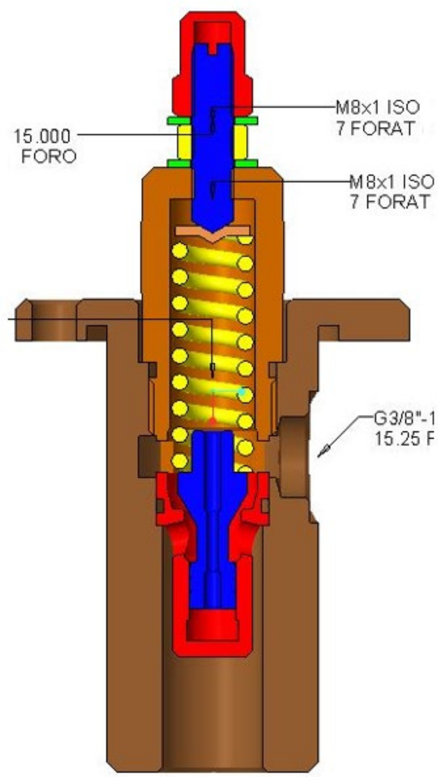

Figure 1. Assembly drawing of the 2-way valve

On this assembly different disassembly sequences have been tested following the methods cited into the previous paragraph. Here a comparison of the four generated sequences is provided. The first disassembly sequence was relied on how it would have imagined disassembling the valve, before studying other more structured methods, so as not to be influenced. Observing the section of the assembly in figure 1 and imagining that it was still mounted on the rest of the machine, it was thought to proceed to disassembly "moving from top to bottom". As follows, the parts of the valve have been numbered and sequences refer to the number assigned to each component. Figure 2 shows an exploded view of the assembly and figure 3 an axonometric one.

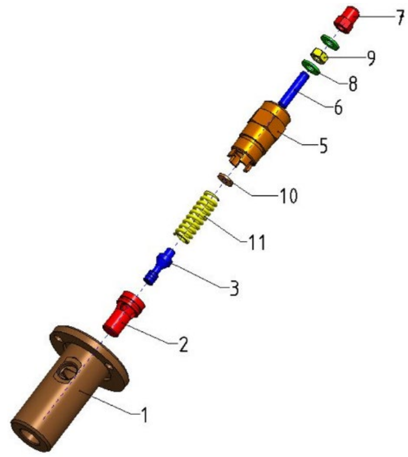

Figure 2. Exploded view of the assembly of the 2-way valve

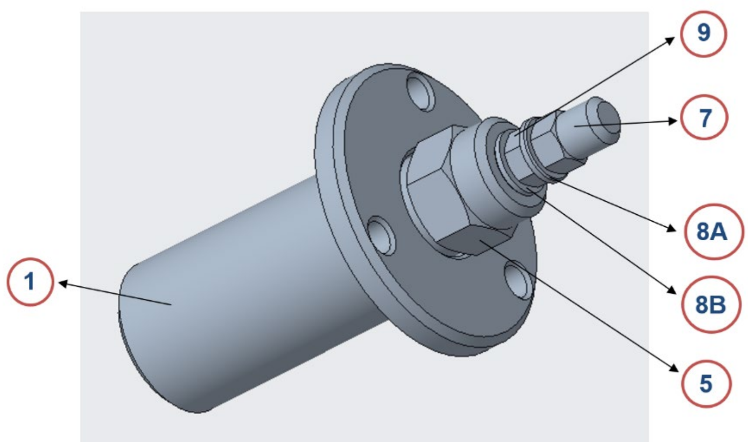

Figure 3. Axonometric view of the assembly of the 2-way valve

Then, following the method suggested by Jianjun, Y. et al (2003), since the purpose (Objective Function) is to obtain a complete disassembly in the shortest possible time, it was used the component number 11 as the piece from which the initial wave (Disassembly Wave) originates, since it is the component that is located most internally to the assembly. Furthermore, it is the component that has the greatest influence on the flow of fluid inside the valve; therefore, it is also a component that is always in constant stress. In total, to get the disassembly of the assembly, 4 disassembly waves have been generated.

Following the method suggested by Favi et al. (2019) and Mandolini et al. (2018), instead, the components identified that belong to the former level, since they are not blocked by other components, are numbers 1 and 7, that is the two outermost components. Consequently, the second level will belong to the components 12, 4, 8A (due to collisions with the first level) and 6 (due to lack of SDR at level 1). After level 3 there are components 2 (a due to collisions with both previous levels) and 7 (due to lack of SDR al level 1 and for collision at level 2). At level 4 there are pieces 8B (due to collisions with all three previous levels) and 3 (due to lack of SDR at levels 1 and 2 and for collisions with level 3). At level 5 there are 5 components (for lack of SDR at the first level and for collisions in the following levels) and 11 (for lack of SDR in the first three levels and by collision with the fourth). Finally, on the level 6 there is component 11, which as in the previous case will turn out to be the last element to be disassembled. Following these observations, it was possible to generate the Disassembly Geometry Contacting Graph of the case study.

By the third method proposed by Mitrouchev et al. (2015), since the number of components is not too high, looking for all the possible disassembly sequences through this method there would give a high possibility of finding sequences already generated by the other applications. Also, to go and compare the disassembly times of the different sequences, with the aim of identifying which takes as little time as possible to reach the goal, were applied suggestions by Desai and Mital (2003). The most significant step was the number 3, from which it was possible to draw the directions to search for a disassembly sequence using an algorithm very specific.

The total number of parts is thirteen, hence the matrix starting will turn out to have thirteen columns and thirteen rows. The different one's levels were composed by assigning to each of them the components that appeared to have one disassembly depth corresponding to zero, in the corresponding column of calculation. At each step, these components were removed from the matrix, reducing it more and more, until the final matrix was reduced to two columns and two rows.

Data about all the sequences formulation have been collected in the following paragraph.

At the end, the calculation of the disassembly times was based on what proposed by Mandolini et al. (2018) and they are reported in the following paragraph too.

The final step was the implementation of VR simulations for obtaining the sequences of disassembly and evaluation of the best for the application in question is going to obtain a verification of what has been studied so far, using simulations to CAD or Augmented Reality, even before the component is sent in production, that is, before having a physical example. In fact, thanks to the following methods it is possible to perform assembly / disassembly simulations that they can be useful both for making design considerations for disassembly, but also for design for assembly, as they can be considered the real physical relationships between one component and the other.

It is possible to identify different types of Augmented Reality, which have been developed and are exploited in different sectors nowadays. In this paper the simulation followed the Marker/Recognition based method. It requires the presence of a detail object of known geometry and saved in a database, called Marker, usually a 2D image (eg barcode, QR code, etc.) which must be recognized to identify the position, orientation in space and the perspective (depth) of user observation. After recognizing and once the reference marker is located, the AR device activates the virtual level of overlay with additional information. The concept behind this method is the recognition of the marker by the device. If the image marker is prepared correctly, the information provided by this type of AR simulation will be of high quality and the tracking will be stable. An accurate and detailed simulation of the disassembly sequence found to be the quickest for the case study was realized by Unity and Vuforia. The method used for the implementation of the simulation is summarized in figure 4 that follows.

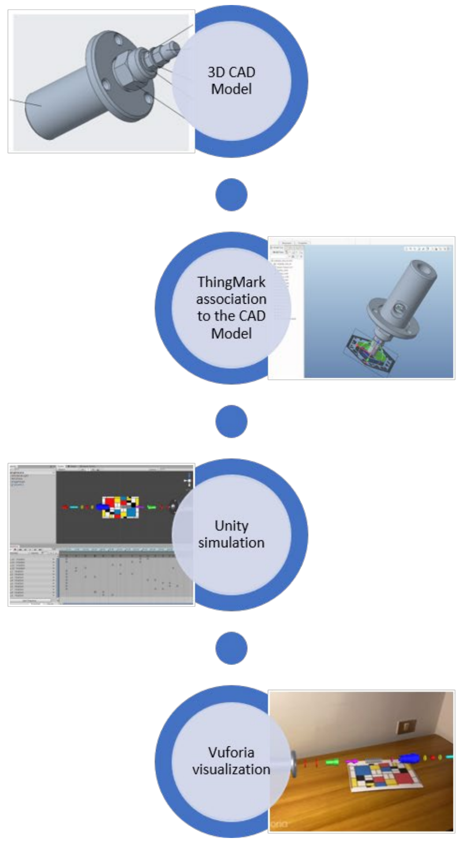

Figure 4. The method followed for the AR simulation.

4. Data Collection

The data collected in this study relate to the disassembly frequencies derived from the application of the above methods. In the first case the sequence was obtained by the authors following common sense indications and derived from the knowledge on the usual practice of operations. In the other cases, the procedures learned from the literature are strictly applied. Table 1 summarizes the sequences found. Table 2 summarizes the calculation of the disassembly times for each sequence.

Table 1. The disassembly sequences details

Sequence number	Applied method	Disassembly sequence
1	By the discretion of the authors	7 – 6 – 8A – 9 – 8B – 5 – 4 – 10 – 11 – 1 – 12 – 2 – 3
2	Following Jianjun, Y. et al (2003)	1 - 4 - 12 - 7 - 8A - 9 - 8B - 5 - 6 - 2 - 10 - 3 – 11
3	Following Favi et al. (2019) and Mandolini et al. (2018)	1 – 7 – 12 – 4 – 6 – 8A – 2 – 9 – 8B – 3 – 5 – 11 – 10
4	Following Mitrouchev et al. (2015)	1 – 7 – 4 – 8A – 12 – 2 – 9 – 3 – 8B – 6 – 5 – 10 – 11

Table 2. The calculation of the disassembly times

Sequence number	Disassembly operations	Disassembly time
1	6 tool changes	62.424s
2	3 tool changes	58,356s
3	4 tool changes	54,288s
4	4 tool changes	55,116s

5. Results and Discussion

Once the four sequences have been generated, following the criteria explained in the previous paragraphs, the best sequence has been selected by taking into account the minimum time spent in the disassembly operations. So, the best sequence resulted the n. 3, as reported in table 2. The next step was the simulation of the disassembly operations, that was implemented by VR technologies. More in particular, it was chosen to make use of the AR technique in order to insert the objects in a real scenario. AR views were realized using the PTC CREO software and, in particular, the 'Target' tool, within the 'Tools' section. Using this tool, a ThingMark, was created in the 3D model space spatial target, which is a visual indication necessary to obtain Augmented Reality, which will "memorize" the 3D structure concerned. Once the desired position with respect to the assembly have been chosen, the model is ready to be fixed into the space, as shown in figure 5.

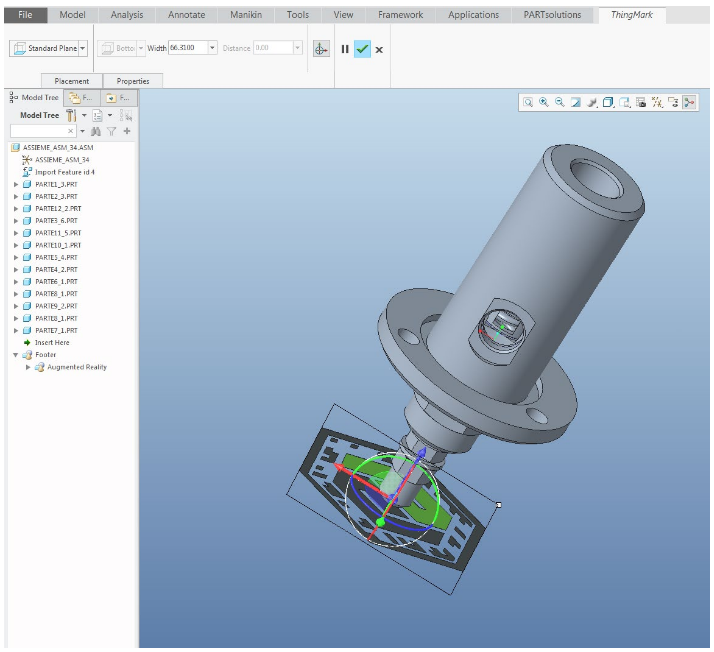

Figure 5. ThingMark application on the 3D CAD model.

The simulation realized by Unity and Vuforia was possible through the generation of an Image Target, corresponding to the 3D CAD model, as shown in figure 6.

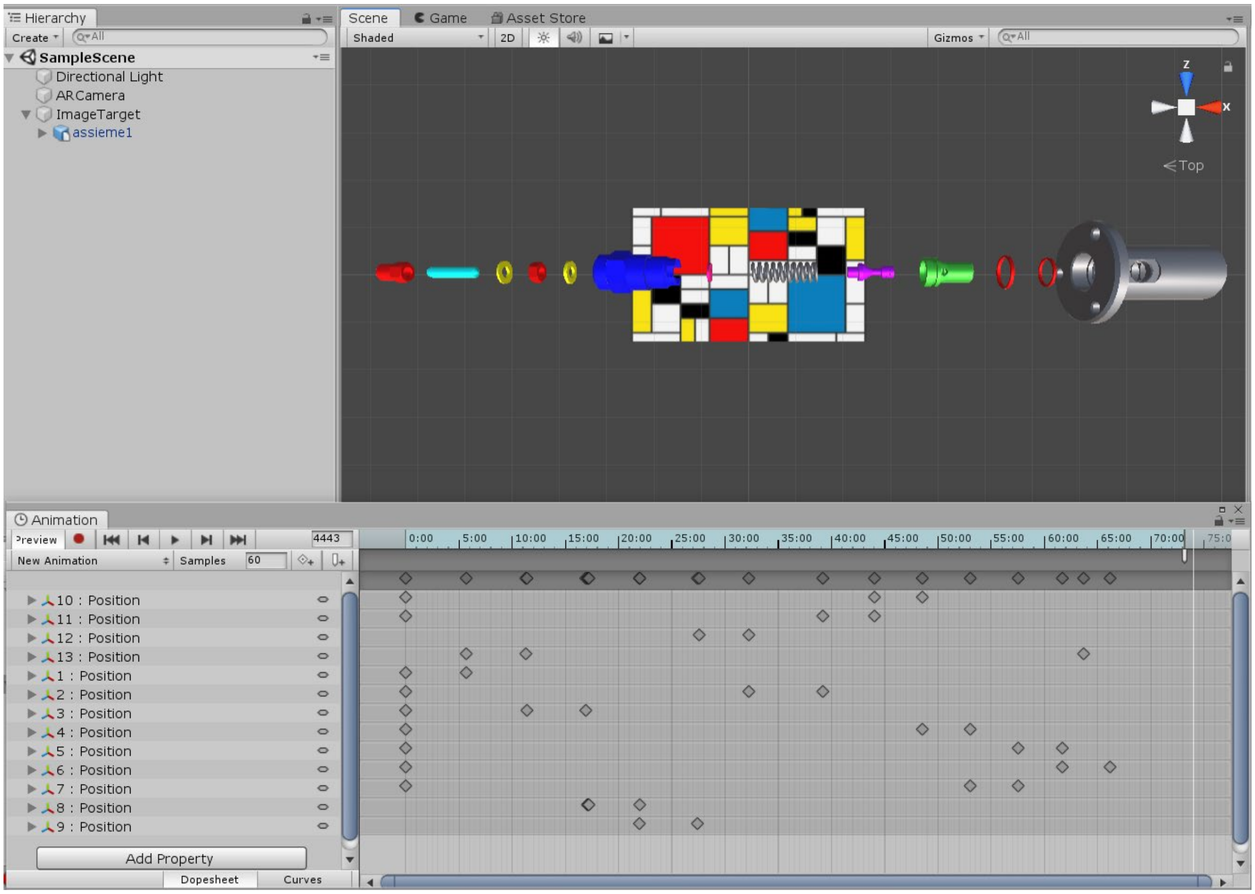

Figure 6. The 3D CAD model into the simulation space.

Then it was possible to go on with the creation of the simulation of the disassembly sequence following the results of method 3, that was proved to be the best among the four. The last frame reproduced in the simulation, that is the final one in which all the parts have been disassembled, is shown in figure 7. It reproduces the disassembly scene in a real scenario.

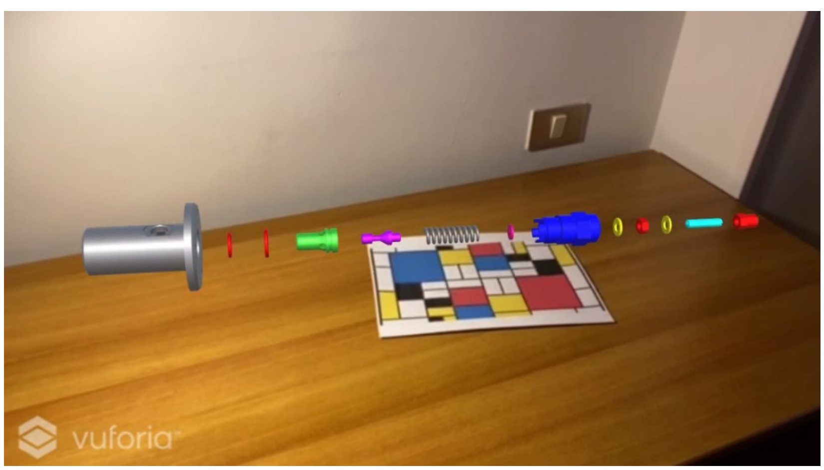

Figure 7. The disassembly completed in AR scenario.

6. Conclusion

This paper presents an integrated approach to the optimization of the design method DfD: it is a mix of strategies that have the common goal of enhance the DfD, by the application of literature suggestions about DSP and by the simulation of the optimal sequence obtained by the current enabling technologies such as the Augmented Reality. The most promising aspect of what described in this paper is the robust investigation about an optimal solution for disassembly of parts, as resulted from catching information about different well consolidated scientific methods and having applied these methods to a real part's assembly, a group of common use in the industrial practice. The DSP methods' application showed a best solution that was measured in terms of gaining of time. DfD design technique turns out to be extremely current dealing with topics of great interest in recent years and its application to real case studies is found to be very interesting. The simulation of the disassembly sequence on a real scenario was easily made by the current availability of promising technologies and allowed to directly catch data from a CAD model to import them in a virtual simulation set in a real scenario. Unity software integrated with the Vuforia extension in this application demonstrated to open new ways to completely revolutionize the manufacturing field, giving a user-friendly tool that allows to reproduce real operations in advance respect to the usual practice, with a consequent gaining of resources.

References

Bajana J., Francia D., Liverani A. and Krajčovič M. Mobile tracking system and optical tracking integration for mobile mixed reality. *Int J Comput Appl*, vol. 53, no. 1, pp. 13-22, 2016

De Amicis, R., Ceruti, A., Francia, D., Frizziero, L., Simões, B. Augmented Reality for virtual user manual, *International Journal on Interactive Design and Manufacturing*, vol.12, pp. 1-9, 2018

Desai, A., and Mital, A., Evaluation of disassemblability to enable design for disassembly in mass production, *International Journal of Industrial Ergonomics*, vol. 32, no. 4, pp. 265-281, 2003.

Favi, C., Marconi,M., Germani, M., Mandolini, M., A design for disassembly tool oriented to mechatronic product demanufacturing and recycling, *Advanced Engineering Informatics*, vol. 39, no. 73, pp. 62-79, 2019.

Francia, D., Caligiana, G. and Liverani, A. DFD Evaluation for Not Automated Products. *Research in Interactive Design,* vol. 4, pp. 439-445, 2016.

Francia, D., Liverani, A., Donnici, G., Frizziero, L., Marinelli, N. A structured index describing the ease of disassembly for handcrafted product, *Cogent Engineering*, vol.6, no. 1, 2019.

Francia, D., Ponti, S., Frizziero, L., and Liverani, A., Virtual mechanical product disassembly sequences based on disassembly order graphs and time measurement units, *Applied Sciences*, vol.9, no. 17, 2019.

Francia, D., Liverani, A. and Caligiana, G., A preliminary evaluation to support DFD of handcrafted products, *International Journal of Mechanical and Production Engineering Research and Development*, vol.9, no3, pp. 1033-1050, 2019.

Francia, D., Donnici, G., Ricciardelli, G.M. and Santi, G.M., Design for six sigma (DFSS) applied to a new E-segment sedan, *Sustainability*, vol.12, no.3, 2020.

Francia, D., Seminerio, D., Caligiana, G., Frizziero, L., Liverani, A. and Donnici, G., Virtual Design for Assembly Improving the Product Design of a Two-Way Relief Valve, *Lecture Notes in Mechanical Engineering*, pp. 304-314, 2020.

Gungor A., Gupta S. M., Disassembly sequence plan generation using a branch-and bound algorithm. *International Journal of Production Research*, vol.39, no.3, pp.481-509, 2001.

Jianjun, Y., Yu,B., Du,L., Li,C., Hu, D., Research on the selectable disassembly strategy of mechanical parts based on the generalized CAD model, *The International Journal of Advanced Manufacturing Technology*, vol. 37, pp. 599-604, 2008.

Jiménez, P., Thomas, F., Torras, C., 3D collision detection: a survey, *Computers & Graphics*, vol. 25, no.2, pp. 269-285, 2001.

Lambert, A.J.D., Disassembly sequencing: a survey, *Int. Jour. of Prod. Res.*, vol. 41, no. 16, pp. 3721-3759, 2003.

Liverani, A., Caligiana, G., Frizziero, L., Francia, D., Donnici, G. and Dhaimini, K., Design for Six Sigma (DFSS) for additive manufacturing applied to an innovative multifunctional fan, *International Journal on Interactive Design and Manufacturing*, vol.13, no.1, pp. 309-330, 2019.

Mandolini, M., Favi, C., Germani, M., Marconi, M., Time-based disassembly method: how to assess the best disassembly sequence and time of target components in complex products, *The International Journal of Advanced Manufacturing Technology*, vol. 95, pp. 409-430, 2018.

Mitrouchev, P., Wang, C. G., Lu, L. X., Li, G. Q., Selective disassembly sequence generation based on lowest level disassembly graph method, *The International Journal of Advanced Manufacturing Technology*, vol. 80, pp. 141-159, 2015.

Osti F., Ceruti A., Liverani A., Caligiana G., Semi-automatic design for disassembly strategy planning: an augmented reality approach, *Procedia Manufacturing,* vol.11, pp. 1481-1488, 2017

Straneo, L., Consorti, R., Manfè, G., Disegno di costruzioni meccaniche e studi di fabbricazione, vol. 3, pp. 459-462, 1972.

Biography

Daniela Francia got a PhD degree in 2008 discussing a final thesis titled "Modeling and simulation of mechanical systems with a high number of degrees of freedom by means of non-conventional methods and CAD systems ". Since 2005, she owned courses at the I and II Faculty of Engineering of Bologna as a tutor for the subjects of Computer Aided Design & Construction Aviation, and later as teacher in Industrial Technical Drawing. In 2010 she became Assistant Professor at the Faculty of Engineering, University of Bologna, in the field of Design and Methods of Industrial Engineering, SSD ING-IND/15. She is involved in several projects and research activities in collaboration with research institutions and private companies. Research interest for Rapid Prototyping, Design and Manufacturing, conventional and not conventional Optimization Methods for industrial applications, numerical and experimental Analysis of bio-mechanical and environment friendly components, Interaction Methods by Virtual Reality applications. The focus research activities are centered on innovative methodologies just like QFD, TRIZ, Design for Assembly, Design for Disassembly, Design for Additive Manufacturing, Design for Six Sigma, Bench Marking. She attended numerous national and international conferences and is author of scientific publications of national and international relevance.

Leonardo Frizziero is engineer, married, father of three children, Leonardo Frizziero got the diploma at Scientific High School "A. Sabin" and graduated at the Faculty of Engineering of the University of Bologna. In academic field, he promotes the scientific issues related to the Mechanical Design and Industrial Design Methods (CAD 2D, 3D, Advanced Design, QFD, TRIZ, DFSS, DFD, DFA, etc.). In 2005, he was recruited by Ferrari Spa, as Team Planner of new Ferrari cars projects. In 2009 he came back to University, obtained the Ph.D. degree and started collaborating with the Design and Methods Research Group of Industrial Engineering becoming Junior Assistant Professor in February 2013 at DIN of AMS University of Bologna. He teaches and follows research in the design fields, participating at various competitive regional, national and international research projects. Since 2018 he has been a Senior Assistant Professor. Since 2017 he is qualified Associate Professor of Design and Methods of Industrial Engineering (ING-IND/15). Prior to the role of university professor, he held relevant positions for some industrial companies.

Alfredo Liverani is a member of CbEM (Computer-based Engineering Methodologies) research group and he is involved in several activities related to Computer Aided Design (CAD), Computer Graphics, Virtual and Augmented Reality. In detail he focuses on real-time visualization and interaction with particular attention to mechanical, aeronautical applications and Industrial Design. Surface modelling, reverse engineering, mesh generation (FEM) and manipulation, virtual prototyping and live simulations are fields investigated in the several publications available at http://diem1.ing.unibo.it/personale/liverani.

Giampiero Donnici is a PhD in "Mechanics and Advanced Engineering Sciences" from the Alma Mater Studiorum University of Bologna. Today he is an adjunct professor at the Department of Industrial Engineering at the same university. He collaborates with the research group Design and Methods of Industrial Engineering at the DIN department of the Alma Mater Studiorum University of Bologna and follows research in the field of Mechanical Design and Industrial Design (CAD / CAE, 3D Printing, QFD, TRIZ, DFSS, DFD, DFA , etc.). He has worked as a mechanical designer in companies producing automatic machines and as a consultant for PLM and PDM systems in companies in the same sector.

Nicoletta Dalledonne is a student of master’s degree in mechanical engineering at Alma Mater Studiorum University of Bologna.