UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN
FACULTAD DE INGENIERÍA MECÁNICA Y ELÉCTRICA

"DEVELOPING A MIXED REALITY ASSISTANCE SYSTEM BASED ON PROJECTION MAPPING TECHNOLOGY FOR MANUAL OPERATIONS AT ASSEMBLY WORKSTATIONS"

POR
LEONARDO VINICIO RODRÍGUEZ PUEBLA

EN OPCIÓN AL GRADO DE
MAESTRÍA EN CIENCIAS DE LA INGENIERÍA AUTOMOTRIZ

JUNIO 2016

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Los miembros del Comité de Tesis recomendamos que la Tesis "DEVELOPING A MIXED REALITY ASSISTANCE SYSTEM BASED ON PROJECTION MAPPING TECHNOLOGY FOR MANUAL OPERATIONS AT ASSEMBLY WORKSTATIONS" realizada por el alumno LEONARDO VINICIO RODRIGUEZ PUEBLA, con número de matrícula 1467730, sea aceptada para su defensa como opción al grado de MAESTRIA EN CIENCIAS DE LA INGENIERIA AUTOMOTRIZ.

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San Nicolás de los Garza, Nuevo León, 06/06/2016

RESUME

Manual tasks play an important role in social sustainable manufacturing enterprises. Commonly, manual operations are used for low volume productions, but are not limited to. Operational models in manufacturing systems based on "x-to-order" paradigms (e.g. assembly-to-order) may require manual operations to speed-up the ramp-up time of new product configuration assemblies. The implications of manual operations in any production line may imply that any manufacturing or assembly process become more susceptible to human errors and therefore translate into delays, defects and/or poor product quality. In this scenario, virtual and augmented realities can offer significant advantages to support the human operator in manual operations. This research work presents the development of a mixed (virtual and augmented) reality assistance system that permits real-time support in manual operations. A review of mixed reality techniques and technologies was conducted, where it was determined to use a projection mapping solution for the proposed assistance system. According to the specific requirements of the demonstration environment, hardware and software components were chosen. The developed mixed reality assistance system was able to guide any user without any prior knowledge through the successful completion of the specific assembly task.

DEDICATION

To my parents who raised me with love and have always support me in the decisions I make.

To my best friend and love of my life Andrea, who pushed me and encouraged me during this journey to achieve the goal.

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1 Introduction

1.1 Introduction and Justification

Manual tasks play an important role in social sustainable manufacturing enterprises. Commonly, manual operations are used for low volume productions, but are not limited to.

Manual operations have always existed and the processes are in constant evolution. Since the human being has different needs, different operations are done. A number of operations are still done manually. Such activities can vary from simple procedures which can be memorized with a few repetitions. However, as the manufacturing processes and manual operations have been developing, the customer demands products with more customizations, therefore manual operation are more complex nowadays.

For those complex procedures, the people in charge have to be well-trained and highly skilled. The experience is highly desired. If it is desired to run the production line but the user does not have the proper knowledge, the user will require a manual or tutorial to accomplish the tasks.

1.1.1 New customer requirements

Manufacturing enterprises may have to reconsider their assembly processes in the near future in light of the need for social sustainable manufacturing as well as the challenge of meeting dynamic and individual customers' requirements and shortened product lifecycles (1) e.g. in the automotive industry, a product lifecycle will be shortened to two-three years in a few years as compared to the current four-seven years and nine-twelve years from a few years ago (2).

Operational models in Manufacturing Systems (MS) based on "x-to-order" paradigms (e.g. assembly-to-order) may require manual operations to speed-up the ramp-up time of new product configuration assemblies.

Automotive Industry

The most significant obstacles toward reducing new product realization time stem from the complexity of the product/process and knowledge or expertise-based product/process development methods. They can be further categorized into: 1.- design phase: Large number of design/engineering changes have to be made after the product has been designed and at times even after it has been built e.g. and average of six thousand changes are made for a new automotive body development; 2.- Pre-production phase: Long ramp up time, especially for complex systems such as flexible machining transfer lines and automotive assembly lines (three-five months); 3.- Full production phase: Low production yield (below design intent expectations: 65-70% for flexible machining line) (2).

A distinction of the automotive industry is the frequency of model changes and the vast amounts of time and labor required to make a changeover. The automotive body assembly is regarded as the least flexible process in the overall vehicle assembly (3). The implications of manual operations in any production line may imply manufacturing or assembly processes become more susceptible to human errors and therefore translate into delays, defects, and/or poor product quality. Nevertheless, today manufacturing processes are getting more and more complex and variable, and therefore when an operation involves human interaction, it remains susceptible to human errors. In the Figure 1 is shown the main advantages and disadvantages of Human Operations.

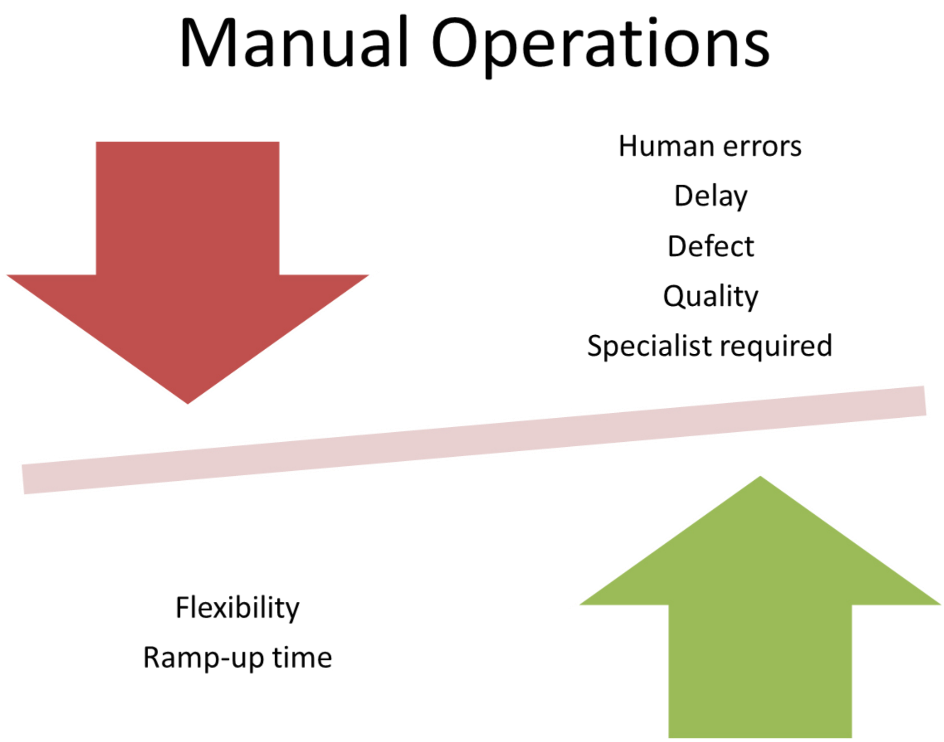

Figure 1. Main advantages and disadvantages of Human Operations

Moreover, manufacturing will still require the human operator in his/her role as micromanager, trouble-shooter, and decision-maker on the shop-floor no matter if it comes to manual workstations or semi- to fully-automated manufacturing modules (4) (5).

The importance of the manual work is therefore currently been reconsidered in a twenty first Century shop-floor which needs to find again the right balance between manual, semi-automated, and automated manufacturing assemblies due to an increased demand for customized products (6).

As can be seen in the Figure 1, Flexibility and Ramp-up time are some of the factors more considered to use manual operations. In this scenario, virtual and augmented realities can offer significant advantages to support the human operator in manual operations. Resulting in a mix of the advantages of human operations and also reducing the human error to the minimumwith the support of MR technologies.

Furthermore, when it comes to such complex processes and sequences, certain operational standards of performance for a specific task or series of tasks may create a high dependency from a particular well-trained operator or specialist, which causes the production stop if he/she is not at his/her workstation.

This research work presents the development of a Mixed Reality (MR) assistance system which permits real-time support in manual operations to reduce human errors such as delays and minimize the need of specialist among short periods of time.

Ramp up time

In the fast-paced world of consumer short development lead times and efficient product ramp-ups are invaluable. The sooner and faster a firm can ramp-up production of a new product, the faster it can start to earn revenues, profit from early market opportunities, establish technology standards and release scarce development resources to support new product development projects. Yet, many companies fail to meet their time-to-market and time-to-volume targets and the complex interrelationships between product characteristics, development lead time and ramp-up performance are largely unexplored (7).

The ramp-up period can be seen as a key opportunity for a company to improve its performance. New methods are put in place for the first time and the real production starts up, bringing challenges and initial inertia before achieving acceptable output (8).

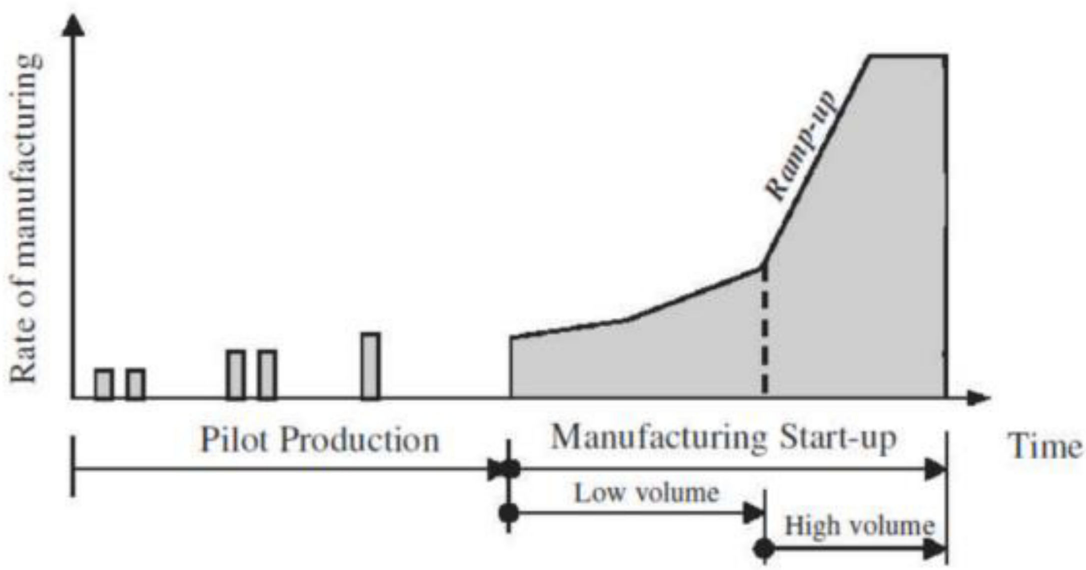

Figure 2. Distinction between start-up and ramp-up (9).

In the Figure 2, is shown the difference between the start-up and ramp-up. The criticality of the ramp-up stage is mostly related to the flexibility required. Most engineering changes are made during the ramp-up of new products, motivated by manufacturability problems (10).

In other studies, it has analyzed the effect of strategy, organization, and management on lead time, quality, and productivity in a field study within the automotive industry. Among other drivers the development process, product complexity, and manufacturing capabilities relate closely to superior development lead time, and ramp-up performance (11).

In ramp-up the firm starts commercial production at a relatively low level of volume; as the organization develops confidence in its abilities (and its supplier's abilities) to execute production consistently and marketing's abilities to sell the product, the volume increases. At the conclusion of the ramp-up three phases, the production system has achieved its target levels of volume, cost, and quality. Yet many companies fail to meet their targets regarding product volume, cost, and quality (12)(13).

Flexibility

The companies have to adapt to the environment in which they operate, to be more flexible in their operations and to satisfy different market segments (customizability). Flexibility is the ability of customizing high quality products in a short time, with a reasonable price. A Flexible enterprise may have the features seen in the Figure 3.

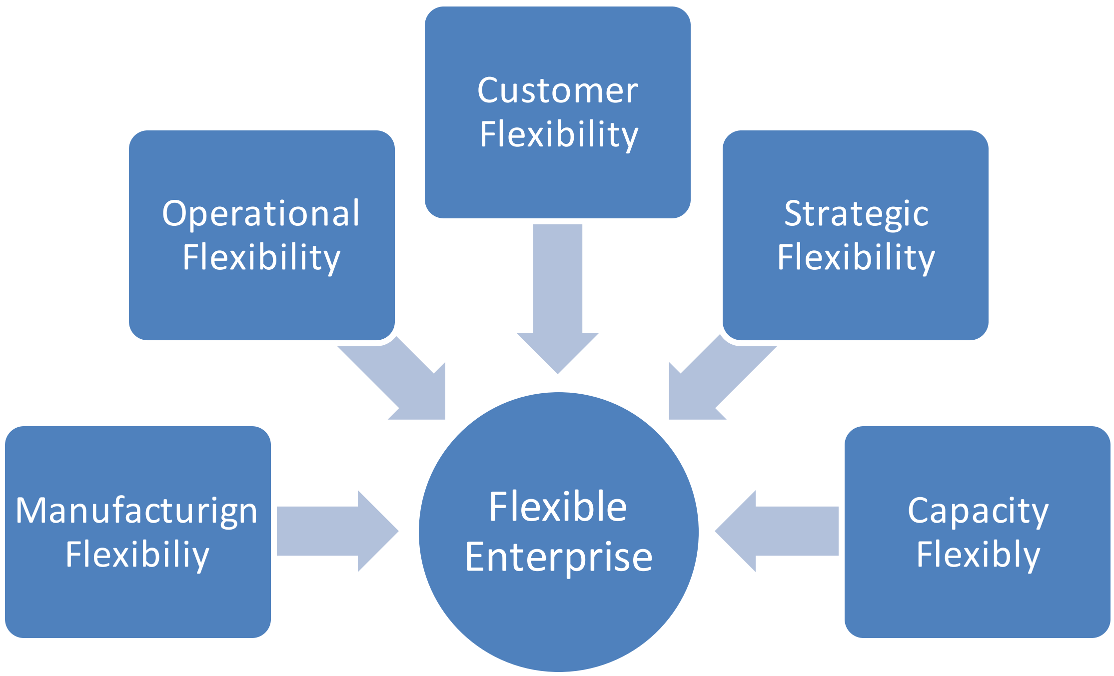

Figure 3. Requirements of a Flexible Enterprise

The average of engineering changes for a new model of an auto part is high, e.g. in 2004 for a new automotive body development, the average of design/engineering changes made after the product has been designed, was more than 6,000 changes (3). In order to reduce time to develop a new car due to changes which a new model imply, in the last two decades, there have been an increased adoption of industrial practices on top auto manufacturers in the area of production system development, to take full advantage of the Time Based-Competition (TBC) strategies such as Quick Response Manufacturing (QRM)(14), Reconfigurable Manufacturing System (RMS)(15)(16), and Agile Manufacturing.

Reconfigurable machines

Manufacturing companies in the twenty first Century will face frequent and unpredictable market changes. One of the characteristic features of the automotive industry is the frequency of model change and vast amounts of time and cost required to make a changeover.

These changes include high-frequency introduction of new products, new product demand and mix, new parts for existing products, new government regulations, and new process technology e.g. in Japan, Toyota was reportedly offering customers five-day delivery from the time the customer designed a customized car on a CAD system (from modular options) to the actual product delivery. This trend has continuously gone up in the last three decades.

To stay competitive, manufacturing companies must possess fully and rapidly responsive MS to all these variables. A responsive system incorporates a production capacity which is adjustable to fluctuations in product demand, is adaptable to new product functions, and is designed to be upgradable with new process technology to accommodate evolving product specifications and government regulations. Current systems, even so-called Flexible Manufacturing Systems (FMS), do not have these characteristics.

The aim of RMS is to design systems, machines, and controls for cost-effective, rapid response to changes in market demand and products. Methodologies for the systematic design and rapid ramp-up of RMS are the cornerstones of this new manufacturing paradigm. The new reconfigurable manufacturing paradigm provides exactly the functionality and capacity needed, exactly when needed.

In the Figure 4 is shown the main characteristics of RMS applied to the design of whole MS, as well as to some of its components reconfigurable machines, their controllers, and also to the system control software.

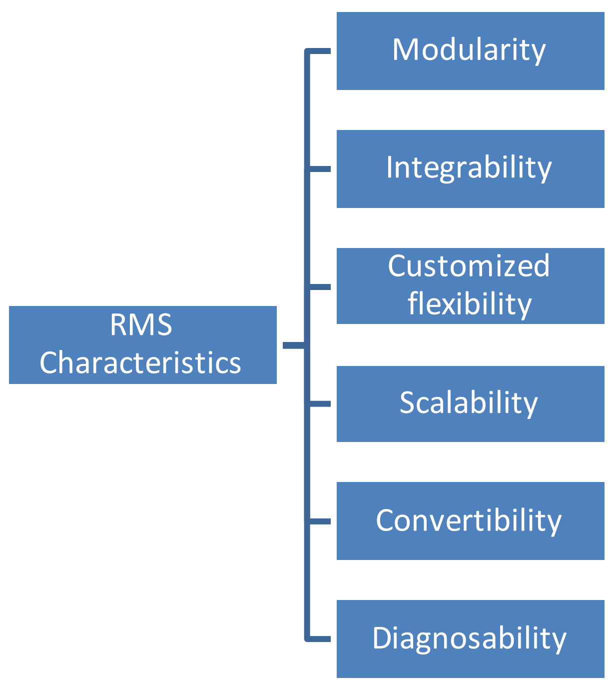

Figure 4. Core characteristics of a RMS (17).

According to the National Science Foundation (NSF) of United States, the Engineering Research Center for RMS expects the RMS will have as big an impact on industry as mass-production and lean manufacturing have had in the twenty century or even bigger.

Re-configurability is defined as the ability to adjust the production capacity and functionality of a MS to new circumstances through re-arrangement or change of the system's components. Components can be machines and conveyors in whole systems, mechanisms in individual machines, new sensors, or new controller algorithms. New circumstances are changing product demand, producing a new product on an existing system, or integrating new process technology into existing MS.

RMS will be open-ended; this make RMS can be improved and upgraded rather than replaced. RMS allows flexibility not only in producing a variety of products, but also in changing the system itself. The key is this type of system must be designed at the onset to be reconfigurable, and must be created from basic hardware and software modules which can be arranged quickly and reliably.

1.1.3 Current assistance in manual operations

In a manufacturing enterprise, the personnel can have different kind of experience, from self-taught individuals to holders of with experience in an automotive factory. However, independently of their background every worker has to take an extensive technical training which provides the necessary knowledge, skills, and attitudes for assuming responsibility over the health of the components and system of the workstation.

Also, commonly automotive industry have international standards, such as ISO 9000:100 and the automotive ISO TS 16949 which ensure to maintain the quality of the product along the whole process. So, it is required to ensure quality and prove it.

Currently in manufacturing enterprises there is Instructional Operations (IO) with the proper Visual Aids (VA) and for more accurate task, Standard Operating Procedures (SOP) which helps the user understand the procedure and guarantee product quality. As shown in the Figure 5, to achieve an operation, manuals try to lead the operator through all the steps, this step implies going back and forth through different stages of the checks and different manuals.

However, when a user without experience requires training for a job position, these printed documents often are not used. A common practice for training users is an old fashioned technique to learn by seeing another partner doing his job. However when new colleagues are trained in the workstation, usually they learn faster than observing only.

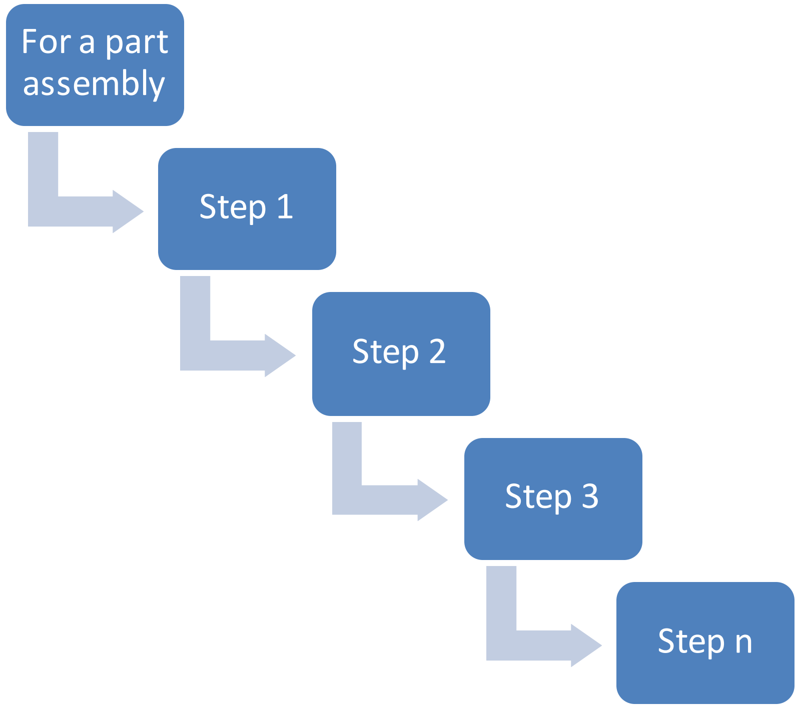

Figure 5. Current process of assisting manual operations with printed manuals.

1.2 Proposed model for assistance for manual operations in assembly workstations

A review of MR techniques and technologies was conducted, where it was determined to use an embedded screen display using Projection Mapping (PM) techniques for the proposed assistance system.

According to the specific requirements of the demonstration environment, hardware and software components were chosen. The developed MR assistance system will be able to guide any user without any prior knowledge through the successful completion of the specific assembly task.

This research work presents the development of a MR assistance system which permits real-time support in manual operations. It is pretended to create a prototype system of MR and enhance it with a recognition system to detect when the operation of each step if completed. This will give the ability to the user to successfully finish an unfamiliar complex assembly processes, commonly found in the manufacturing processes of automotive parts. The assistance system will be enhanced with an external recognition system which uses camera and sensors to read the environment.

The system will consist basically in a projector mounted vertically in a fixed position over the assembly workstation covering the areas were the part and tools interact. The user can receive the instructions directly on the workstation. The instructions will be projected in the workstation. In order to the user can perceive the images correctly, this will be previously corrected to the expected location of the user. It means, the projections can only be seen correctly with a certain angle, it means, a specific point of view. The point of view is carefully chosen to the expected location of each assembly process.

The Figure 6 shows the concept of PM. The original image have a different angle from the surface were it will be projected. With techniques of PM it is possible to adapt any projection to different shapes.

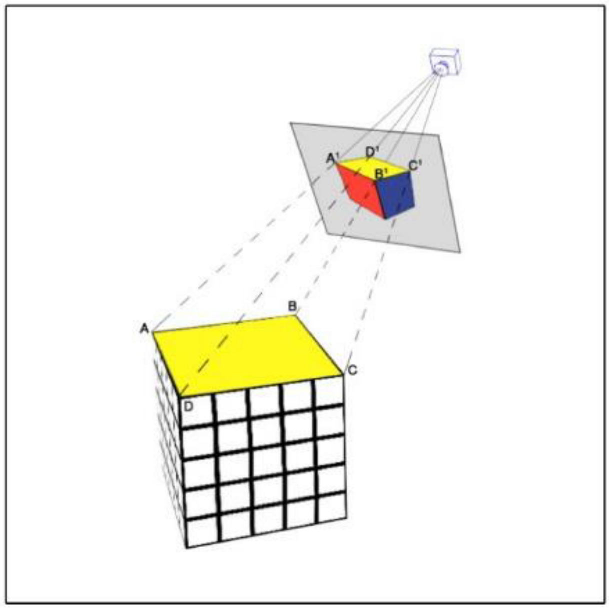

Figure 6. Concept of PM. Retrieved (18).

The assistance system will accelerate the transfer of knowledge from the current manuals of assistance. Currently in manufacturing enterprises there is IO with the proper Visual Aids and for more accurate task, SOP which helps the user understand the procedure and guarantee product quality. With the system developed is expected to reduce delays understanding easier the instructions.

Some of the advantages of this proposed model of assistance, is developing a MR assistance system will provide real-time assistance to the operator by projecting instructions onto the workstation environment. So, will reduce undesired and time consuming procedures traditional way such as reading instructions from papers. Otherwise, with the proposed model, users would gain information in a modern and interactive way, showing exactly what part or tool take, were can be found the part/tool and the right palace were it is required to locate the part/tool into the Workstation/Part. Also, the user will be able to receive instructions directly on the workstation, with a friendly interaction and free of wearing gadgets or head mounted devices. This will also benefit reducing paper for printed manuals.

1.3 Project Impact

The importance of this Research and Technology Development (RTD) is the contribution in the development of new Systems and methodologies to improve the flexibility and Ram-up time preserving the integrity and quality of the product. This thesis is project for developing an advanced instructional system to perform manual operations, to determine the feasibility of the introduction of MR systems based on PM to assembly workstations of Automotive Factories.

This project is expected to become a guide to embrace automotive manufacturers to use more technologies, to use Virtual Reality (VR) and Augmented Reality (AR) to assist operations in real time in assembly workstations. Also to ease further projects in VR and AR based on PM to assist manual operations.

1.4 Objectives

The motivation of this research is to improve the method of assistance of automotive manufacturing processes with more information not available in regular work environments, in this way accelerate the cognitive process which new users have during supporting an unfamiliar assembly workstation and the stage of familiarizing with complex processes.

The scope of this project is to create a prototype system by means of MR enhanced with a gestural interface to enhance the cognitive process and ability of a user who holds a job in complex assembly processes which are commonly found in the manufacturing processes of automotive parts. This tool is going to be developed using a projector, so the user can receive the instructions directly on the workstation. Is worth to mention the MR system will be adjusted for a correct angle perspective, so, this enables the user to receive the assistance at the best positions to realize the operations.

During the investigation is expected to accelerate the transfer of knowledge from the current manuals of assistance and troubleshooting procedures of a company by using the MR based on PM technology along with the several advantages that PM have, like receive instructions directly on the workstation, a friendly interaction, and free of wearing gadgets or head mounted devices, also savings in printed manuals.

This research work presents the development of a MR assistance system proposed in this RTD work, will provide real-time assistance to the operator by projecting instructions onto the workstation environment. The chosen set-up was a projector mounted in a fixed position over the assembly workstation. The objective of this thesis work is to evaluate the system requirements and the feasibility to incorporate MR assistance systems to manufacturing modules of Automotive Enterprises.

The case of this RTD work refers to the manual assembly of a business card holder assembled in a poke-yoke, where the user choses the correct parts and the proper tools for each step as following: Slide the clip in the glass piece, then put a distance plate and a steel piece on the glass piece, finally use a hammer and a chisel to apply pressure.

1.5 General Hypothesis

During the development of this project the main question to be answered is: Can Virtual and Augmented Realities be used as a tool to improve the knowledge of products assembly and processes?

1.5.1 Specific Hypothesis

It is also desired to respond if it is possible to enhance an assembly workstation with a MR assistance system based on PM? Does the assistance system can be used to reduce human errors such as delays? Will the system reduce the need of specialist among short periods of time?

2 Literature Overview

The definition of Virtual Reality has always been difficult to formulate thus the concept of an alternative existence has been pawed at for centuries. A common phrase for this technology is "If you can dream it, VR can make it." It is a medium for progress, not the progress itself. VR is a Virtual Environment Interaction Technique (VEIT), but is not the only one. There are different types of VEIT such as VR, AR and MR which combine both techniques.

2.1 Virtual Reality, Augmented Reality and Mixed Reality

The main difference between VR, AR, and MR, is VR immerge into a Virtual Environment (VE) whereas AR can expand virtual objects in to the real world. Both should be able to allow the user to experience the creativity to your limits inside the artificial world. To expand the limits of reality is one of the main attractions of VR for user experience. In other hand, MR is a technique which is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time.

2.1.1 Virtual Reality

VR is often referred to as immersive multimedia or computer-simulated reality. VR replicates an environment which simulates a physical presence in places in the real world or an imagined world, allowing the user to interact in that world. Virtual realities artificially create sensory experiences, which can include sight, hearing, touch, and smell.

In a VE is possible to expand your creativity, to the beyond of your imagination. For this visualization, devices are often employed to increase the immersion of the VE. The most common virtual realities are displayed either on a computer screen or with special stereoscopic displays, and some simulations include additional sensory information and focus on real sound through speakers or headphones targeted towards VR users. Some advanced haptic systems includes tactile information, generally known as force feedback in medical, gaming and military applications.

VR can be defined as the computer-generated simulation of a three-dimensional image or environment which can interact within a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors. The simplest form of VR is a 3-D image which can be explored interactively at a personal computer, usually by manipulating keys or mouse the content of the image moves in some direction or zooms in or out. More sophisticated efforts involve such approaches as wrap-around display screens, actual rooms augmented with wearable computers, and haptic devices which let you feel the display images.

In a VE, objects are created by computing techniques such as simulations. With the use of computer systems can be created, modified, and optimized a design (19) in order to create virtual objects and VE. The design process is typically used to produce imagery which is of a high caliber and tends to represent realistic environments or stylized narratives. In can be produced images itself or use image representations to visualize physical environments. The physical representations contribute to the perception which is the image primary importance. Environmental techniques influence stems directly from a historical change in the way we perceive the moving image and interaction experience.

Computer Graphics (CG) and visual effects are common elements of a VE. Visual effects are used to alter and refine video and to produce epic scenes which could never be accomplished using physical sets. VE have been widely used in Video games since this technology immerse. Ever since the invention of Media, as Television, Movies, and Video Games, designers, viewers, and players have always wanted the experience to be more real. The human have always wanted to see on screens as if he were connected to the real life. There have been many steps taken to make this possible (20).

VE have shown considerable promise as a natural form of human-computer interaction. In a virtual world you can use your eyes, ears, and hands much as you do in the real world: Move your head to set your view-point, listen to sounds which have direction, reach out your hands to grab and manipulate virtual objects. Virtual world technologies e.g. head-tracking and stereo, Head Mounted Displays (HMD) provides a better understanding of three-dimensional shapes and spaces through perceptual phenomena such as head-motion parallax, the kinetic depth effect, and stereopsis (21).

2.1.2 Augmented Reality.

In the case of AR, the devices used are often more complex and therefore more expensive, it is for this reason AR does not have many projects related as much as its counterpart RV, however in recent years as technology has advanced, the components costs has decreased, it has caused AR projects be more affordable. Of the main characteristics of the devices the AR camera to detect the real environment and hence starting supplements show the interaction between both side's results in AR. For these reason more devices currently used in AR have camera and a display element, these two requirements are met by smart glasses and smartphones.

2.1.3 Mixed Reality

MR is the merging of real world and virtual worlds to produce a new environment where physical and digital objects can co-exist and interact. MR is composes by a mix of AR and VR in the same environment.

As the result of the increasingly development of new products such glasses with displays and smartphones, AR has been increasing CAD models of machines, robotic station, tools as well the layout of from the enterprise which involves the assembly sequence in order to make a full VE as real as possible.

Although VR has been developing over many years, only recently has reached the necessary development to have real applications. The application of techniques of VR and AR has potential applications in a large number. However systems focused on specific areas and then gradually go climbing a larger field, they tend to be more successful than those who directly want to cover many applications.

2.2 VR motivation.

The idea of using computer resources to give more comprehension of the real world and to help human see better, to offer the viewer a convincing illusion and an intense feeling of being immersed in a mediated world to complement information generated by computer three-dimension all environments can be considered as the reason of the motivation (22). The VR is expected to enable an understanding of design as an experience of the intended reality (23).

Also, it can be considered part of the motivation in the development of VR the fact sometimes people want to escape their lives for a moment, e.g. it has been seen previously during the crisis as the great depression. Movies during this time were extremely popular because people wanted to get away and enjoy themselves for an hour and not be in their lives. They could feel happy for a moment because they were watching other people living great. They were laughing, crying, feeling exciting and the movies made them feel good. Today, the content available to watch is enormous and it is everywhere. The human being can watch it on the Internet, the television, Xbox, or any other gaming platform. People are constantly stepping out of their own lives to see a piece of someone else's. The human wants the ultimate experience whether it is life, or life inside a box. The human is always being immersed in content, and peeking into the lives of someone else to get away from who he is, or to experience something he normally cannot.

Also, in the entertainment industry have impulse the development of VR techniques since its beginnings video games have fundamentally changed the expectative to interact with virtual worlds, and they have ushered in the hardware necessary for individuals to be able to do digital modeling on their personal computers. There is a vast variety of genres in gaming which allow individuals to interact with media and seemingly guide or explore the progression of the narrative. This interaction, whether it is from a first person perspective or an overview, is the key component of the gaming experience. Players take on a role in video games, and they interact with the environment, creating a dialog between the player and the content. With the development of games, the human have become accustomed to moving through worlds and it changes how the human begin to edit and transform data. This has developed the capability for individuals to directly manipulate information and create interactive media.

These VE are being more and more popular because of their intense game play. Intense game play makes you feel more like you were in it, and shows the direction we are headed. People are jumping on the 3D wagon left and right to be a part of it and create new content.

Technology is getting so advanced that it is hard for us to catch up with all the latest going on. The desire for realistic content is always increasing. Now that 3D is a possibility, people are reacting to it more on the digital games and animation side than anything else. In the clip of the base jumper jumping out of a plane, the gamer can get a sense of he is actually falling, and someone having a connection to the experience like never before which it is fascinating. People can experience things they would normally never do or do not have the chance to.

This is starting to get popular in the medical side as well, with helping people get over phobias. As it can be seen in the clip, there are studies going on to see if people can get over their fear e.g. fear of heights and closed spaces through a VR simulation through a virtual world. This is interesting fact, because when will the difference be unnoticeable? When will the human be watching and forget he is watching a movie? This can be a huge benefit for people who are afraid of a lot of things and help them get over it by actually doing it in a non-harmful way. The technology is ultimately filling the gap between reality and virtual space (24).

2.2.1 The origin of Virtual Reality and Augmented Reality

VR has been developing for decades. There are numerous projects that developed HMD and glasses. However the technology was too expensive to be available to general public, this may be the main reason VR have been used Enterprises for specific uses. In the 2012 the enterprise Google released Google glasses. With Google glasses general public was able to use this techniques again for a long time. In last years, several brands have launched their own VR hardware such as HTCvive, Microsoft Hololens, and oculus rift. To understand the future is required to know where we come first. In the next paragraphs some VR machines/devices are shown.

Advances in Science and Industry

The first traces of VR came from the world of science fiction. The Pygmalion's Spectacles of 1935 was presented by the science fiction writer Stanley G. Weinbaum. Stanley presented a comprehensive and specific fictional model for VR in his short story. In the story, the main character, Dan Burke, met an elfin professor, Albert Ludwig, who invented a pair of goggles which enabled. Ludwig claimed that his invention can make "A movie that gives one sight and sound, taste, smell, and touch. You are in the story, you speak to the shadows (characters) and they reply, and instead of being on a screen, the story is all about you, and you are in it."

Stanley's Pygmalion's Spectacles is recognized as one of the first works of science fiction that explores VR (25). Weinbaum's career in science fiction was very short but influential.

In 1938, Antonin Artaud described the illusory nature of characters and objects in the theatre using the term Virtual Reality" in his book "The Theater and its Double (26)."

The Figure 7 shows a device patented by Morton Heilig in 1962 under the name: Sensorama simulator. The Sensorama simulator aims to simulate a theater. The device of Morton is an immersive, multisensory machine that aimed to stimulate four of the five senses: Sight, hearing, smell, and touch. Also, Heilig created his own 3D motion picture camera for capturing the short films that would be at the center of the experience. It was a side-by-side dual film 35 mm camera and was small enough to be used as a portable device.

Figure 7. Sensorama Simulator developed by Morton Heilig in 1962.

The Sensorama was able to display stereoscopic 3D images in a wide angle view, it provides body tilting, supply stereo sound, and also had tracks for wind and aromas to be triggered during the film. Unfortunately Heilig was unable to obtain financial resources for his visions and patents, and so the Sensorama work was paused. Nowadays the system is part only remembered as a curiosity in C history.

For decades, a well-known VR device has been the HMD. Since the beginning of the VR, a HMD was employed. The Figure 8 shows the headset Sword of Damocles developed by Ivan Sutherland and Doug Sproull in 1968 which is recognized as the first VR device. HMD may be the most known VR device; however VR is not limited wearable devices.

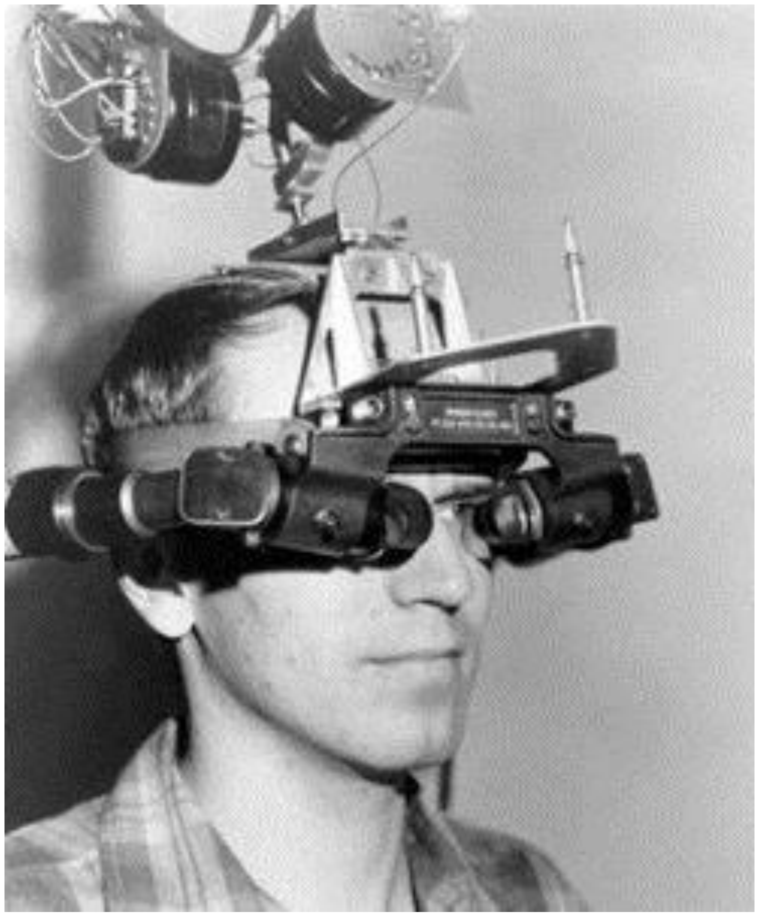

Figure 8. World first VR device "The Sword of Damocles".

The sword of Damocles was done by the fundamental idea to present the user with a perspective image which changes as he moves. The retinal image of the real objects is two- dimensional. With this principle was determined that is possible to place suitable two-dimensional images on the observer's retinas, creating the illusion he is seeing a three-dimensional object. The image presented by the three-dimensional display must change in exactly the way the image of a real object would change for similar motions of the user's head. The rotation of the eyeball could be considered in the system development, however it was not considered due to the complexity measure which involves eye rotations.

The optical system The Sword of Damocles magnifies the pictures on each of two tiny Cathode Ray Tubes (CRT) to present a virtual image about eighteen inches in front of each of the user's eyes. Each virtual image is roughly the size of a conventional CRT display. The user has a 40 degree field of view of the synthetic information displayed on the miniature CRT. Half-silvered mirrors in the prisms through which the user looks allow him to see both the images from the CRT and objects in the room simultaneously. The miniature CRT mounted on the optical system form a picture about one half of an inch square.

By the 1970s, computer-generated graphics had replaced videos and models. These flight simulations were operating in real time, though the graphics were primitive. In 1979, the military experimented with HMD. These innovations were driven by the greater dangers associated with training on and flying the jet fighters which were being built in the 1970s. By the early 1980s, better software, hardware, and motion-control platforms enabled pilots to navigate through highly detailed virtual worlds.

It was expected computer gain control over, or reframe and reposition what is seen, recorded, stored, and used, not simply to make the act of -wearing- and -seeing- benefit commercial interests and the setup of the National Security Agency (NSA).

The contribution of Steve Mann to the history of wearable's and the event of Space Glasses today is to think outside the box and non-proprietarily about the entire idea of wearable computing. Mann's explorations into the use of the eyeball itself as a screen upon which images are projected (as mentioned earlier), operating thus as a kind of "veil" of images over vision, closes the gap even further between the anatomical and the technologized body. His Eye tap headset, used as part of his developing research for several decades, utilizes the eyeball in this way. The wearer's nervous and optical system are as nearly close to the electronic impulses the flickering signifiers of electronic networks as possible, suggesting an interrelationship and influence of one to another as a form of consciousness. This computer enabled, networked -seeing- self, moving within today's wireless, wearable reality, experiences the new social relations of a now mobile human-machine.

By 1980, Jaron Lanier popularized the term of VE. Lanier is considered a modern pioneer of the field; In 1985 Jaron founded the company VPL Research. VPL Research has developed several VR devices like the Data Glove, the Eye Phone, and the Audio Sphere. VPL Research authorized the warrant of the Data Glove to New York video game company Mattel. Mattel used this technology and made an accessory known as the Power Glove. It was hard to use and not popular at all. However, the price for this accessory was $75. It might be the earliest affordable VR device.

The availability in the middle 1980s of cheap, portable, consumer Liquid Crystal Display (LCD) televisions and more powerful CG machines from Silicon Graphics Inc. (SGI) made it possible to create a more capable VR system. The first prototype of the NASA VE Workstation was built from a motorcycle helmet, Watchman LCD displays, and wide-angle stereoscopic optics (27).

In 1986 with the support of NASA, Warren Robinett developed a VE Workstation incorporated the first data glove used in VR (See the Figure 9). The glove measured the bending angles of the finger joints and also included a tracker to measure the hand's position and orientation. Using the gloves the user can interact with the virtual world grasping virtual objects, or using hand gestures as commands. A command of the system was using the index finger to fly through the virtual world in the direction pointe. Also, hand gestures were used to scale the surrounding virtual world up or down.

Figure 9. First NASA HMD developed in the 1986 (27).

In 1998, David Cox at the MIT designed a series of Virtual Reality Modeling Language (VRML) floating AR floating 3D -Signs- which were designed to -stack- and work in combination with each other. The objects seamed -un-solid- when moving and -solid- when not moving. Objects included a windmill, an email mailbox, a navigational compass, a globe, etc. These were tested using a laptop and SGI based system called DIORAMA developed by Karrie Karahalios of the Social Media Group.

Advances to the general public

Until some years ago, VE has only been shown for general public for entertainment. Films and games are the most known application of VE. To understand the perspective of the world in VR technology is require making a review of the projects which have had more impact worldwide.

Terminator and Robocop was one of the first AR movies in the 1980s and 1990s. The use of AR by superimposes text and graphics over a view of the real world became synonymous with the viewpoint and “personality” of the cyborg.

VR have been seen in videogames, in 1985 the company Sega created a VR videogame Sega's Master System with over thirteen million units sold worldwide, a flickering headset which recreated the effect of 3D in a private setting. The VR made possible to create a unique effect across different games.

In 1991, Sega announced the Sega VR headset for arcade games and the Mega Drive console. Sega announced the work was underway on a VR peripheral which was supposed to usher in a new era of gameplay. Dubbed the Sega VR, the project consisted of a complex Ideo headset that allowed the gamer to immerse in the game they were playing. The game consisted of two LCD screens were accompanied by stereo headphones and the entire unit rested on a comfortable headband that would fit the shape of the user's head. Using Inertial sensors were possible to track and react to the movements of the user's head. An adjustable elastomeric band which ran lengthwise over the head helped minimize its weight and reduce strain (28).

The headset used three separate technologies: 3D realism, movement tracking, and stereo sound to produce a full 3D world. The entire experience was created by mimicking the actual human sight process. The system used binocular parallax. Binocular parallax refers to focusing on an object, each of our eyes receive a slightly different image (basis for 3D movies)which is both then fused together in the brain, giving us our sense of three dimensions. The Sega VR headset's dual LCD screens would recreate this effect, similar to the Master System's LCD 3D glasses, only on a much more powerful scale. The sense of immersion came from the headset's ability to track the movement of the user's head and react accordingly, e.g. if something flew over the player in the game and he moved his head to follow, using internal sensors with refresh rate higher than one hundred times per second the player streamed seamlessly over to that portion of the sky, showing everything in the direction he faced.

The headset made its final appearance in 1993 at the Consumer Electronics Show (CES). It was shown behind closed doors to a thoroughly underwhelmed audience, but the project finished when a writer left a bad review commenting the game was unresponsive blur which quickly lost any and all appeal. After the review the project never progressed beyond the prototype stage and Sega officially claimed it was halted due to users hurting themselves by moving while wearing the headset. They stated the sense of immersion was so realistic; it could potentially cause injury to children who played it. However, playing the game for more than ten minutes was enough to realize this was impossible, given the limitations of the hardware. The most likely scenario probably had to do with the unit's inability to produce a satisfactory effect. There were reports of testers getting motion sickness while playing and almost the half of the users got –cyber sick-. None of the four announced games were ever shown to the public and no other titles were ever announced. Unable to create the true, lifelike sense of immersion they had promised, Sega wisely pulled the plug in 1994 and Sega VR faded quietly into obscurity.

2.2.2 Projects in the actually

In the past, VR and AR were a dream, largely limited to the realm of science fiction. But now, nearly every gamer has already played VR and AR games. The hottest names in VR and AR are Oculus, Jaunt and Magic Leap. The technology with Billion Dollar investments the technology is becoming more affordable. With an all-new slew of immersive technology and content set hitting the market in 2015 and 2016 (29).

There are several VR/AR applications which are currently used, just to mention some of them: Virtual Simulations and Cave Automatic Virtual Environment (CAVE). Also, some enterprises have incorporated virtual stores e.g. CVS Pharmacy.

CVS Virtual 3D store

CVS pharmacy launched one of the first virtual stores on an apple tablet.

The CVS Vice President, Brian Tilzer, told the CVS app provides the millions of customers who visit CVS.com on a tablet device each month with a virtual feeling of visiting their neighborhood CVS/pharmacy from their homes or on-the-go.

CVS website reaches millions of visit monthly using a tablet and many of the customers use iPads in particular. The idea of the app was to empower the customers on their path to better health through innovative and personalized technologies. With a tablet app, customers are able to enjoy the services available on the website and in all stores for a seamless experience which works with their on-the-go lifestyle.

Tablets are an ideal platform to create this virtualized, 3D drugstore shopping experience, because they rely on strong visuals and gesture-based movements. Customers can easily manage prescriptions for themselves and their families and look up essential drug informationThe Figure 10 illustrates the experience using the CVS app.

The CVS app incorporates an interactive, user-friendly virtual CVS/pharmacy interface relies on gesture-based movements. The movements are native to touch-screen tablet environments. Tapping on main areas of the store launches different apps, some of the apps are:

Figure 10. Illustration of the CVS Virtual store.

- Pharmacy Services with Enhanced Prescription Management. Swiping the finger, customers scroll through all their prescriptions, they are able to schedule refills and viewing prescriptions available for pick-up.
- Photo Center. Users can upload photos from their tablet camera roll to print for pick-up at a local CVS/pharmacy. The CVS pharmacy will introduce support for additional tablet platforms and continue to enhance the app, offering additional new features which deepen the virtual

shopping experience and offer informative and innovative ways for customers to interact with pharmacy services (30).

2.3 Areas in VR/AR applications

The Figure 11 shows the main areas to consider when developing a VR and AR system: Wearability, Affordability, Interaction, Vision, Immersion, Usability, and Flexibility.

Figure 11. VR and AR Areas.

2.3.1 Wearability

The wearable plays an important role in VR applications. Wearability involves devices such as HMD or glasses. The fundamental concept of a HMD is to impose a virtual image upon the visual Field Of View (FOV). Assessment of the wearability of a HMD based mobile AR system should consider how the human visual system copes with the virtual image being introduced within the users' FOV whilst being presented immediately in front of the users' eyes. Wearable computers place loads on the human body. Previous studies have found wearing backpacks and devices in the head can result in physiological, biomechanical, and comfort effects (31).

To determine the wearability of computer systems, a set of criteria can be useful. Energy cost, the Biomechanical criteria, and the comfort are some criteria; those criteria are shown in the Figure 12. For each measure, the value obtained from an assessment can be associated to a level of effect ranging from Low to Extreme.

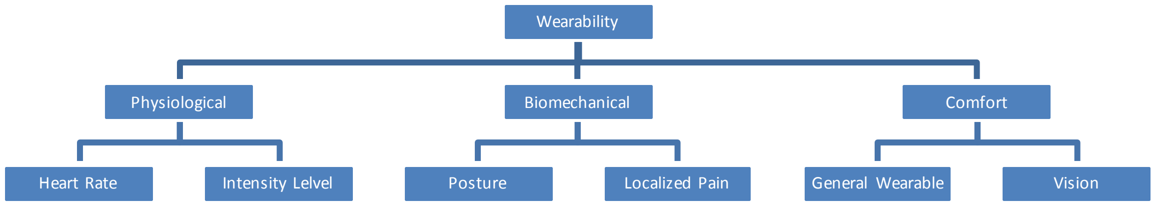

Figure 12. Wearability of wearable devices.

Physiological

Physiological criteria make reference to the energy expended during an activity. Loads attached to the body have measurable effects on the energy expended. Muscle force is required to reduce the effects of the load's weight. The physiological wearability can be divided in Heart Rate and Intensity level. The intensity level can be measured with the Borg Rating of Perceived Exertion (RPE).

Perceived exertion is how hard you feel like your body is working. It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue. A person's exertion rating provides a good estimate of the heart rate during physical activity (32).

Biomechanical

Biomechanical wearability is considered as to musculoskeletal loading, localized at a specific body's region. To determine the values from low to extreme, the heart rate is used as Astrand proposed (33).

Biomechanical effects are defined in terms of musculoskeletal loading and can be assessed using different methods, e.g. modeling (34) or electromyography to measure levels of muscular exertion (35).

Comfort

Comfort is a sensation and state of being which many people seek when they are working in the office, driving in a car, flying on an airplane, or laying in a hospital bed (36).

The wearability comfort is a general overall sense of wellbeing or a specific system or area of the body. Wearable computer assessments should include elements of comfort analysis. The Comfort Rating Scales (CRS) were developed specifically to assess the comfort of wearable technology (37). The CRS attempt to develop a comprehensive assessment of the comfort status of the wearer of any item of technology by measuring comfort across six dimensions. These dimensions are the following:

- Emotion
- Attachment
- Harm
- Perceived change
- Movement
- Anxiety

2.3.2 Interaction Techniques

To immerse a user in a VR application, is required to create a VE to learn how to interact with information and controls distributed about a user instead of concentrated in a window in front of him. Identifying natural forms of interaction and extend them in ways not possible in the real world is required (21). It is possible to interact or control a VE with different ways, the Figure 13 shows the most common interaction techniques.

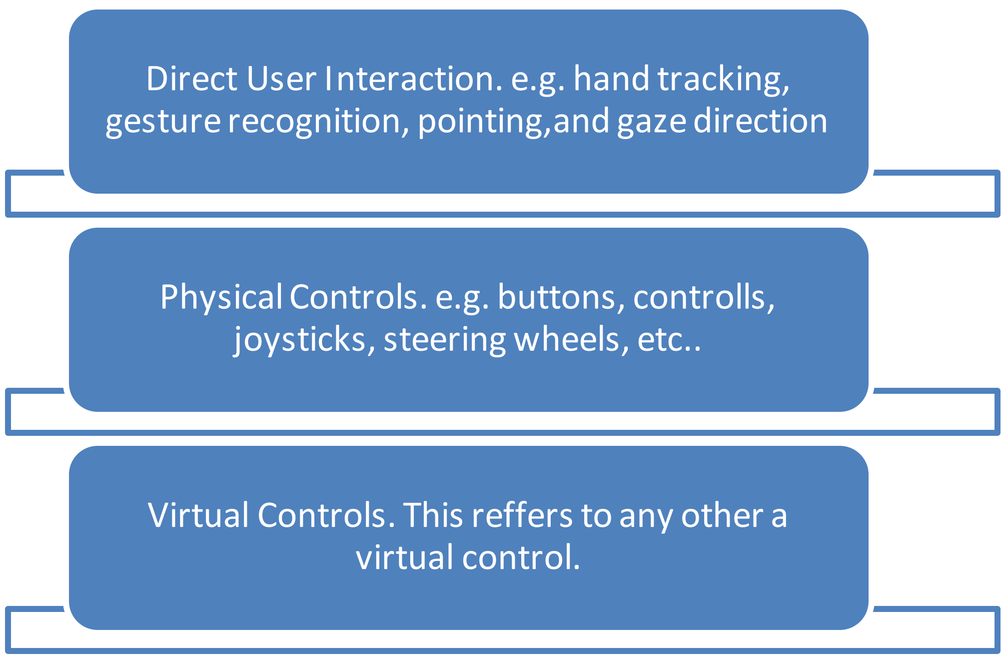

Figure 13. Manipulation techniques to interact with VEIT (21).

As it is shown, the direct user interaction basically consists in hand tracking, gesture recognition, pointing. In this way, the user's interaction is natural and intuitive.

Also, physical devices include, but are not limited to: Push buttons, dials, joysticks, and steering wheels. With physical control is possible to have natural mappings making easier interaction tasks. To maximize the user's immersion into the VE, physical control can be used to interact in a virtual world e.g. driving games often a steering wheels, those wheels are used to increase the approaching to a real driving experience. However, when it is required to combine a real physical device for better precise control of an interaction task e.g. to positioning an object with high accuracy, usually there is lack of integration.

There are no limits of interfaces to be implemented as a virtual control for a VE. This great flexibility is the key advantage of virtual controls. However some of the disadvantages is the lack of haptic feedback and the general difficulty of interacting with a virtual object.

2.3.3 Vision

It is required to handle engineering and testing problems for computer vision systems. Vision technology is helpful to simulate intelligent creatures within future VR systems (38). Some of the vision problems in 3D scene reconstruction are: shapes from diverse techniques, sensor calibration, and multisensory integration motion analysis.

The huge amount of test data provided by an immersive simulation with simultaneous access to ground-truth data should allow boosting the accuracy and robustness of many algorithms.

Active vision adaptation, learning and performance evaluation.

Active vision control the sensors to allow e.g. focus on specific parts of the scene track moving objects or to compensate for platform motion (39). Simulation allows performing experiments in an earlier phase and without finalizing the mechanical design. Typical hardware components for active vision are motorized lenses, and gyroscopes, which can be properly modeled within the simulation system. The -Level of Detail- concept in graphics simulations (40) where the currently viewed parts of the scene are presented in more detail than others is closely related to the ideas of active vision and multi-scale representations.

Adaptation and Learning Current machine perception techniques computer vision in particular lack the required robustness reliability and flexibility to cope with the large variety of situations encountered in a real-world environment. Many existing techniques are critical in the sense even minor changes in the expected task environment can affect the quality e.g. different lighting conditions geometrical distortions changing vegetation etc. can strongly degrade the performance of the system or even make it fail completely. Although results have been disappointing in the past there are good reasons to believe adaptation and learning can increase the robustness and flexibility of current vision techniques. There are many forms of learning applicable for vision including statistical parameter estimation clustering function approximation structural learning self-organization and neural network training. Existing applications include low-level processing feature selection and grouping model acquisition from examples map learning and 3D object recognition. The problem of automatic or interactive acquisition of knowledge for object recognition acquisition of object model is probably among the most urging and challenging problems in vision. Using immersive simulation is possible to provide several important solutions to the learning problem in vision:

- Large sets of realistic examples can be created and processed with reasonable effort.
- Supervised learning is possible without human intervention since ground truth data and actual model information are available from the simulator.
- Closed-loop or exploratory learning where specific critical training data are generated in response to the learning progress can be performed if needed.

2.3.4 Immersion

Immersion is the perception of being physically present in the VE. The perception is created by surrounding the user in images, sound or any other sense providing an engrossing total environment.

Immersion is to experience a submersion to representation, fiction or simulation. Immersion can also be defined as the state of consciousness where the user awareness of physical self is transformed is surrounded in a VE. The degree to which the virtual or artistic environment reproduces the real world determines the suspension of disbelief. So, is expected for a good immersion, the level of suspension of disbelief be high.

Immersion can be categorized in three categories (41) as shown in the Figure 14, they are: Tactical, Strategic and Narrative.

Tactical Immersion. Tactical immersion is experienced when performing tactile operations which involve skill, e.g. in video games, players experience feelings while perfecting actions which result in success.

Strategic Immersion. Strategic immersion is more cerebral, and is associated with mental challenge. Chess players experience strategic immersion when choosing a correct solution among a broad array of possibilities.

Narrative Immersion. Narrative immersion occurs when the user becomes invested in a story, and is similar to what is experienced while reading a book or watching a movie.

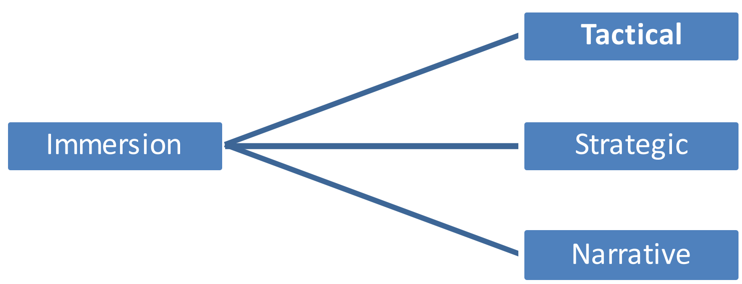

Figure 14. VR Immersion categories (41).

To create a sense of full immersion, the five human senses must perceive the senses through:

- Panoramic 3D displays
- Surround sound acoustics
- Haptic and force feedback
- Smell
- Taste

2.3.5 Usability

Usability is how easily a human-made object will be used. The usability can be measured to any invention of the human being, e.g. a website, a book, a tool, a machine, a process, etc. VR systems can suffer from severe usability problems such as conceptual disorientation and inability to manipulate objects (42).

There is a need to develop novel usability testing environments and methodologies because computerized interactive systems are evolving and the current labs are limited. The new techniques will be necessary for testing a new generation of interactive systems, such as AR, VR, and mobile devices. It is true today's VR provides very limited tactile feedback (43).

To evaluate the usability of a VR, a proposed process is using the model of interaction which was used as the underpinning for earlier cognitive walkthrough methods (44). Since VR poses new problems of navigation, orientation, and movement for user interaction, we have extended existing models to describe the user's mental and physical actions in 3D worlds. An overview of the interaction theory for VE with further details of its validation is reported Designing VE for usability (45).

Since immersive environments and virtual worlds are highly different from Graphical User Interfaces (GUI)(46), there is a need to question the applicability for immersive environments. New methodologies can be adapted from the old or entirely new methodologies may need to be developed, as is probably the case for mobile applications (47).

2.3.6 Flexibility

Flexibility can be defined as the ability to be easily modified as well the ability to be susceptible of modification or adaptation.

FMS are required to minimize costs. Realizing test in physical prototypes is fairly expensive. For these cases VR offers a flexibility to use different reconfigurations of system's components such as machines, robots, etc. as well as the products produced on these systems.

A FMS is an integrated, complex computerized automated material handling devices and Numerically Controlled (NC) machine tools which can simultaneously process a variety of part types (48). Flexible systems must have automated parts transfer and short setups (49).

Flexible systems commonly are confused with nonflexible system e.g. some systems are called flexible because they produce a variety of parts. For this reason it is important to detail the kind of flexibility, some of the most known flexibilities are:

- Machine flexibility
- Process flexibility
- Product flexibility

Machine Flexibility

It is required to make changes easily, to produce a given set of part types e.g. time to replace worn-out or broken cutting tools, the time to change tools in a tool magazine to produce a different subset of the given part types, and the time to assemble or mount the new fixtures required. The machine flexibility can be divided in:

- Technological Progress
- Proper operation assignment
- Transportation Technology

Process Flexibility

Process Flexibility is also known as Job Flexibility. Process Flexibility is the ability to produce a given set of part types, as the cost decrease, the flexibility increase. Also, a flexible process decreases cost while working in low volume production. The process Flexibility can be divided in: Machine Flexibility and Multipurpose CNC machining centers.

Product Flexibility

Product Flexibility is the ability to change over to different products. This flexibility is also known as Action Flexibility.

2.3.7 Affordability

Affordability is the characteristic that will impact in the cost and in the return of investment factor. Some projects are not developed according.

2.4 VR Companies and Investment

VR and AR are considered as the technologies which have more growth opportunities in the future. Therefore, large technology is accelerating the purchase of startups dedicated to creating software able to merge the real world and the virtual world. Figure 15 shows the most relevant enterprises. Some enterprises e.g. Oculus and Samsung have a very strong presence in the market for VR gadgets.

The investment on VR and AR realities can be divided in three categories:

- Hardware
- Software
- Content

Hardware, Samsung, Kinect, HTC vive, and Play Station VR just to mention some are the main enterprises in the hardware development; Software, in Software development we have Amazon, NVidia, and Unity; Content, some well-known enterprises developing content only are: Blippar, Vantage TV, and Immersive Entertainment.

Also, some enterprises are focused developing their products covering more than one area. In Hardware and Software development is Microsoft Hololens, designed to keep immersed in a reality enriched by holograms users; in Hardware and content development is GoPro, considered as the world's most versatile camera brand; in Software and Content development there are some enterprises such as Linden Lab, iDream Sky Technology.

Finally, Enterprises which development is in the intersection of the three categories already stated, just to mention some of them are Oculus Rift, Magic Leap, and Jaunt.

However, there are several enterprises investing in VR and AR technologies.

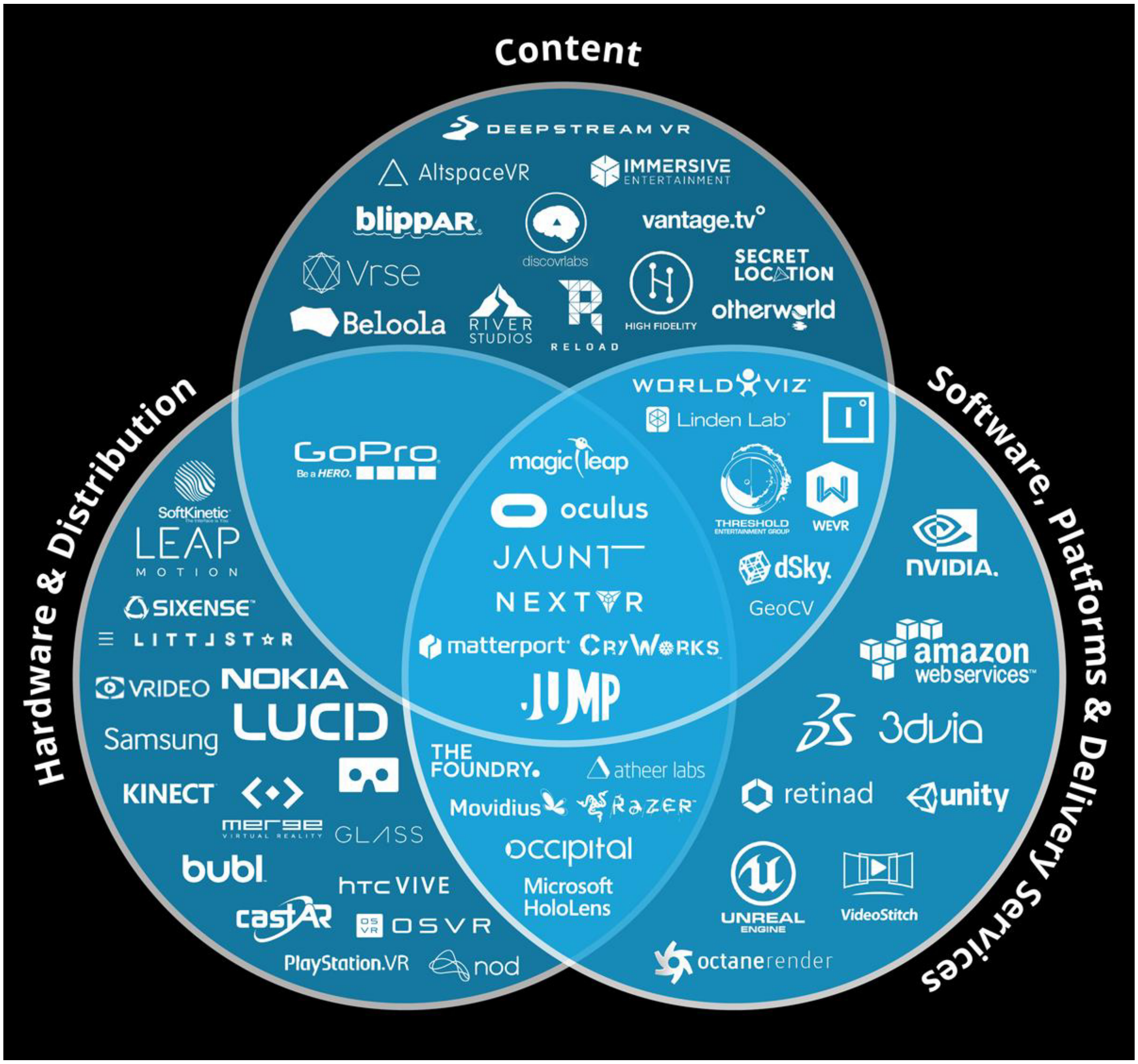

Figure 15. VR and AR enterprises by the research area (29).

It is difficult to estimate the value of new immerging markets, such as VR and AR industry. Specialist dedicated in the Analyst of markets, believe in the coming years AR and VR technologies will enjoy individual growth and also they will be able to expand into new markets.

Venture capitalists estimate VR may be the hot thing in today's technology. Products like Oculus Rift HMD and Google glasses backed Magic Leap. However, to have more profitability with VR and AR technologies, it is expected investor will wait a long time.

Adam Draper, Founder and CEO of Boost VC, a startup accelerator said "There's a lot of flow of money happening." He made VR one of the firm's two investment pillars.

According to a report by Digi-Capital, the field of VR and AR could reach a total of 150,000 million dollars in revenue for 2020 (see the Figure 16). The technology has gotten so much attention even before actually getting to consumers. It is expected the technology will win more AR share, with a predicted growth of up to 120,000 million, whereas the VR would be only 30,000 million.

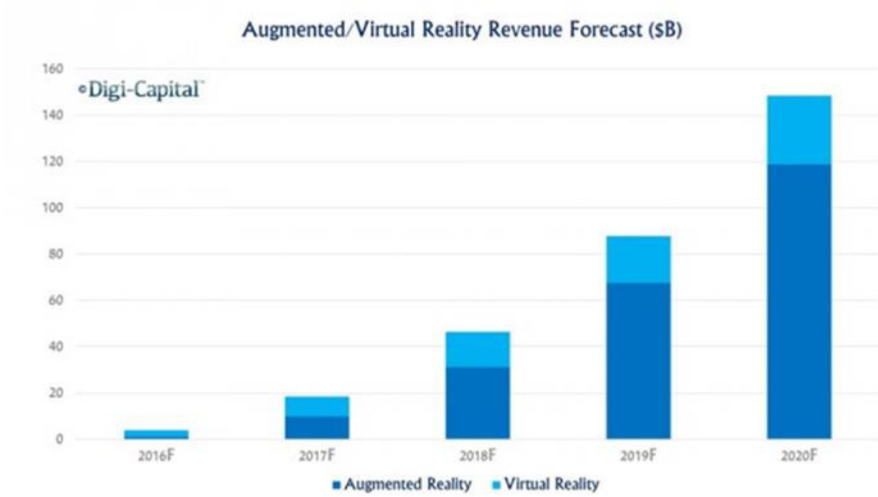

Figure 16. AR /VR Revenue Forecast (50)

It is difficult to estimate the value of a merging technology; however it is clear the payoff on VR and AR investments will not come anytime soon. For example, Nabeel Hyatt, venture partner at Oculus investor Spark Capital, states it is required to have to have a pretty long view on these companies. Occulus Rift invested almost two years of very public testing because basically there's no user base. Also, Alexander Taussig, a partner at Highland Capital in a conference suggested to the developers to do not take money from VCs who are not prepared to wait a few years for results.

Rothenberg Ventures started investing in VR after investment director Dylan Flinn experienced the developer version of the Oculus Rift. The investment director sees VR as the next evolution of human-computer interaction, and they have invested creating a social VR platform, and 3D modeling startup Matterport, Altspace VR (51).

It is estimated the revenues in VR and AR will be of at least two to three years, said Flinn. One reason is hardware do not have mass appeal yet, not least because some of the most prominent products such as those from Oculus and Magic Leap are not even released yet. One of the main reasons Oculus Rift have waited before the release, is the company does not want to ship a headset which makes the nausea as the early VR gear Sega VR which was discontinued due to the cyber sick.

There's no really compelling content for VR yet, apparently VR studios are still searching for the magic formula. In one conference Ben Miller, director of content development at WEVR, said: "No one knows how to tell a story in immersive entertainment." There are many VR spectacles however it has not reached the user experience desired.

For researches and investors in this technology, the fact Facebook, Google, Sony, and other giants have get involved in this technology it may seems the chances to develop a competitive technology have been reduced, specially to build an end-to-end display platform however there are still more opportunities, such as easier-to-use content creation and data visualization tools and software for eye tracking, gaze input, and voice placement, said Miller.

AR software and services could have similar economics to today's mobile market, as they both cannibalize and grow it. A large AR user base would be a major revenue source for TV/film, enterprise, advertising, and consumer apps from Facebook to Uber to Clash of Clans. Amazon and Alibaba would have an entirely new platform for selling to a mass audience. Together with innovative applications nobody has thought of yet, AR's scale could prove a bonanza for mobile networks' voice and data businesses.

According to DigiCapital, AR revenue could hit $120 billion by 2020. In the Figure 17 is show how the AR market could look like by 2020.

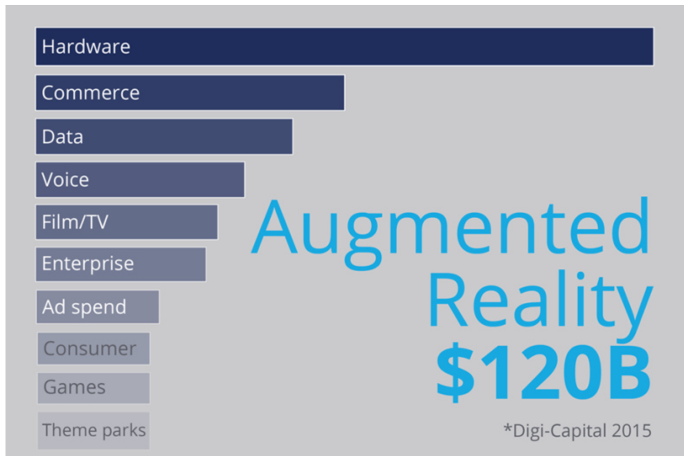

Figure 17. AR Revenue share 2020. Digi-Capital 2015

The AR Hardware investment will lead followed aCommerce with the half of the investment of the Hardware. Data, Voice, Film/TV, Enterprise, Add advertising, Consumer apps, Games and Theme park category will have significantly less investment.

In other hand, aaccording to DigiCapital, VR revenue could hit $30 billion by 2020 as shown in the Figure 18.

Figure 18. VR Revenue share 2020. Digi-Capital 2015

As it can be seen, AR is expected to have more revenues in more applications than VR. AR will be invested in the fields of commerce data, voice, ad spends, and consumer when the investment of his counterpart VR are not considered in the study.

3 Supporting Technologies for Mixed Reality Assistance Systems

VR support offers a competitive advantage to the engineers; it is possible to interact with the environment to solve the problems effectively and efficiently (52). Inside a VE is possible to generate assembly simulations, plans, and evaluations. This way you avoid potential problems even before creating the real factory. Also it helps to improve the product quality and product design cycle time. Virtual Reality Learning Environment (VRLE) satisfies the different learning needs users might have. Studies had found students prefer the modules of Simulation of manufacturing process and practical exercise (53).

3.1 Virtual, Augmented and Mixed Reality

VR usually use screens as displays to show the VE, but when it is desired to show a set of instructions projected directly on the workspace it is also required to use AR techniques.

MR Systems are systems which combine real and computer-based information. Table 1 shows a comparison of the advantages of three environmental visualization techniques.

Table 1. Virtual, Augmented and Mixed Reality comparison.

Advantages	AR (Glasses)	VR (Display)	MR (Projector)
Instructions in a Real Environment	X		X
Multiple viewers		X	X
Correct Visualization from any angle		X	X
Hang-on/wearable devices free		X	X
Portability to desired workstation	X		
Assistance special for a Workstation		X	X
Repeated sequence until completing task	X	X	X
Reduction of delay time due to parallel assistance.	X	X	X
Reduction of teaching effort	X	X	X
Perform any variation possible	X	X	X
Obtain assistance immediately	X	X	X
Improved flawless launches	X	X	X
Needed time to prepare the assistance system	X	X	X

Almost all tools used to interact with virtual world are separated from those used to interact with the real world it forces the user to switch between operation modes resulting in a discontinuous interaction (54).

This system will provide users assistance projecting instructions with a fixed perspective-correct imagery of the manufacturing module environment without wearing devices neither optical positioned in front of the user's eyes. These characteristics facilitate team training experiences and virtual assistance which allow users to easily interact with their teammates while wearing their standard issue gear.

There are a large variety of tools which are useful for creating MR solutions using PM, however there is still lack of integrating them to make a system to assist manual assembly operations for manufacturing modules, it was not found. One of the most relevant research in PM, is the Illumiroom conceptual system under development of Microsoft, It augments the area surrounding a television screen with projected visualizations to enhance the traditional living ROOM entertainment experience.

It is required to make an assistance system which integrates assembly processes of an automotive manufacturing enterprise using MR technology to facilitate to speed up manual operations.

3.2 Projection Mapping

PM has many alternate names including the original academic term Spatial Augmented Reality (SAR) and Video Mapping.

PM is a technique to turn objects, often irregularly shaped, into a display surface for video projection. PM can be used in surfaces of any kind of shapes, turning them into interactive (55). Some of the simplest projections are made over surfaces with geometric shapes which can be flattened without stretching their surfaces (56). Some of the criteria's to consider when designing a high performance simulation are the Geometry, the Image blending and warping, brightness, and latency (57).

The PM can be done in complex industrial landscapes, such as buildings, small indoor objects or theatrical stages. Also, PM can be used for advertising, live concerts, theater, gaming, computing, decoration and more. Specialized software or simple software's can be used to adjust the virtual content and the physical objects.

PM was first known in the early 1990s when projection based surround screen displays became popular. One of the most known is the CAVE, a multisided, immersive projection room. But there are other examples of semi immersive, immersive cylindrical and spherical spatial displays. In general, spatial displays detach the display technology from the user and integrate it into the environment. Compared to HMD or body mounted displays, spatial displays offer many advantages and solve several problems related to visual quality e.g. resolution, field-of-view, focus, etc., technical problem e.g. tracking, lighting, etc., and human factors e.g. cumbersomeness, etc.

Many VR devices have been developed away from HMD however a large variety of AR devices, has a strong focus of mobile AR applications, and makes it continues using HMD. The reason HMD displays are still used might lie in Video see-through and optical see-through HMD have been the traditional output technologies for AR applications for almost four decades.

However, HMD suffers from several technological and ergonomic drawbacks which prevent them from being used effectively in many application areas. HMD will also be enhanced by future technology, leading to a variety of new and different possibilities for mobile AR.

Novel approaches have taken AR beyond traditional eye-worn or hand-held displays enabling additional application areas. New display paradigms exploit large spatially-aligned optical elements, such as mirror beam combiners, transparent screens, or holograms, as well as video projectors. SAR displays are able to overcome technological and ergonomic limitations of conventional AR systems. Due to the decrease in cost and availability of projection technology, personal computers, and graphics hardware, there has been a considerable interest in exploiting SAR systems in universities, research laboratories, museums, industry, and the art community. Parallels to the development of VE from head-attached displays to spatial projection screens can be clearly drawn. It is possible an analog evolution of AR has the potential to yield a similar successful factor in many application domains. Thereby, SAR and body-attached AR are not competitive, but complementary.

3.2.1 Projection Mapping Fundamentals

The light is a fundamental element, relevant for all display technology. The atomic view on light gives hints on how it is generated. To understand how the light travels, is required to know the light properties.

As a starting point, is required to know the geometry of the light. Hence the Electromagnetic (EM) waves are important to describe how simple optical elements, such as mirrors and lenses work. After this, it can be seen how images are formed by light rays in a single spatial spot or area in a three dimensional space.

The structure and functionality of the human eye is as complex as an optical system itself, it interplay two eyes leads to visual depth perception. The human depth perception can be adjusted when viewing flat images on a stereoscopic display. The fundaments of PM can be categorized as shown in the Figure 19.

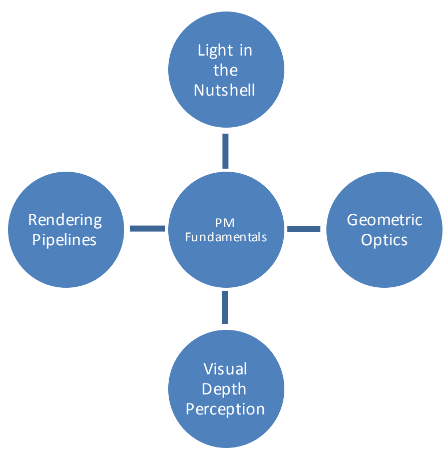

Figure 19. PM Fundamentals.

Light in a Nutshell

To understand the light is required to understand the atomic level, the photons and electrons. The Figure 20 shows the planetary model of Niels Bohr. Atoms consist of a nucleus and electrons which orbit the nucleus.

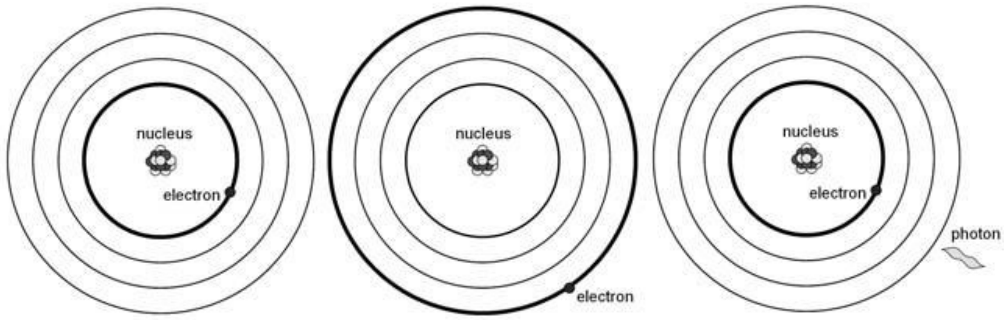

Figure 20. Planetary model of atom: (a) electron orbiting the nucleus in a non-excited state; (b) excited electron after quantum leap; (c) electron releasing a photon while dropping back into a non-excited state (58).

In the center of the atoms there are Protons, and in the exterior are the electrons. The electrons move around the orbit. The electrons also have the ability to move from atom to atom, this flow is called electricity.

There are many levels of orbit in an atom. The electrons usually are found in the lowest orbits, by default in the orbit closest to the nucleus. If the atom is excited by external energy, the electron can move from lower to higher energy orbits. This shift from a lower to a higher energy state is called quantum leap (58).

According to the first law of energy, the energy cannot be destroyed or created, but transformed. When the electrons are moved from orbit to orbit, the electrons have to release energy when they drop back to lower energy states and the electrons do so by releasing packages of energy called photons.

According to the amount of energy, Photons have a frequency which relates to the amount of energy they carry which, the size of the drop from the higher state to the lower one. They travel in waves with a specific phase, frequency, and amplitude, but they have no mass. These EM waves travel in a range of frequencies called EM spectrum.

A small part of this spectrum is the EM radiation which can be perceived as visible light. Since light behaves like waves, it shares many properties of other waves and the light waves can interfere with each other. Depending on their phase, frequency, and amplitude, multiple light waves can amplify or cancel each other out. Light which consists of only one wavelength is called monochromatic light. Light waves which are in phase in both time and space are called coherent. Monochromaticity and low divergence are two properties of coherent light. If a photon passes by an excited electron, the electron will release a photon with the same properties. This effect called stimulated emission and is used today to produce coherent laser light. In general, "normal" light consists of an arbitrary superimposition of multiple incoherent light waves which create a complex interference pattern. Light travels in waves with a variety of different orientations. The waves can be polarized selecting waves with a specific orientation.

Depending on the material properties, light can be reflected, refracted, scattered, or light absorbed by matter. The Figure 21 shows some possible results when light interacts with different materials properties.

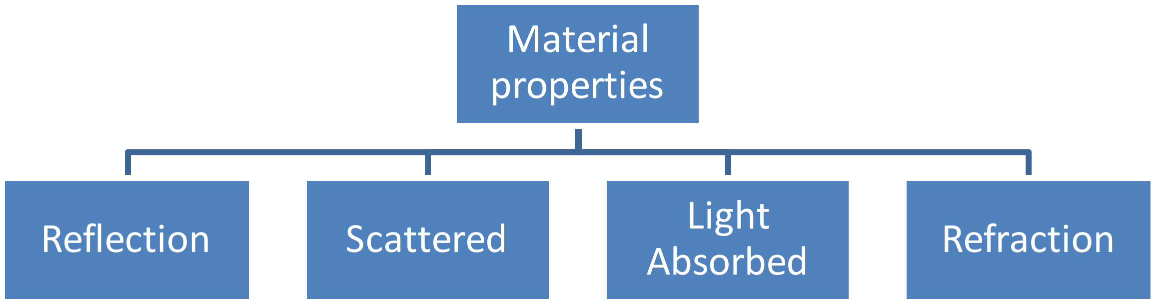

Figure 21. Main Material properties in projections.

Reflection. If the light is reflected, the light is bounced off a surface .If the particle is larger than the wavelength, light will be reflected. Imperfections on the reflecting surface cause the light to be scattered or diffused in different directions. Light can also be scattered when it collides with small particles. The amount of scattering depends on the size of the particle with respect to the wavelength of the light. Such particles radiate light at the frequency of the absorbed light in different directions. This process is called Rayleigh scattering. If the particle is smaller than the wavelength then, the light will be absorbed. The light absorbed can be converted into heat (energy transformation). Refraction occurs when light travels across the boundaries of two mediums. In a vacuum, light travels at the speed of light. If travelling through a denser medium, the light is slowed down and causes it to alter its direction.

Geometric Optics

Optics refers to all appearances perceived by the human eye. In geometric optics, the light is represented by individual rays (straight lines), the light is homogeneous and isotropic.

The formation of point's images

Optical instruments can form images from a number of point light sources (objects). Light rays emitted from an object can be reflected and refracted within the optical instrument and are finally perceived by a detector (e.g. the human eye). If all light rays emitted from the same object (po) travel through the optical system within the same image (pi), then the point's po and pi are called a stigmatic pair. This image property is called stigmatism, and the optical system which supports stigmatism between all object-image pairs is called an absolute optical system.

The basic precondition for stigmatism can also be derived from Fermat's principle. It states the optical path length for every light ray travelling from po to pi is constant.

If points (objects or images) are formed by a direct intersection of light rays, then these points are called real object otherwise they are considered as a virtual object If light rays do not directly intersect at a point, they can form virtual points (or images) otherwise they are known as a real image.

In the Figure 22 is shown the stigmatic image formation. At the left side is shown a real object with a real image, in the middle a real object with a virtual image, and to the right can be seen a virtual object which creates a real image.

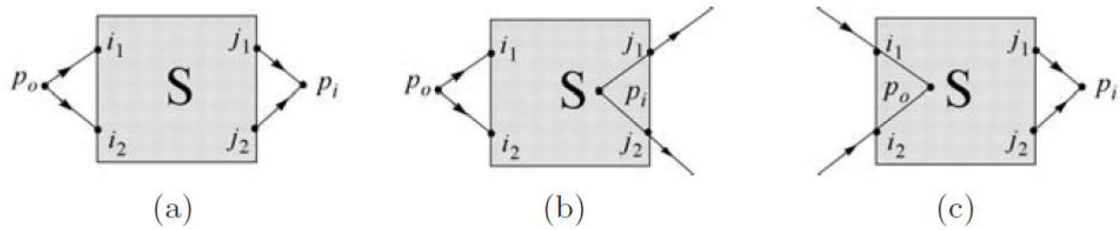

Figure 22. Stigmatic Formation.

Optical Elements

There are two main characteristics: Reflection and Refraction.

Reflective Optics

Reflective Objects are used in microscopy applications which require chromatic correction over broad spectral ranges. Reflective Objects use two mirrors to form an image or focus a laser in a variety of imaging or laser applications. Reflective Objects are high magnification solutions to applications in the ultraviolet, visible, or infrared. Also, reflective objects can be coated for additional performance over a specific wavelength range or laser line.

Mirrors are considered as exclusively reflective optical systems. The medium that light rays travel through mirrors is homogeneous and can be further idealized a mirror surrounded by air, and the medium air is approximately equivalent to the medium of a vacuum.

Refractive Optics

The most commonly objects are refractive. In a refractive design, the light which passes through the system is refracted, or bent by the optical elements. Typically the optical element is anti-reflection coated to reduce back reflections and improve overall light throughput. Refractive objectives are often used in machine vision applications when it is required extremely fine details resolution.. There are multiple refractive object designs, each utilizing different optical configurations. The designs can range from two elements in basic achromatic objectives to fifteen elements in plan-apochromatic objectives (59).

Visual Depth Perception

The light rays which are emitted by objects or images which are finally perceived by light-sensitive components called detectors. The most common detector for optical systems is the human eye which forwards the detected light information to the brain.

The interplay of the two eyes which receive different images of the same environment enables the brain to reconstruct the depth information. This phenomenon is called stereoscopic vision. Stereoscopic vision can be fooled with stereoscopic displays which present two artificially generated images of a VE to the eyes of a human observer. As in the real world, these images are interpreted by the brain and fused into a three-dimensional picture.

The human eye

The human eye consists of spherical interfacing surfaces and represents a complex optical system itself. An approximate of the diameter of the human eye is 25 mm and it is filled with two different fluids. The iris is the muscle which regulates the amount of the incoming light by expanding or shrinking. The cornea and the elastic biconvex lens below the iris bundle the transmitted light in such a way different light rays which are diffused by the same point light source are projected to the same point on the retina. Note the projection is flipped in both directions horizontally and vertically. The retina consists of many small conic and cylindrical cells which detects light, called photoreceptors. The photoreceptors are categorized into rods and cones. The resolution of the eye depends on the density of these cells which varies along the retina. If the distance between two point projections is too small, only one cell is stimulated and the brain cannot differentiate between the two points. To recognize two individual points, the two stimulated cells have to be separated by at least one additional cell; otherwise the points cannot be differentiated. The limited resolution of the human eye is the reason why light rays emitted from a single object point pass through an optical system which does not support true stigmatism, still appear to intersect at a single image point.

Stereoscopic vision

Two different points of view of the same object are required to sense depth perception. The human eye separation is about 6.3 cm, this makes the images perceived by the eyes be slightly shifted horizontally and rotated around the vertical axis.

The relative displacement between two projections of a single object onto two different focal planes is called retinal disparity. The sensing cells are used by the brain to fuse the images of both eyes, and to approximate the relative distance of the object. When the difference between the two images is too large, they cannot be fused by the brain and the object space appears twice. This effect is called diplopia. To fuse the images, the eyes have to rotate around the vertical axis until they face the focal point. This mechanism is called vergence. The eyes can either rotate inwards to focus at close objects (convergence) and outwards to focus distant objects (divergence). When the alignment of the eyes is parallel, the eyes are focusing to an infinite distance.

Spatial Stereoscopic Presentation

It is possible to determine the fictive light rays emitted and intersect the eyes. This is possible using the eyes' positions; the fictive lights are approximated by representing the eyes with single points located at the eyeball's center. The rays are projected onto the display surface and result in the positions of the pixels finally drawn on the display.

Classification of Stereoscopic Displays

There are several stereoscopic displays. We will see a general overview focusing more on the technology considered which impacts more in the project developed, using PM.

In the Figure 23 is shown a classification of the stereoscopic displays. They are divided in two main categories: Goggle-bound displays and Auto-stereoscopic displays. The main difference between them is goggle-bound displays require using additional glasses to support a proper separation of the stereo images whereas auto-stereoscopic displays do not require glasses.

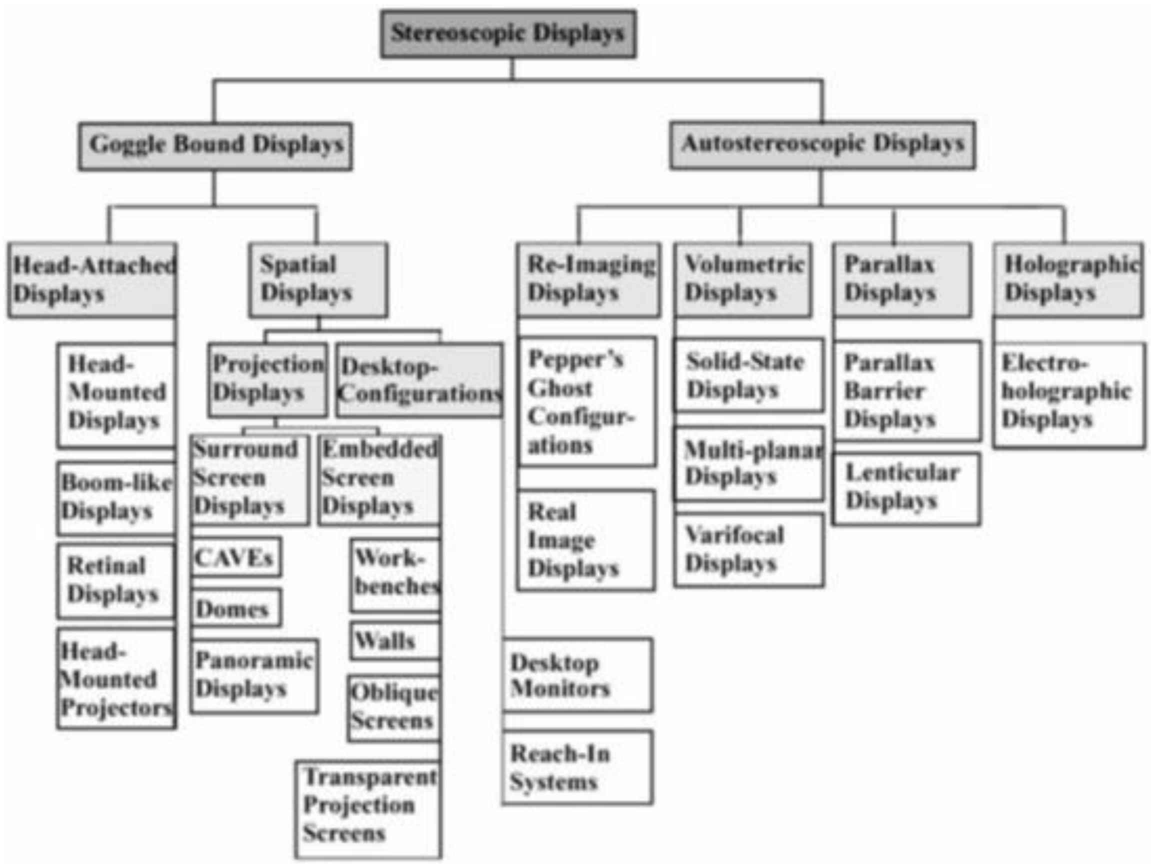

Figure 23. Classification of stereoscopic displays (58).

Goggle-bound displays. Goggle-bound displays require the user to wear additional devices in from of the eyes, usually as goggles to support a proper separation of the stereo images. The goggles can be divided in head-attached displays and spatial displays. The difference between them is Head-attached displays provide individual display elements for each eye, and consequently can present both stereo images simultaneously. Examples of this category are the HMD, BOOM like displays, Retinal displays and Head Mounted Projectors. HMD (60)(61) and BOOMs (62) use motion of the actual display screens.

Spatial displays use screens spatially aligned within the environment. However, the user has to wear field-sequential or light-filtering goggles to support a correct separation of the stereo images. This separation technique is known as shuttering, because both stereo images is visible to one eye only.

Spatial displays can be further divided into desktop configurations and projection displays. In desktop configurations, monitors can be used as a possible stereoscopic display is the traditional desktop-VR approach (63). Fish tank VR setups are classified as non-immersive since, in contrast to large screens, the degree of immersion is low.

Projection displays can use any projection light source such as CRT, LCD, Liquid Crystal on Silicon (LCOS), Digital Light Projectors (DLP), LED, Laser, and hybrid light source to beam the stereo images onto single or multiple, planar or curved display surfaces.

It is possible to project by the front of the surface as well as by backwards. The most common projection is by the front, this means the projectors are located on the same side of the display surface as the observer. Rear projections are made locating the projector at the opposite side of the display surface. An advantage using rear projection is this way is avoided the observer interfere with the projection frustum and cast a shadow onto the display surface.

Projections displays can be divided in Surround screen displays and embedded screen displays. Surround screen displays. Surround screen displays uses PM techniques (also known as SAR techniques). Surround screen displays surround the observers with simple displays or using PM techniques to create displays in multiple surfaces such as planar, curved or irregular surfaces. The most known of surround screen displays are the CAVE, Domes, and Panoramic displays whereas embedded screen displays integrate a single, or a small number of display surfaces, into the real environment. Thus, the users are not immersed into an exclusively VE, but can interact with a semi-immersive VE which is embedded within the surrounding real environment.

This thesis work develops a MR technique based in PM as an embedded screen display.

3.2.2 Projection Mapping Based systems

Correct projection of the imagery on large screens can also create a VR experience; there are a large number of projects based on PM. SAR based on projections have been used for different applications, e.g. PM is used in CAVEs, Dooms and to re-create automotive accident scenes by video tracking.

Cave Automated Virtual Environment

CAVE is an environment enhanced with VR consisting of a square room with images projected with rear projector. The CAVE is located inside a larger room which must be absolutely dark when the CAVE is in use to improve the visual quality. For a full immersion, it is required the viewer wears special glasses synchronized with the projectors. The floor of the CAVE can be sliced as a Treadmill so the user can walk around in the small room around the image to study it from all angles. Sensors within the room track the viewer's position to align the perspective correctly.

The CAVE was developed for scientific and engineering applications mainly to overcome limitations of HMDs. CAVEs have been used for research into a wide range of disciplines including archaeology, architecture, art, biology, engineering, geometry, geology, meteorology, and physics.

The CAVE makes use of large, fixed screens more distant from the viewer, this makes possible to share the VR experience with multiple people at once allowing users to collaboratively examine and manipulate complex 3D models with natural interaction (64).

The CAVE is an effective and convincing VR application which expands the use of VR, also CAVE increases the quality of the virtual experience allowing multi-user session. The CAVE has minimum error sensitivity due to rotational tracking noise and latency associated with head rotation compared to HMD and BOOM (65).

The CAVE, at its origin it was described a VR /scientific visualization system in detail and demonstrates projection technology applied to virtual-reality goals achieves a system which matches the quality of workstation screens in terms of resolution, color, and flicker-free stereo (65).

Video tracking

Video Tracking is a photogrammetric technique for obtaining three-dimensional data from a scene using video (66). Kineticorp use PM techniques to improve the ability to take video footage of a roadway. The main purpose of Kineticorp is to take an accident scene which contains physical evidence in order to reconstruct the incident creating a three-dimensional, scaled accident scene diagram with rectified photographs mapped onto the geometry. The video footage is done through photogrammetric and PM processes.

According to Kineticorp, PM is a computer visualization technique of wrapping or mapping video or photographs onto three-dimensional geometry and adjusting the size and shape of the map so it follows the size and shape of the target objects.

Currently, Kineticorp uses PM to generate a scaled three-dimensional computer model of an accident scene from video footage. This method, which combines the previously published methods of video tracking and camera projection, includes automated mapping of physical evidence through rectification of each frame (18).

The rectification of the process of adjusting the size to different shapes and wrapping videos, results in an accurate virtual model in detail, lighting, and scale since it is built directly from the photograph. The result of adding the technology of video tracking with three-dimensional camera PM is a scaled computer model of the accident scene which includes photographs of the evidence mapped onto the geometry at the correct scale and location all from a single video drive through. Developing both of these concepts into one method of Video Projection Mapping (VPM) combines the ease of building a three-dimensional accident diagram from a video drive through with the accuracy and clarity of analyzing scaled photographic data.

The process of video tracking utilizes principles of photogrammetry to determine three-dimensional data from two-dimensional images. In the same way VPM is really PM of single photographs multiple times and over the course of a distance traveled by a camera, video tracking determines three-dimensional data for each frame of a video in the same way the photogrammetric process will determine data for a single photograph. Video tracking simply does this process for each frame. And the additional benefit of video tracking is the computer-generated camera solved in the video tracking process can be used to project the video frames onto the roadway geometry built from video tracking. It is in the automatic solving of the camera the two processes of PM and video tracking can be used to create photorealistic three dimensional computer models of a roadway complete with any visible evidence scaled correctly and positioned correctly on the computer model for analysis purposes.

The projection-mapped images are a series of still frames from captured video, using video is the same process as rectifying a single photograph on a three-dimensional surface, except the rectification occurs for each frame of the video.

3.3 Software's used to create Virtual Environments

Computer-Aided Design (CAD) is the use of computer programs to create two or three dimensional graphical representations of physical objects. CAD software may be specialized for specific applications. CAD is widely used for computer animation and special effects in movies, advertising, and other applications where the graphic design itself is the finished product. CAD is also used to design physical products in a wide range of industries, where the software performs calculations for determining an optimum shape and size for a variety of product and industrial design applications (67).

In product and industrial design, CAD is used mainly for the creation of detailed 3D solid or surface models, or 2D vector-based drawings of physical components. However, CAD is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies, to the definition of manufacturing methods. This allows an engineer to both interactively and automatically analyze design variants, to find the optimal design for manufacturing whereas minimizing the use of physical prototypes.

Before computer technology became common and cheap enough for individual and commercial use, technical drawing or drafting developed into a discipline in engineering, and architecture for communicating how a structure should be constructed. The drafting procedure used an inclined flat board over which a straight edge known as a T-square could slide and rotate, thereby enabling the draftsman to create geometric shapes with different rotations. Other tools such as compasses and French curves made it possible to draw circles, arcs and splines.

Orthographic projection was used to represent a three dimensional object in terms of two dimensional objects. Typical orthographic projections of an object were presented as isometric and oblique views. The simple geometric shape shown could require about fifteen minutes for an average draftsman to create. A personal computer running CAD software can create the shape in few milliseconds (68).

The benefits of CAD include lower product development costs, increased productivity, improved product quality and faster time-to-market.

- Better visualization of the final product, subassemblies and constituent parts in a CAD system speeds the design process.
- CAD software offers greater accuracy, so errors are reduced.
- A CAD system provides easier, more robust documentation of the design, including geometries and dimensions, bills of materials, etc.
- CAD software offers easy re-use of design data and best practices.

There are different companies which develops CAD software applications. Siemens, Dassault Systems, and Autodesk are some examples of world widely known companies of CAD software. These companies have different specialized brands for specific solutions:

3.3.1 Siemens

Fibersim

Fibersim is a suite of software that supports all of the unique and complex design and manufacturing methodologies necessary for you to engineer innovative, durable and lightweight products and parts made of advanced composite materials.

NX

NX is the successor of Unigraphics. NX offers the industry's broadest suite of integrated, fully associative CAD/CAM/CAE applications. NX touches the full range of development processes in product design, manufacturing, and simulation, allowing companies to encourage the use of best practices by capturing and re-using product and process knowledge.

Seat Design Environment (SDE)

Seat Design Environment is software fully integrated into commercial 3D CAD systems, for designing, and manufacturing innovative transportation seat systems and interior components.

Solid Edge

Solid Edge is a portfolio of software tools which address all aspects of the product development process 3D design, simulation, manufacturing, design management and more, thanks to a growing ecosystem of apps. Solid Edge combines the speed and simplicity of direct modeling with the flexibility and control of parametric design made possible with synchronous technology.

Syncrofit

Syncrofit is a family of specialized engineering products for designing and manufacturing complex assemblies and large aero-structures. It allows you to author and manage the assembly interfaces and hundreds of thousands of fasteners which are typical in an airframe.

3.3.2 Dassault Systems

Dassault systems provide business and people with virtual universe to imagine sustainable innovations. Dassault systems Delivered on the 3D experience platform, enabling 3D Design, Engineering, 3D CAD, Modeling, Simulation, Data Management, and Process Management.

Some of the 3D modeling app which belongs to Dassault Systems are:

Catia

As products and experiences continue to increase in complexity, performance, and quality targets are becoming more demanding. Catia gives solutions for this challenge, enabling rapid development of high-quality mechanical products.

Mechanical engineers equipped with Catia 3D Modeling tools can gain insight into key factors of quality and performance early in the product development phase. Digital prototyping, combined with digital analysis, and simulation, allows product development teams to virtually create and analyze a mechanical product in its operating environment. Catia Engineering provides the platform which enables engineers to create any type of 3D assembly, for a wide range of engineering processes.

From product to transportation industries, the style & design of the product plays a major role of the business success on the market. Develop shape & material creativity, reach a high level of surface sophistication & quality, and get the right decision tools with physical & virtual prototypes, are the key elements of Catia Design to boost design innovation.

From 3D sketching, subdivision surface, Class-A modeling to 3D printing, reverse engineering, visualization, and experience, Catia Design provides all the solutions for Design Creativity, Surface excellence, and Product experience.

Solidworks

Solidworks design software is as simple as it is powerful enabling any company to bring its vision to life and capture global markets.

Solidworks solution is an intuitive, integrated 3D design environment which covers all aspects of product development and helps maximize your design and engineering productivity. Over two million designers and engineers worldwide use Solidworks to bring designs to life from the coolest gadgets to innovations for a better tomorrow.

Get up to speed quickly with Solidworks and unlock the benefits of this powerful 3D design solution for rapid creation of parts, assemblies, and 2D drawings. Application-specific tools for sheet metal, weldments, surfacing, and mold tool and die make it easy to deliver best-in-class designs.

Some of the key benefits of Solidworks are:

- 3D Solid Modeling
- Large Assembly Design
- Sheet Metal Design
- Weldments
- Plastic and Cast Part Design
- Mold Design

Geovia

Geovia provides 3D experience Universes to Model and Simulate our Planet from the vast expanse of the geosphere to the smallest details of urban settlements. It supports the sustainable capture, use and re-use of natural resources across the planet. From mining to urbanization, delivers innovations to improve life on earth.

With Geovia, mine site productivity can be increased through the automation of workflows for processes such as grade control. Automation eliminates repetitive tasks, helps to reduce errors, and is underpinned by visual validation of designs to further improve productivity.

Using Geovia, data can be centralized and secured, making it accessible whenever it is required. In addition to enabling effective collaboration, you benefit from robust audit trails, giving you increased confidence in creating reports of: 1.-Joint Ore Reserves Committee (JORC). 2.-Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports (The VALMIN Code) and 3.-National Instrument (NI) 43-101 and other requirements.

Some of the key benefits of Geovia are:

- Tools to help achieve better ore body or seam modeling accuracy
- Increased confidence in Resource estimation and Reserves calculations
- Improved mine site and user productivity

- Common interface promotes faster user adoption

Biovia

Biovia solutions create an unmatched scientific management environment which can help to science-driven companies in order to create and connect biological, chemical, and material innovations to improve the way we live.

The Biovia portfolio is focused on integrating the diversity of science, experimental processes, and information requirements across research, development, and manufacturing. Capabilities cover scientific data management; biological, chemical, and materials modeling and simulation; open collaborative discovery; scientific pipelining; enterprise laboratory management; enterprise quality management; environmental health & safety; and operations intelligence.

Biovia is committed to enhancing and speeding innovation, improving productivity and compliance, reducing costs, and accelerating product development from research and product ideation through commercialization and manufacturing for science-driven enterprises of all industries.

Key feature and benefits of Biovia:

- Create enterprise-wide intelligence that helps reduce cycle times for product commercialization
- Manage and connect scientific innovation processes and information with other product lifecycle systems
- Electronically capture, and access consistent data to improve insight into process and product quality from early design through full commercialization
- Streamline data access and reporting across the enterprise and reveal information in the most appropriate way for stakeholders to help improve decision making
- Facilitate collaboration, internally and across external research networks to access, organize, analyze, and share information
- Design and selection of molecules, biologics and materials, using modeling, simulation and predictive analytics

3.3.3 Autodesk

Create high-quality concepts and designs early in the design process. Help improve decision making with near-photorealistic real-time visualization. Cut cost and time with simulation. Increase efficiency and quality in production engineering, and improve flexibility and results in production planning.

Autodesk have a lot of different Softwares; some of the most known Softwares are:

AutoCAD

AutoCAD have been from 32 years ago, since 1982, AutoCAD 2016 marks the 30th major release of the world’s most popular CAD program. AutoCAD have a design and documentation software help speed your work, and how CAD features add precision to your drawings. View designs more clearly with Stunning Visual Experience and document in context with Coordination Model.

Some of the features in design are:

- Stunning Visual Experience

- Coordination Model
- Reality computing (enhanced)
- Online maps
- Surface Curve Extraction tool
- Surface analysis

Alias

Alias is an Industrial design and Class-A surfacing software. Alias provides sketching, modeling, surfacing, and visualization tools for industrial, product, and automotive design. Create compelling surface designs with Alias Digital Prototyping tools. This software has the following features:

- Alias Concept. (For Automotive conceptual design)
- Alias Surface. (For Automotive design and styling)
- Alias Auto Studio. (For Automotive design and styling)
- Alias Design. (For costumers)
- Alias Speed Form. (For Automotive fast concept modeling)

3DS MAX

3DS MAX is a 3D modeling, animation, and rendering software. Customize, collaborate, and create 3D content quickly with 3DS Max 3D modeling, animation, and rendering software.

3.4 Input devices

An important part of the system is the input devices used. Input devices are mainly responsible for giving the user the feeling of connecting to the system, to create immersion. An input device is a peripheral (piece of computer hardware equipment) used to provide data and control signals to an information processing system such as a computer or information appliance, e.g. keyboards, mouse, scanners, digital cameras, and joysticks.

Also there is video input devices used to digitize images or video from the outside world into the computer. The information can be stored in a multitude of formats depending on the user's requirement. Cameras with sensors are used to digitize images or video from the outside world into the computer. The information can be stored in a multitude of formats depending on the user's requirement.

The ability to track a person's movements and determine what gestures they may be performing can be achieved through various tools. Although there is a large amount of research done in image/video based gesture recognition, there is some variation within the tools and environments used between implementations.

Gesture recognition is a topic in computer science and language technology with the goal of interpreting human gestures via mathematical algorithms. Gestures can originate from any bodily motion or state but commonly originate from the face or hand. Current focuses in the field include emotion recognition from face and hand gesture recognition. Many approaches have been made using cameras and computer vision algorithms to interpret sign language. However, the identification and recognition of posture, gait, proxemics, and human behaviors is also the subject of gesture recognition techniques (69). Gesture recognition can be seen as a way for computers to begin to understand human body language, thus building a richer bridge between machines and humans than primitive text user interfaces or even GUIs, which still limit the majority of input to keyboard and mouse.

Gesture recognition enables humans to communicate with the machine and interact naturally without any mechanical devices. Using the concept of gesture recognition, it is possible to point a finger at the computer screen so the cursor will move accordingly. This could potentially make conventional input devices such as mouse, keyboards and even touch-screens redundant.

Gesture recognition can be conducted with techniques from computer vision and image processing. The literature includes ongoing work in the computer vision field on capturing gestures or more general human pose and movements by cameras connected to a computer (70)(71)(72).

The term gesture recognition has been used to refer more narrowly to non-text-input handwriting symbols, such as inking on a graphics tablet, multitouch gestures, and mouse gesture recognition. This is computer interaction through the drawing of symbols with a pointing device cursor (73).

Micro-Electro-Mechanical Sensors have been useful in the development of recognition system devices some of the devices used for gesture recognition are shown in Table2.

Table2. GestureRecognitionDevices

Gloves	Gloves can provide input to the computer about the position and rotation of the hands using magnetic or inertial tracking devices. Furthermore, gloves can detect finger bending with a high degree of accuracy, or even provide haptic feedback to the user, which is a simulation of the sense of touch. The first commercially available hand-tracking glove-type device was the Data Glove (74). Glove-type devices can detect hand position, movement and finger bending.
Cameras	Using specialized cameras such as structured light or time-of-flight cameras, one can generate a depth map of what is being seen through the camera at a short range, and use this data to approximate a 3D representation of what is being seen. These can be effective for detection of hand gestures due to their short range capabilities (75).
3D cameras	Using two cameras whose relations to one another are known, a 3D representation can be approximated by the output of the cameras. To get the cameras' relations, one can use a positioning reference such as a lexian-stripe or infrared emitters (76).
Manual Controllers	These controllers act as an extension of the body, when gestures are performed, some of their motion can be conveniently captured by software. An example of manual controller devices is the Mouse, where the motion of the mouse is correlated to a symbol being drawn by a person's hand, as is the Wii Remote or the Myo armband, which can study changes in acceleration over time to represent gestures (77). Devices such as the LG Electronics Magic Wand, the Loop and the Scoop use Hillcrest Labs' Free space

	technology, which uses MEMS accelerometers, gyroscopes and other sensors to translate gestures into cursor movement. The software also compensates for human tremor and inadvertent movement (78)(79).
Camera	A standard camera can be used for gesture recognition where the environment would not be convenient for other forms of image-based recognition. Software-based gesture recognition technology using a standard camera which detects robust hand gestures, hand signs, as well as track hands or fingertip at high accuracy has already been embedded in Lenovo's Yoga ultra-books, Pantech's Vega LTE smartphones, Hisense's Smart TV models, among other devices (80).
Gesture recognition	Gesture recognition is the ability of a device to identify and respond to the different gestures of an individual. Most gesture recognition technology works with a camera-enabled device, which is placed in front of the individual. The device beams an invisible infrared light on the individual and is reflected back to the camera and onto gesture recognition Integrated Chip (IC). The IC, with help of gesture recognition software, creates a depth map of the images received and responds appropriately to the movements in front of the camera. The key advantage of gesture recognition technology is no physical contact is required between the individual and the gesture recognition device.

The Global Gesture Recognition Market is expected to witness significant growth, growing at a Compounded annual growth Rate (CAGR) of 29.2 percent during the period 2013-2018. TechNavio analysts have pinpointed the top gesture recognition technology companies expected to contribute to market growth during the forecast period:

Table 3. Top gesture recognition technology companies (81).

GestureTek	The inventor and Pioneers of the Video Gesture Control (VGC) revolution. Over 25 years of delivering technology for gesture controlled immersive Surfaces, Signs, Displays and Games. Back in 1986, invented and shaped the field of 'applied computer vision' for computer-human interaction, and have continued inventing new VGC technologies ever since. The company's multi-patented VGC technology lets users control multimedia content, access information, manipulate special effects, even immerse themselves in an interactive 3D virtual world – simply by moving their hands or body. GestureTek delivers Wii-like gesture-control without the need to wear, hold or touch anything.
CogniVue	CogniVue provides embedded vision processing performance per power through multitier innovation in vision processing. It can enable 100x gains in the processing of complex algorithms, and high level vision expertise providing added value to our customers' customers. CogniVue has focused on building industry alliances and collaboration with solution partners, suppliers, and universities.

EyeSight	Founded with the vision of revolutionizing the way people interact with digital devices. EyeSight brought natural human interfaces to countless devices; Eyesight is a top leading provider of gesture recognition technology. The company is led by a team of highly experienced Image processing professionals, with extensive expertise in research, implementation, and optimization of real time algorithms for embedded platforms.
Omek	Omek's innovative gesture recognition technology provides tools to add gesture recognition and motion tracking to your applications. The technology is used in large range of devices, from TVs, and game consoles, to PCs, tablets, notebooks, smartphones and automotive infotainment systems.
Prime Sense 3D	Prime Sense 3D sensing technology combines both hardware and software. The PrimeSense NiTE™ perception algorithms are considered as one of the most robust and advanced 3D middleware available in the market. It provides the application with a clear user-control, whether it is hand-based control or a full-body control. The algorithms utilize the depth, color, IR and audio information received from the hardware device, which enable them to perform functions such as hand locating and tracking; user segmentation; user skeleton joint tracking; and more.

4 System Development

For the proposed MR assistance system, it was necessary to gain full knowledge of the business cardholder assembly sequence and its surrounding environment, and to have a clear idea of the operational instructions for each assembly task to be assisted during the performance of the manual operations, so the mentioned success factors for PM of the assembly sequence be properly considered when mapping the working area and parts to be assembled.

The manual assembly workstation is basically equipped with an assistance system and a recognition system (82). The assistance system provides real-time instructions streaming from the Manufacturing Execution System (MES) on a screen in front of the operator. This assistance system was extended (augmented) by/with the PM solution proposed, the instructions can now be visualized directly on the workplace and the operator be assisted in a natural way while operations are performed, the workflow recognition system determines the actual work context, e.g. if the operation has been finished, the recognition system automatically displays the next instruction. Alternatively, the system can completely be controlled in a manual fashion way with a click.

The Figure 24shows the case of this RTD work, it is shown the workstation of a manual assembly of a business card holder. The workstation contains a poke-yoke, where the user choses the correct parts and the proper tools for each step as following: Slide the clip in the glass piece, then put a distance plate and a steel piece on the glass piece, finally use a hammer and a chisel to apply pressure.

Figure 24. Business Card Holder´s Manual Assembly Workstation ©SmartFactory^{KL}

- Step 1. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so that the operator can take the right part involved in the operation e.g. take glass piece from the box, the system recognition automatically detects the action and continue with next step.
- Step 2. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled. e.g. place glass on the base with the groove facing up, the system recognition automatically detects the action and continue with next step.
- Step 3. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. take clip from the box, the system recognition automatically detects the action and continue with next step.
- Step 4. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled. e.g. slide clip into the groove, the system recognition automatically detects the action and continue with next step.
- Step 5. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. take the distance plate from the box, the system recognition automatically detects the action and continue with next step.
- Step 6. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled. e.g. put the distance plate on the glass piece, the system recognition automatically detects the action and continue with next step.
- Step 7. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. take the steel piece from the box, the system recognition automatically detects the action and continue with next step.
- Step 8. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled. e.g. place the steel piece over the assembly, the system recognition automatically detects the action and continue with next step.
- Step 9. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly so the operator can take the right part involved in the operation and highlights where the part should be assembled e.g. Take the assembly and Rotate it 90 degrees and place it into the slot, the system recognition automatically detects the action and continue with next step.
- Step 10. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. take the hammer from the tools area.
- Step 11. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. take the chisel piece from the tools area.
- Step 12. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled the surface to interact. e.g. Gently hit on the three small openings on the top of the assembly.

- Step 13. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled. e.g. Rotate the assembly 180 degrees and place it into the slot, the system recognition automatically detects the action and continue with next step.
- Step 14. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the assembly and highlights where the part should be assembled the surface to interact e.g. gently hit the other side with the hammer, the system recognition automatically detects the action and continue with next step.
- Step 15. The instructional system shows the instruction in the MES screen as well as it provides the PM of the instruction on the module so the operator can take the right part involved in the operation e.g. put back the hammer and the chisel to the tools area, the system recognition automatically detects the action. The Sequence is completed.

Furthermore, the modeling and rendering of the list of parts and tools involved in the manual assembly sequence of the business card holder, as well as the workstation (assembly module) as a 3D virtual world was made by a set of image computations of abstract and mathematical 3D-models describing the real world. However any image of the parts and tools involved can be used for the projection instructions.

4.1 Operations Perspective.

In order to make the PM instructions more realistic, it was required to implement a set of best practices for the proposed MR assistance system:

4.1.1 Perspective.

In order perceive properly a projection, the projector must be located in the same point of view, otherwise the projection is distorted. Since the beamer was positioned over the workstations, pointing towards the floor to cover the required projection area for each image (workstation, part, and tools).

To correct the image distorted is required to adjust the projections with the user's perspective. According to the operator's angle/point of view, the image perspective view was adjusted. The 3D modeling and rendering was done with Autodesk 3DS MAX software.

4.1.2 Meshing.

Meshing is used to display an image over an irregular area, e.g. a groove. The image was divided into sections; for meshing the images is required to deform the images in more complex ways. Meshing is processes well known in Finite Element Analysis (FEA).In FEA, the product is meshed to create more simple mechanical analysis. The process of meshing an image for calibration, is similar but with other purpose. For PM a mesh is required to have control points, used to adjust the image to irregular surfaces and shapes.

Each part and tool was meshed, the Figure 25 shows how a distance plate of a business card holder. In the left side is the original part, and in the right side the images is divided in quadrants. For this case the distance plate was meshed in four frames for two frames.

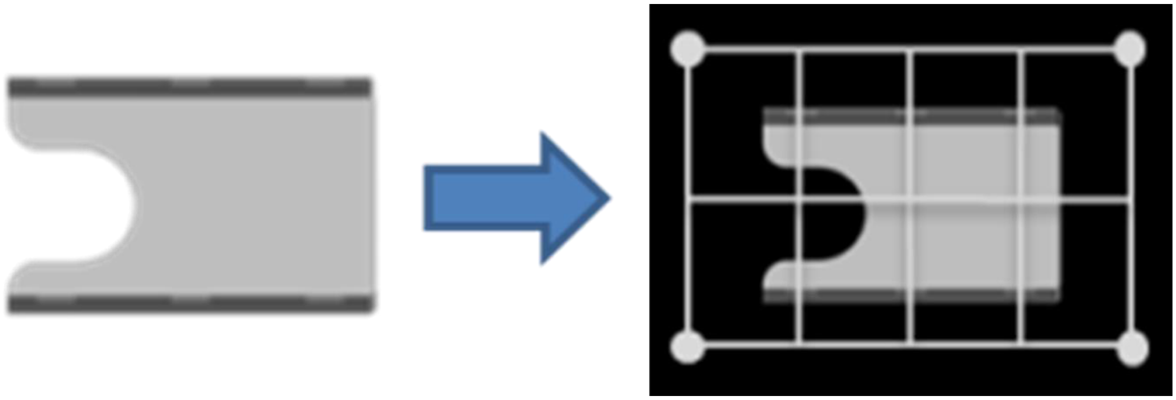

Figure 25. Meshing process of a Steel piece of Business Card Holder ©SmartFactory[KL]

4.1.3 Calibration.

Once the image is meshed; the control points of the mesh are adjusted to the environments shapes. For this was required to display an image with the projector and then, adjust the control points so the operators can see the images without distortion.

The Figure 26 shows the process of an image being calibrated in an irregular surface. The image is adjusted to fit the desired position.

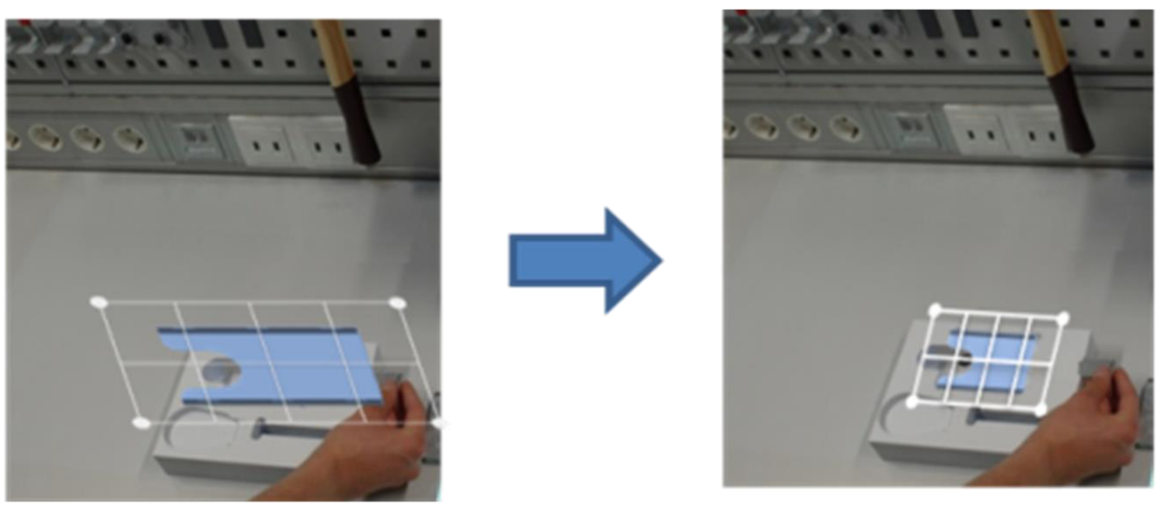

Figure 26. Calibration process of an image using control points, image projected over the ©SmartFactory[KL] Assembly Workstation.

4.2 Software

For the given environment of a manual assembly workstation, it was used different software's (See the Figure 27): A CAD software for 3D modeling and rendering parts and tools, a PM software, used to display the images properly to the environment, and finally, the system was enhanced with a recognition system developed by the DFKI.

Figure 27. Softwares used for the development of the instruction system

4.2.1 CAD software.

A CAD software was used for 3D modeling of parts and tools e.g. to be shown in any sequence of any instruction to be followed by an operator. The 3D modeling was done in Autodesk 3DS MAX, because it is possible to create 3D content quickly, modeling and rendering.

4.2.2 PM software.

A PM for images environment calibration was required. In the development of the system, it was used the Video Projection Tool (VPT7) which allows to adjust the instruction images correctly in the manufacturing module.

VPT 7 consists of three windows: Interface, Preview and Output. The output window is the window which should be on your projector output. In the Preview window you can make modifications to calibrate the images according to the surface. But of them can be controlled from the lower part of the Interface Window. The main window and it is divided in five sections as showed in the Figure 28.

The steps in order to setup up a PM are:

1. Create a new project
2. Create layer
3. Load image
4. Assign image to a Layer
5. Layer calibration
6. Layer adjustments
7. Saving steps (Presets)
8. External Communication
9. OSC Communication commands

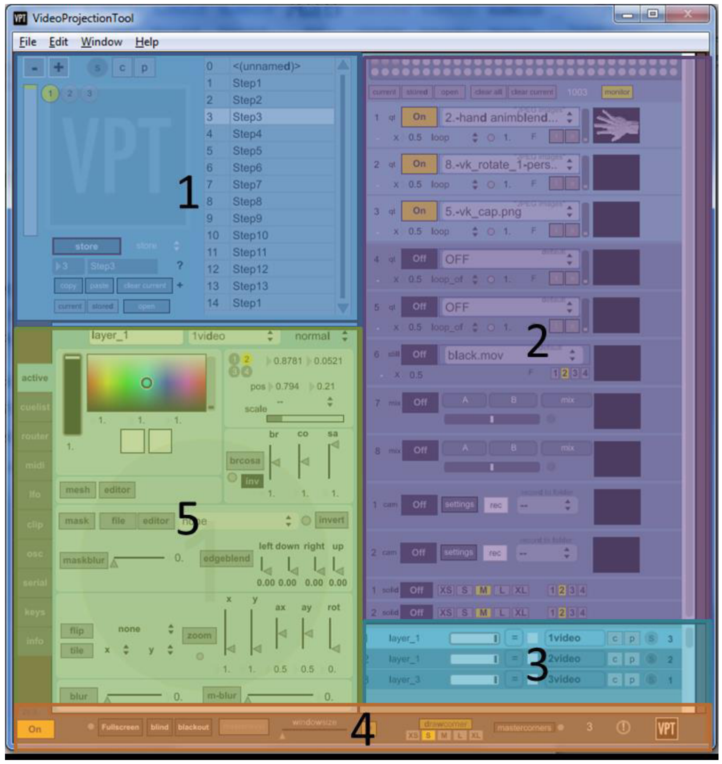

Figure 28. Sections of the main windows of Software VPT 1.- Create Layers and Presets (Mapping), 2.- Load Images and Videos (Source), 3.- Assign Images to Layers, 4.- Control Bar (Output), 5.- Control tabs (Advanced functions).

Layers

Once you have all the instruction files, it is necessary to choose a surface in which part of the environment it have to be displayed each instruction e.g. if it is necessary to press a button, a <Hand> image can be displayed over the button. The surface required to project the <Hand> have to be manually calibrated. For each surface is necessary to create a new layer.

The larger the surface, the more complex the layer calibration will be. The layer is the surface where an image is displayed. The layer is calibrated to the shapes, so the image assigned to these layer fits to the environment with irregular surface.

In the Figure 29 is shown the subsection to create layers and presets. Creating a new layer or deleting an existing one can be done with the buttons "+" and "-"respectively in the subsection 1; the layers are shown in the subsection 2, there is possible to select the proper layer; Subsection three is to save a preset. The preset is a combination of the layer and its calibration using control points and the image assigned to each layer. For the instruction system, for each step to accomplish the assembly, there is a preset; finally, subsection four is the presets.

a) Create New Layer

Each time you open the software VPT7, it also opens two display windows: Preview & Output. To create a new layer you only need to press <+> button. It is possible to add as many layer as desired; the layers are auto-named in ascendant numbers.

Automatically when a new layer is created, the last one appears at the front. In case one or more layer is overlapped, it will be no possible to see part or a complete layer.

Figure 29. Layers and Presets section in software VPT.

b) Calibrate Layer

Once you have created a new layer, you may want to add an image to the layer, To calibrate the layer to the surface, first, you have to select the properly layer. May sure your projection solution is working properly and working in the final position, otherwise you will have to calibrate each layer every time the projector moves. In the <Preview Window> the layers are displayed, to adjust them is only necessary to select and drag the four points to the real scenario area.

c) Layer-Image Adjustment

In some situations you may find useful to modify the original image e.g. if is necessary to modify the size, color as well a rotation. These functions are part of the “Active” tab; they are displayed in the lower-left part, of the main VPT windows.

d) Image-Video

You should already have your own images and videos to display, which will be show to the user in order to assist him to perform the manual operations. if something is missing, or you need to modify the, or well, the perspective is not the adequate, you can use the software Autodesk 3DS to assurance the best image quality. However some details can be done with the same software.

As soon as you start working with the VPT tool you may notice you can only be able to load six different images in each step which it means you will be only able to highlight or use six images sources for each step or well scenarios, however you can have as many layers ass you need in each step, and the image source can be shared.

To display an Image or Video in a layer, it is necessary to make two steps: Load an image-video to VPT7 and then assign the image-video to a layer.

e) Create Image Files

First, have to make sure you already have all the images-videos you will need to display. If is something missing you can easily create your own image or video to show to the user in order to assist him to perform his manual operations. It can be an Image or a Video file. It can be generated using NX8 and Teamcenter or well, any other editor as well Autodesk 3DS. Just make sure to save them in JPEG or PNG format file.

f) Load Image-Video to VPT

In the upper-right section of the main window of VPT7 there are six slots to adding image-video, each slot receive the name Video followed by a number “Video#”. To load an image-video to VPT7, you have to drag the folder which contains the images or videos files to the dropdown list. In the dropdown list select the file. It is also necessary to press the On-Off button to active it. The position of the Video-Slot position does not affect the actions.

g) Assign Image-Video to a Layer

In the lower-right section of the main window of VPT7 it can be found the layer section. Here you can assign a previously loaded image-video to each layer. You may choose from <Video1> to <Video6> according to the file you want to display. You can use the same image for multiple layers.

h) Saving Options

There is not such a thing to save the whole works as a file. The route File->Save and File->Save as will always be de-activated.

To save the progress is required to save every step of the scenario you have. It is saved as a preset by clicking on <Store>. You can not specify where to save it, it is only saved and the next time you open software VPT, this automatically load the presets.

i) Presets

A preset defines the layer position, calibration and the images or videos associated to each layer. A preset contains the total numbers of layers. You can customize any layer for each preset, but you cannot add or delete layers for a specific preset. If you delete or add a new layer in a preset, it will be added and deleted respectively in all presets.

To save a preset you have to name it as a number and press the “Store” button. Additionally it is possible to assign a description for each preset.

j) Processing Instructions

In the deployment of an advanced instruction system to perform manual operations, for many advantages it is desired to control the instructions remotely. For personal customized assistance it can also be remotely controlled.

4.3Hardware Solutions

It was used different hardware for the development of the instruction system. Certain equipment was used because it was previously in use in the lab also there is special equipment required for this project e.g. the projector. The projector chosen was carefully chosen according to the desired specifications.

4.3.1 Beamer Selection

A large variety of beamer solutions and price make important to choose wisely to fit your requirements according to the environment specifications. It can be found on internet useful tools to find your projection solution, e.g. Projector Central website. However is important to know which aspects have to consider, even some of them often are not included in manufacturer's Datasheet specifications and also which features can even been ignored according to your specific Instruction System requirements for the projection solution.

Is helpful to define at the beginning, the surface dimensions where it is necessary to make projections. With the projection area helps to define the throw ratio required of the beamer. The throw ratio is a relationship between the Width and Distance; the throw ratio affects the distance to mount the projector. With the projection surface area calculation is possible to determine the required brightness intensity. Throw Ratio, is a relation of the projection Width and Distance, and its formula is shown is Ecuation1.

$$\text{THROW RATIO} = \frac{Distance}{Width} \qquad (1)$$

Brightness

Brightness, current brightness specifications only measure the total amount of white light projected stated in lumens (83). For practical uses, it was found a good empiric approach is considering a relation of four between the projector total brightness and the environment brightness; however it may differ according to brands and technology. A process control room should be lit at a luminance of 300 lux. For more accurate decisions, a manual measurement of the brightness can be done with a lux meter.

$$\text{Lux} = \frac{Lumen}{m^2} \qquad (2)$$

A Lux unit (lx) is the International System Unit of illuminance which defines the Luminous Flux in per unit area. One Lumen in one square meter means one lux, see equation 2. Additionally, since PM is a technique to project over different shapes, the projection angle may vary, and makes larger a surface over a shape. For a given amount of luminous intensity, the illuminance is inversely proportional to the square of the throw distance (84).

In consequence the brightness projection decreases as the angle projection increases e.g. a shape of one m, when positioning at 60° it doubles its size up to two m as it can be shown in the Figure 30.

Source Illumination Technology

Over the last years, interest in laser-based projectors has been increasing within the Professional Audiovisual Industry. As a major technological development which could eventually replace traditional lamp-based systems, manufacturers are bringing various laser-based projectors to market and describing those using different terms (85).

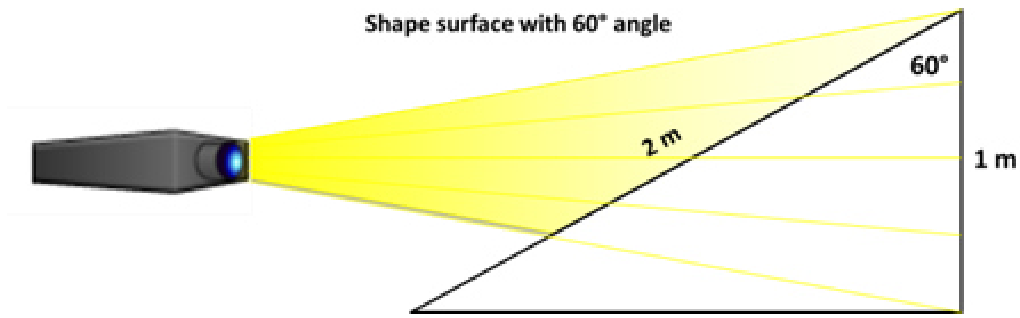

Figure 30. Projection angle and brightness intensity comparison.

According to the light source, it can be classified as:

- CRT
- LED
- Laser
  - RGB laser (3 Laser Diode)
  - Laser phosphor (1 Laser Diode)
    - Hybrid (Laser + LED)

Also, the projector can be classified by the technology used. The most common technology are LCOS, DLP, LCD, Pico Projector and Laser.

They were compared in the brightness, contrast ratio, inputs, portability and price. The results are shown in the Figure 31.

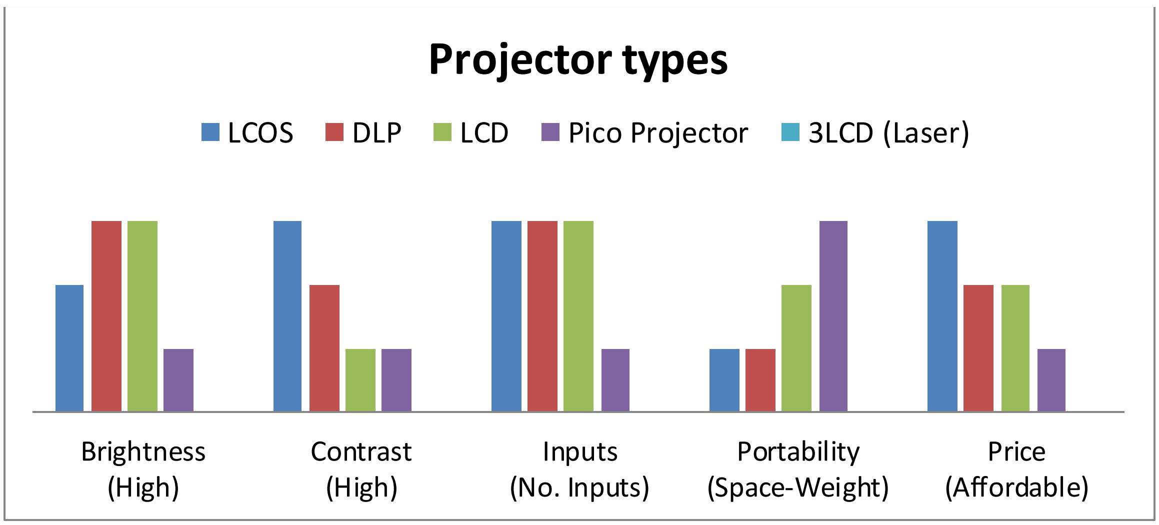

Figure 31. Comparison of different types of projectors.

The aspect ratio is the relation between the width and the height. In the Figure 32 is shown the width and height of the projection area.

Using the considerations commented previously, the brightness intensity should be x3 times of the ambient brightness. It was compared more than one hundred projections of six different brands, and technology. It was found Casio projector with Laser and LED hybrid technology would fulfill our requirements.

Table4 shows a comparative of Casio projectors, Width, Height and the Max Room Brightness acceptance.

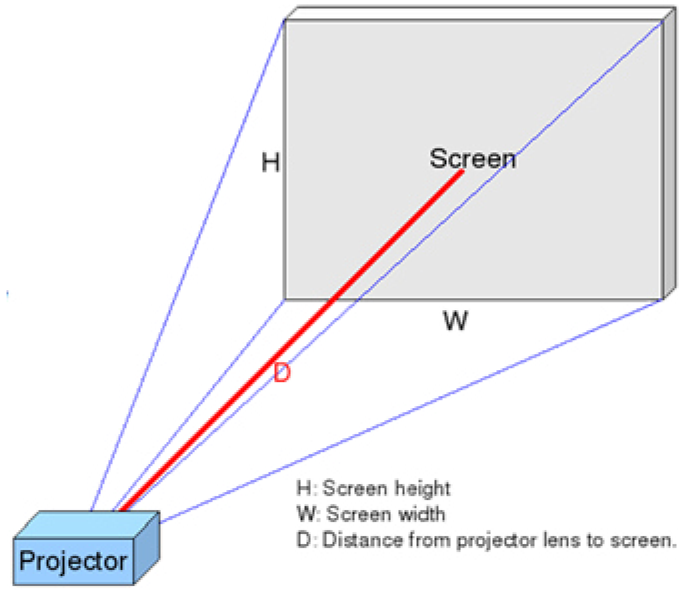

Figure 32. Dimensions of a projection (86).

To determine how much brightness is required, it was considered the brightness required for a manufacturing module. According to the regulatory framework for work place Health and Safety in Great Britain, a process control room should be lit at a luminance of 300 lux (87). The projection brightness in order to ensure an image quality perceived by the user should be at least three times higher of the room brightness, which give us a minimum of 900 lx desired.

According to the dimensions of the projection area, as the surface increase, the brightness intensity decrease. Using the aspect ratio can be obtained the area of the projection; the brightness of the projector is the total brightest output. To obtain the brightness intensity the total brightness was divided by the area. The result is the Brightness intensity of the projection.

4.3.2 Automatic Detection/Recognition System

The user can control the system in a manual fashion way with a click to proceed to next step while operations are performed. Additionally, the system was enhanced with a recognition system so the system determines the actual work context, e.g. if the operation has been finished; the recognition system automatically displays the next instruction.

Table4. Casio projectors comparative.

Projector Model	Total Brightness (Lum)	Throw Ratio	Aspect Ratio	Resolution	Contrast	Width	Height	Max Brightness acceptance (Lux)
XJ-A146 Demoware	3000	1.4-2.8	16-9	1280*800	1800	1	0.5625	1185
XJ-A256 - Demoware 2	3000	1.15-2.3	16-10	1280*800	1800	1	0.625	1067
XJ-M251	3000	1.32-1.93	16-10	1280*800	1800	1	0.625	1067
XJ-A252	3000	1.15-2.3	16-10	1280*800	2000	1	0.625	1067
XJ-M255 DEMOWARE 3	3000	1.32-1.93	16-10	1280*800	1800	1	0.625	1067
XJ-M256	3000	1.32-1.93	16-10	1280*800	1800	1	0.625	1067
XJ-A255 - Demoware 2	3000	1.15-2.3	16-10	1280*800	1800	1	0.625	1067

The automatic detection of hands movement was implemented using an already existing recognition system of the German Research Center for Artificial Intelligence (DFKI) and Smart Factory, Kaiserslautern, based on the camera with sensor motion control.

In the Figure 33 is shown a general workflow of the execution system. First the instruction system starts projecting the correct instruction to assist the operation desired. While the user is executing the instruction the recognition system is available to detect the action of the user, and it determines when the user has successfully executed the assisted instruction, then the recognition system sends a message to the instruction system and it sends the next instruction. This process is repeated until the assembly process is successfully completed.

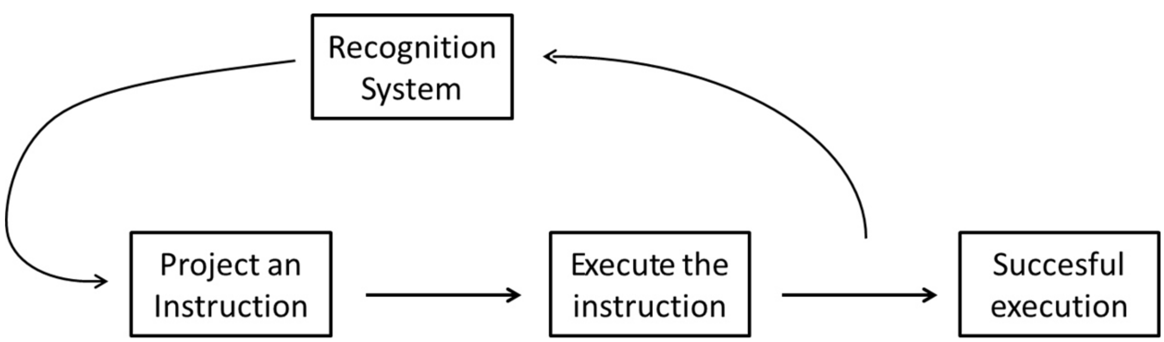

Figure 33. Execution system flow diagram.

4.3.3 System Integration with Java

In order to communicate the instruction system and with the recognition system it was required to create an integration. For this integration a java code was created in order to make possible the readings taken by the recognition system be useful and fully functional with the instructional system based on PM.

Since the PM tool used is capable of socket based communication, the java integration was done by sending instructions by a serial port. The software used for the PM, is capable to establish communication by serial, with a USB input or by a network, listening from port 6667. The Figure 34 shows the PM software. In the control tabs there is a dedicated are for serial communication.

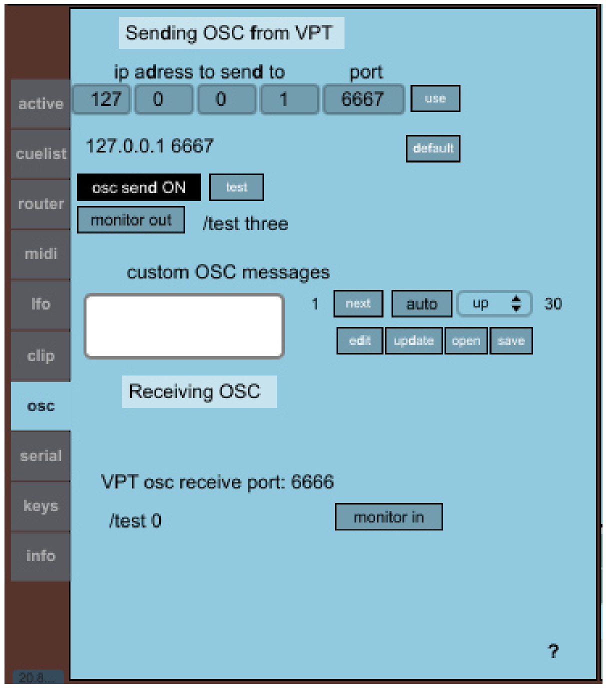

Figure 34. Socked based communication interface of software VPT.

The system allows read instructions sent by an external system, for e.g. a recognition system. In order to establish a communication among other computers, it is necessary to use the Open Sound Control (OSC) protocol. An advantage of using OSC protocol is, it gives you freedom to use any programming language such as python, Java, or C++.

Communication with OSC protocol

To communicate the recognition system with the PM software, it was required to send messages with a socket based communication, the messages are sent in a protocol which can be read by the PM software; A communication protocol to allow the interaction among computers and other multimedia devices, optimized for networking technology. It was used the OSC.

The communication between the recognition system and PM software was possible with three commands, which allows to advance to next step, return to previous step, and to skip to a specific step.

Instruction Operations

For meshing and calibration, each step requires making a -preset-. A preset is an array of layers and images which save the correct configuration, this way the projection is ready to project the instruction when the user finish the previous instruction; The preset makes the image be ready with the correct visualization. To display an image it is necessary to first Load the image, e.g. the clip, to the VPT7 and then assign it to a Layer. A Layer is a section area where the instructions are displayed; it can cover a small area or the entire surface; however the larger area, the more complex it will be, in this case, the layer of the clip. The layer is distorted with meshes to correct the image projection to adapt it to the workstation and assembly shapes the system was developed as simply as possible, using only the three commands:

- preset i
- presetprev t
- presetnext t

When the recognition system detects the user has finished an instruction, then a sign is sent in OSC protocol, to change the instruction operation for another step. The -Preset I- receives an instruction to skip to a specific step, whereas the -PresetPrev t- and -PresetNext t- skip the instruction to the previous and Next step to accomplish the assembly procedure.

5 Discussion and Results

The intention of this chapter is to report the results and finding of the investigation questions presented in chapter I, recalling:

Can Virtual and Augmented Realities be used as a tool to improve the knowledge of products assembly and processes? Is it possible to enhance an assembly workstation with a MR assistance system based on PM? Does the assistance system can be used to reduce human errors and delays? Will the system reduce the need of specialist among short periods of time?

In this section, it is also summarized the results of the software developed to present the solution proposed. Figure 24 in page 55, shows the Business Card Holder´s Manual Assembly Workstation ©SmartFactoryKL, where this thesis project was implemented. To begin start using the MR instructional system, is required to manually select the desired process and then the system automatically guides the operator through the procedures until the user finishes.

5.1 Results of the Assistance System

The Instructional system was developed using two subsystems. Previously to the implementation, as a requirement, is to gather operation instructions and determine the auxiliary views required to assist the operation. Those auxiliary views can be simulated with a 3D software e.g. 3DS MAX, from Autodesk.

Every process consists of two or more steps. Every step or instruction has a visual aid which is projected directly in the working module. The instructions are shown with a projector in the assembly workstation; it was chosen a laser projector. Since the projections are displayed in irregular surfaces, the images are deformed and can only be seen from the same point of the source (projector angle). The first subsystem employed solves this problem, using PM techniques is possible to calibrate images to irregular surfaces, so the user can see the projected instructions at his working position.

The PM or calibration was manually developed in this work; however the system is developed so it is only required to calibrate the system the first time only, for each visual aid required. This way, if the same instruction is repeated along the operation two or more times, the image is calibrated the first time only and is saved (pre-set).

The second subsystem employed in this thesis project, is a recognition system developed by the DFKI/Smart Factory for the same case of study. The recognition system consists of a camera with sensors to detect hand movement and gestures. The actions manually executed by the user can be summarized with a set of movements as open-close the hand or translating the arm. These actions are recognized by the system and use this information to read when the operations are successfully achieved. Enhancing the instruction system with the recognition system makes possible to execute the manual operations fluently without the distraction of manually skipping the instruction by pressing a button to the next step.

To start the assistance with the instructional system the computer have to be powered on and the projector too. Then is only required to execute the PM tool and open the file of the operation to do. In the Figure 35 is shown the windows which pop up when executing the PM software. Once this, the system will be able to guide the user from the begging of the task until it be successfully accomplished.

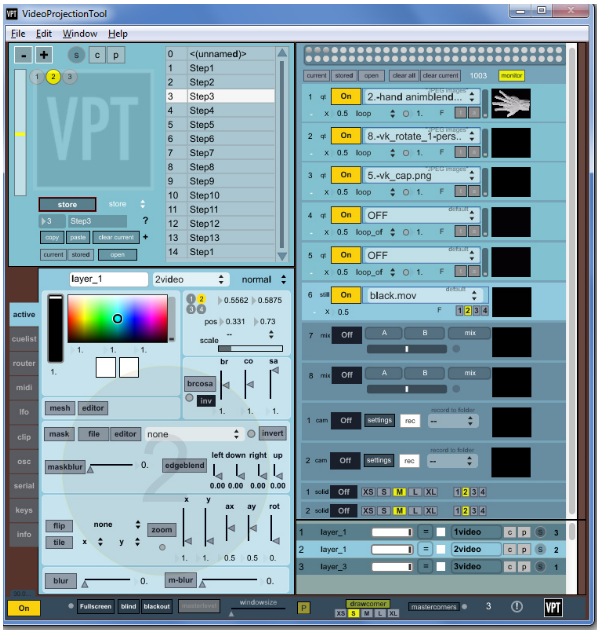

Figure 35. Main window of software VPT

5.2 Discussion

MR Instructional system based on PM showed it is possible to understand and execute the assembly process of products. Projecting the instructions in the working module the user was able to achieve the sequence.

The users were able to identify the parts ad tools involved in the operation as well as its location where it can be found. This makes easier the process of using the proper parts and tools. This support is beneficial in scenarios were similar parts can be confused, e.g. by using small screws, the user may confuse and take pieces from a different location and cause quality problems as well as delays. The instructional system in the scenarios brings the advantage of highlighting the proper stock location to novices. In the Figure 38 is shown an example of how the instructional system helps to find the proper location, a hand is telling the user in which part of the toolbox is located the part required.

Time

The knowledge required to replicate the MR instructional system based on projections mapping basically will be determined by the number of operations and the shape complexity of the projection surface. Another factor to consider is the ability of the engineer to handle with the meshing and calibration.

Developer's Ability.

Since the meshing and calibration sequence is done manually, an important factor in the development time is the developer's ability to adjust correctly the layers for a correct visualization. The developer's criteria when considering the mesh size and the properly position of the control points, is one of the key factors to succeed in the development. In the development of the instructional system I found is highly desirable to have availability of the workstation and to have a computer-laptop near the workstation is beneficial due to the back and forth feedback.

Location of the Image.

Where is the best area to place the instruction? This will also be determined by the developer's criteria e.g. the developer has to determine where the hand (see Figure 36) will be placed. The image could be positioned above the box, on one side, tilted, etc.

Cost

Costs for the implementations are mainly determined by the hardware solution as well as the software employed. As discussed in Chapter 4, the projector chosen must fill the environment's requirements so the hardware cost will vary according to the environment's surface and its area.

Disciplines

For the system development, the team should have knowledge of multiple disciplines such as 3D modeling design and programming. Experience in manufacturing operations are highly desired, e.g. assembly and welding operations.

Implementation-Installation

We found the implementation of projection instructions should not be a problem for the workstation functionality. Since there is no physical contact with the workstation, the projector can be mounted far from the manual operation is executed as well in almost any position and place.

Figure 36.Instructional System indicating the proper section of the Toolbox.

6Conclusion and future work

6.1 Conclusion

The development of the mixed reality assistance system based on projection mapping technique was proposed and developed in this investigation with the objective of demonstrating the advantages of using mixed reality techniques in order to improve automotive manufacturers operations. This project aims to reduce human errors and delays caused by the lack of specialist among short periods of time.

Virtual Reality and Augmented Reality commonly known as Mixed Reality system can be useful with projection mapping to assist human operations. The system developed can be implemented in workstations which involve human interaction. Some of the main advantages I found in the system during the implementation are the system can be implemented but is not limited to assist manual operations they are shown in Figure 37.

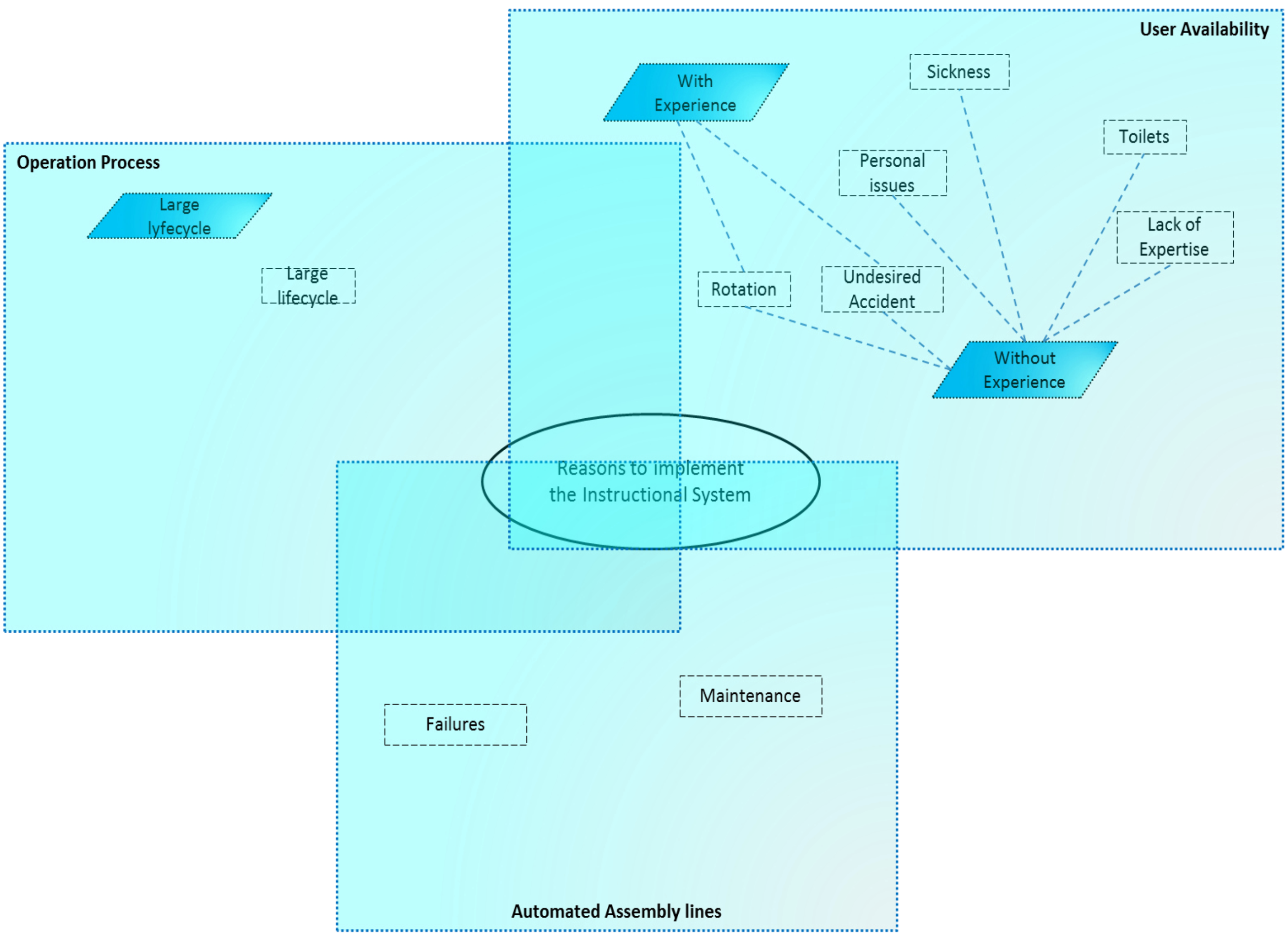

Figure 37. Suggested cases of study for a Successful system Implementation

The system developed showed good results when assisting a user without prior knowledge of the manufacturing module. The system succeeded to highlight the parts and tools, also to indicate the specific location of the workstation where the parts have to be placed. And the user was able to identify understand the tasks.

6.2 Future Work

Automatic Calibration System

Since the entire environment has to be manually calibrated, for each implementation it is required knowledge of diverse software solutions involved. Also it still requires a lot of authoring effort. Further work improvement scan consist of an automatic calibration system added to the instructional system using depth sensors so it can track the environment, which means optically identifying real objects and making possible layers auto-calibration. A recommend device is the Microsoft Kinect, because it already includes many sensors for depth and color as well as a microphone array and is Microsoft Windows friendly. As seen in Figure 38, the calibration system will scan the real environment and send them to the PM software, so it re-adjusts the image calibration if required.

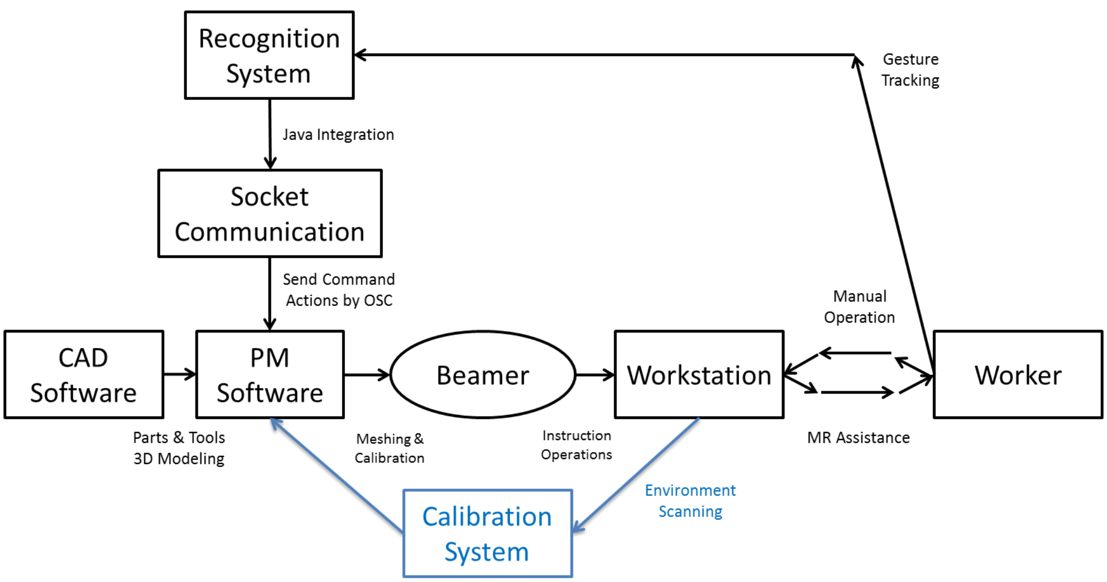

Figure 38. Calibration System

Material Reflectivity

More future work can be improving the limitation of the proposed MR assistance system is the reflectiveness on some materials, e.g. when projecting over a plastic transparent surface, the image quality decrease. The same occurs when projecting on surfaces at high degree field of view from the projector, a pixel stretching cause a poor quality image. The projection can be calibrated, but the quality is limited by the projection angle, the bigger the angle the worse the image.

Publications and participation on international forums during the development of the project

- ✓ Virtual and Augmented Reality in Education (VARE 2015). Monterrey, Mexico. 2015.
- ✓ Hannover Fair 2015. Hannover, Germany. 2015.

Abbreviations and Acronyms

AR: Augmented Reality

CRT: Cathode Ray Tube

CAVE: Cave Automatic Virtual Environment

CRS: Comfort Rating Scales

CAGR: Compounded Annual Growth Rate

CG: Computer Graphics

CAD: Computer-Aided Design

CES: Consumer Electronics Show

DLP: Digital Light Processing

EM: Electromagnetic

SGI: Enterprise Silicon Graphics Inc.

FEA: Finite Element Analysis

FMS: Flexible Manufacturing System

DFKI: German Research Center for Artificial Intelligence

GUI: Graphical User Interfaces

HMD: Head Mounted Displays

IO: Instructional Operations

IC: Integrated Chip

LCD: Liquid Crystal Display

LCOS: Liquid Crystal on Silicon

MES: Manufacturing Execution System

MS: Manufacturing System

MR: Mixed Reality

NSF: National Science Foundation

NSA: National Security Agency

NC: Numerically Controlled

OSC: Open Sound Control

PM: Projection Mapping

QRM: Quick Response Manufacturing

RPE: Rating of Perceived Exertion

RMS: Reconfigurable Manufacturing System

RTD: Research and Technology Development

SDE: Seat Design Environment

SAR: Spatial Augmented Reality

SOP: Standard Operating Procedures

TBC: Time Based-Competition

VGC: Video Gesture Control

VPM: Video Projection Mapping

VE: Virtual Environment

VEIT: Virtual Environment Interaction Technique

VR: Virtual Reality

VRML : Virtual Reality Modeling Language

JORC: Joint Ore Reserves Committee

NASA: National Aeronautics and Space Administration

NI: National Instrument

NX: Software for 3D modeling

3DS MAX: Software for 3D modeling

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Index

List of figures

List of tables

Appendix 1. Beamer Selection.

The color quality output of laser projectors (see the Figure 39) was considered in the beamer selection.

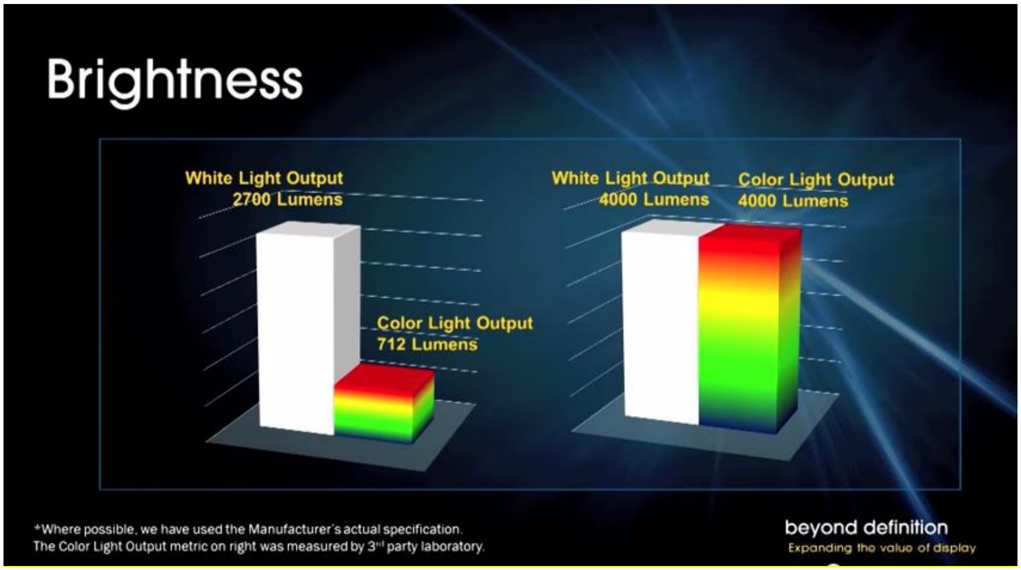

Figure 39. Beamer Color Output

For the Projector selection, it was searched information of different brands and types. The information gathered is the following.

Brand	Type	Model	ProjectorBrightness	Price	Throw Ratio		Aspect Ratio		Width	Height	Area
Infocus	LargeVenue	IN5134	4,000	$2,599	2.20	1.50	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5135	4,200	$5,399	3.00	1.50	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5142	6,000	$4,282	3.00	1.50	4	3	1.0	0.8	0.8
Infocus	LargeVenue	IN5144a	5,500	$3,881	3.00	1.50	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5145	5,000	$5,472	3.00	1.50	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5312	4,500		2.00	1.60	4	3	1.0	0.8	0.8
Infocus	LargeVenue	IN5316Hda	5,000		1.93	1.54	16	9	1.0	0.6	0.6
Infocus	LargeVenue	IN5542	7,500		2.30	1.80	4	3	1.0	0.8	0.8
Infocus	LargeVenue	IN5544	6,500		2.30	1.80	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5552L	8,300		2.35	1.75	4	3	1.0	0.8	0.8
Infocus	LargeVenue	IN5554L	7,000		2.38	1.81	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5555L	7,000		2.27	1.73	16	10	1.0	0.6	0.6
Infocus	LargeVenue	IN5312a	6,000		2.00	1.60	4	3	1.0	0.8	0.8
Infocus	LargeVenue	IN5312	4,500	$2,899	2.00	1.60	4	3	1.0	0.8	0.8
Infocus	Short Throw	IN126STa	3,300	$667	0.52		16	10	1.0	0.6	0.6
Infocus	Short Throw	IN136UST	3,300	$1,049	0.35		16	10	1.0	0.6	0.6

Infocus	Office	IN116a	3,000	$419	1.80	1.50	16	10	1.0	0.6	0.6
Infocus	Short Throw	IN118DSTa	2,700	$899	0.52		16	9	1.0	0.6	0.6
Infocus	Interactive	IN3926	3,000	$1,425	0.38		16	10	1.0	0.6	0.6
Infocus	Short Throw	IN124STa	3,300	$540	0.60		4	3	1.0	0.8	0.8
Infocus	Office	IN112a	3,000	$289	2.20	1.90	4	3	1.0	0.8	0.8
Infocus	Office	IN114a	3,000	$349	2.20	1.90	4	3	1.0	0.8	0.8
Infocus	Interactive	IN3924	3,000	$849	0.48		4	3	1.0	0.8	0.8
Infocus	Short Throw	IN134UST	2,800	$839	0.44		4	3	1.0	0.8	0.8
Infocus	Mobile	IN1112a	2,200	$999	1.70	1.55	16	10	1.0	0.6	0.6
Infocus	Mobile	IN1110a	2,100	$879	1.70	1.55	4	3	1.0	0.8	0.8
Optoma	Ultra Mobil	X304M	3,000		1.90	2.20	4	3	1.0	0.8	0.8
Optoma	Mobil	DS325	2,800		1.20	2.00	4	3	1.0	0.8	0.8
Optoma	Mobil	S300	2,800		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Mobil	S313	3,000		1.70	2.17	4	3	1.0	0.8	0.8
Optoma	Mobil	DS330	3,000		1.97	2.17	4	3	1.0	0.8	0.8
Optoma	Mobil	S316	3,200		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Mobil	DX325	2,600		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Mobil	X300	2,800		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Mobil	DX330	2,800		1.97	2.17	4	3	1.0	0.8	0.8
Optoma	Mobil	X302	3,000		1.97	2.17	4	3	1.0	0.8	0.8
Optoma	Mobil	DX345	3,000		1.95	2.51	4	3	1.0	0.8	0.8
Optoma	Mobil	DX346	3,000		1.95	2.51	4	3	1.0	0.8	0.8
Optoma	Mobil	X315	3,200		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Mobil	X316	3,200		1.95	2.15	4	3	1.0	0.8	0.8
Optoma	Desktop	FX5200	3,300		1.97	2.17	4	3	1.0	0.8	0.8
Optoma	Desktop	EX631	3,500		1.97	2.17	4	3	1.0	0.8	0.8
Optoma	Desktop	EX400	3,700		1.60	1.92	4	3	1.0	0.8	0.8
Optoma	Desktop	X401	4,000		1.60	1.92	4	3	1.0	0.8	0.8
Optoma	Desktop	X600	6,000		1.80	2.11	4	3	1.0	0.8	0.8
Optoma	Short Throw	ZX212ST	2,300		0.63		4	3	1.0	0.8	0.8
Optoma	Short Throw	X305ST	3,000	$626	0.63		4	3	1.0	0.8	0.8
Optoma	Short Throw	X306ST	3,200	$667	0.63		4	3	1.0	0.8	0.8
Optoma	Ultra Short Throw	X307USTi	3,300		0.43		4	3	1.0	0.8	0.8
Optoma	Ultra Short Throw	X307UST	3,300		0.43		4	3	1.0	0.8	0.8
Optoma	Ultra Short Throw	EX685UT	3,000		0.38		4	3	1.0	0.8	0.8
Optoma	Ultra Short Throw	EX685UTis	3,000		0.38		4	3	1.0	0.8	0.8
Optoma	Pico	PK320	2,000		1.80		4	3	1.0	0.8	0.8
Optoma	Pro Scene	X501	4,500	$1,420	1.39	2.26	4	3	1.0	0.8	0.8
Optoma	Pro Scene	X605	6,000	$2,719	0.80		4	3	1.0	0.8	0.8

Optoma	Pro Scene	X605	6,000	$2,719	1.60	2.00	4	3	1.0	0.8	0.8
Optoma	Pro Scene	X605	6,000	$2,719	2.00	3.00	4	3	1.0	0.8	0.8
Sony	Ultra Short Throw	LSPX-W1S	7,584	**$50,000**					1.0	0.0	0.0
Sony	Home Teather	VPL-HW40ES	1,700	$1,999					1.0	0.0	0.0
Sony	Home Teather	VPL-VW1100ES	2,000	$27,999			17	9	1.0	0.5	0.5
Sony	Home Teather	VPL-VW600ES	1,700	$14,999			17	9	1.0	0.5	0.5
Sony	Home Teather	VPL-HW55ES	1,700	$3,499					1.0	0.0	0.0
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	1.39	2.23	16	10	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	2.34	3.19	16	10	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	3.18	4.84	16	10	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169 (Equivalent)	$4,758	0.85	1.00	16	10	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	1.39	2.23	16	9	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	2.34	3.19	16	9	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	3.18	4.84	16	9	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169 (Equivalent)	$4,758	0.85	1.00	16	9	1.0	0.6	0.6
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	1.39	2.23	4	3	1.0	0.8	0.8
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	2.34	3.19	4	3	1.0	0.8	0.8
Sony	Profesional Display	VPL-FHZ55	15,169	$4,758	3.18	4.84	4	3	1.0	0.8	0.8
Sony	Profesional Display	VPL-FHZ55	15,169 (Equivalent)	$4,758	0.85	1.00	4	3	1.0	0.8	0.8
Sony	Profesional Display	VPL-CW255	17,065		1.32	1.91	16	10	1.0	0.6	0.6
Sony	Profesional Display	VPL-CX 235	15,548		1.66	2.41	4	3	1.0	0.8	0.8
LG	Laser Beam	Hecto	10,000	$7,999	0.25	0.00	16	9	1.0	0.6	0.6
LG	Laser Beam	Hecto	2,000	$3,299	0.25	0.00	16	9	1.0	0.6	0.6
LG	Laser Beam	SA565	2,500	$1,674	0.30		4	3	1.0	0.8	0.8
LG	Laser Beam	SA560	2,500	$1,399	0.30		4	3	1.0	0.8	0.8
LG	Laser Beam	SA560	2,500	$779	0.30		16	9	1.0	0.6	0.6
Christie	1 Chip DLP	DWX555-GS							1.0	0.0	0.0
Christie	1 Chip DLP	DHD555-GS		$17,995					1.0	0.0	0.0
Christie	1 Chip DLP	DWU555-GS		$18,995					1.0	0.0	0.0
LaserWorld	Laser Beam	EL-200RGB		$679					1.0	0.0	0.0

Varytec	Laser Beam	FX-Laser		$229					1.0	0.0	0.0
Panasonic	AllExpensive $3´000+			$3,300					1.0	0.0	0.0
ViewSonic		PRO9000	1,600	$1,279	1.50	1.80	16	9	1.0	0.6	0.6
Optoma		ZW212ST	2,500	$1,472	0.52		16	10	1.0	0.6	0.6
Mitsubishi		WL7050U	4,700	$1,790	1.50	2.70	16	10	1.0	0.6	0.6
Mitsubishi		WL7050U	4,700	$2,690	0.80		16	10	1.0	0.6	0.6
Casio		XJ-A141	2,500	$729	1.40	2.80	4	3	1.0	0.8	0.8
Casio		XJ-A146 Demoware	3,000	$829	1.40	2.80	16	9	1.0	0.6	0.6
Casio		XJ-A146	2,500	$930	1.40	2.80	4	3	1.0	0.8	0.8
Casio		XJ-A242	2,500	$951	1.15	2.30	16	10	1.0	0.6	0.6
Casio		XJ-M245 Demoware	2,500	$987	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-A142	2,500	$990	1.40	2.80	4	3	1.0	0.8	0.8
Casio		XJ-A142	2,500	$990	1.40	2.80	16	9	1.0	0.6	0.6
Casio		XJ-A256 - Demoware 2	3,000	$999	1.15	2.30	16	10	1.0	0.6	0.6
Casio		XJ-M241	2,500	$1,032	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-M246	2,500	$1,046	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-M245	2,500	$1,049	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-M251	3,000	$1,049	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-A147	2,500	$1,095	1.40	2.80	4	3	1.0	0.8	0.8
Casio		XJ-A247	2,500	$1,109	1.15	2.30	16	10	1.0	0.6	0.6
Casio		XJ-A252	3,000	$1,120	1.15	2.30	16	10	1.0	0.6	0.6
Casio		XJ-M255 DEMOWARE 3	3,000	$1,123	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-M256	3,000	$1,212	1.32	1.93	16	10	1.0	0.6	0.6
Casio		XJ-A255 - Demoware 2	3,000	$1,218	1.15	2.30	16	10	1.0	0.6	0.6
Casio		XJ-H1650	3,500	$1,561	1.60	1.91	4	3	1.0	0.8	0.8
Casio		XJ-H1650	3,500	$1,561	1.60	1.91	16	9	1.0	0.6	0.6
Casio		XJ-UT310WN	3,100	$1,704	0.28		16	10	1.0	0.6	0.6
Casio		XJ-H1700	4,000	$1,750	1.60	1.91	4	3	1.0	0.8	0.8
Casio		XJ-H1700	4,000	$1,750	1.60	1.91	16	9	1.0	0.6	0.6
		XJ-H1750	4,000	$1,880	1.60	1.91	4	3	1.0	0.8	0.8
		XJ-H1750	4,000	$1,880	1.60	1.91	16	9	1.0	0.6	0.6
Casio	Short Throw	XJ-ST155	3,000	$2,249	0.68		4	3	1.0	0.8	0.8
Casio	Short Throw	XJ-ST155	3,000	$2,249	0.68		16	9	1.0	0.6	0.6
Casio	Short Throw	XJ-ST145	2,500	$2,049	0.68		4	3	1.0	0.8	0.8
Casio	Short Throw	XJ-ST145	2,500	$2,049	0.68		16	9	1.0	0.6	0.6

Appendix 2. Paper published of the system development

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Developing a Mixed Reality Assistance System based on Projection Mapping Technology for Manual Operations at Assembly Workstations

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Abstract. Manual tasks play an important role in social sustainable manufacturing enterprises. Commonly, manual operations are used for low volume productions, but are not limited to. Operational models in manufacturing systems based on "x-to-order" paradigms (e.g. assembly-to-order) may require manual operations to speed-up the ramp-up time of new product configuration assemblies. The implications of manual operations in any production line may imply that any manufacturing or assembly process become more susceptible to human errors and therefore translate into delays, defects and/or poor product quality. In this scenario, virtual and augmented realities can offer significant advantages to support the human operator in manual operations. This research work presents the development of a mixed (virtual and augmented) reality assistance system that permits real-time support in manual operations. A review of mixed reality techniques and technologies was conducted, where it was determined to use a projection mapping solution for the proposed assistance system. According to the specific requirements of the demonstration environment, hardware and software components were chosen. The developed mixed reality assistance system was able to guide any user without any prior knowledge through the successful completion of the specific assembly task.

Peer-review under responsibility of organizing committee of the 2015 International Conference on Virtual and Augmented Reality in Education (VARE 2015)

Keywords: Virtual Reality; Augument Reality; Mixed Reality; Projection Mapping; Manual Assembly; Assistance.

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1. Introduction

Manufacturing enterprises may have to reconsider their assembly processes in the near future in light of the need for social sustainable manufacturing as well as the challenge of meeting dynamic and individual customers' requirements and shortened product lifecycles [1]. The importance of the manual work is therefore currently been reconsidered in a 21st Century shop-floor that needs to find again the right balance between manual, semi-automated and automated manufacturing assemblies due to an increased demand for customized products [2].

Moreover, manufacturing will still require the human operator in his/her role as micro-manager, trouble-shooter and decision-maker on the shop-floor – no matter if it comes to manual workstations or semi- to fully-automated manufacturing modules [3] [4]. Nevertheless, today manufacturing processes are getting more and more complex and variable, and therefore when an operation involves human interaction, it remains susceptible to human errors. Furthermore, when it comes to such complex processes and sequences, certain operational standards of performance for a specific task or series of tasks may create a high dependency from a particular well-trained operator or specialist, so that production stops if he/she is not at his/her workstation. For these situations, to reduce human errors and dependencies in particular operators, advanced Human-Machine Interfaces (HMI) based on Augmented (AR) and Virtual (VR) Reality can be used as a means for assistance and training [5].

Virtual Reality (VR) makes it possible to explore complex problems without high costs and risk(s) related to physical prototypes, and thus allows to effectively and efficiently develop problem solutions in a virtual stage [6]. Inside a virtual environment, it is for example possible to create, test and analyze complex assembly processes. In this way it is possible to analyze and consequently avoid potential problems even before the assembly is actually performed. A *Virtual Reality Learning Environment (VRLE)* is a system that satisfies the different learning needs that operators might have, such as: knowledge, comprehension, simulation, application and creativity. Moreover, it has been found that apprentices prefer at the first stages of their training the use of manufacturing processes simulations over an initial practical exercise due to 3D methods, selection of process parameters and process planning [7]. An example of VR technology usage in manufacturing enterprises is the VISTRA system [5], which is a comprehensive platform for VR operator training of manual assembly processes with the aim to speed-up the ramp-up times and increase operators productivity in automotive production.

Augmented Reality (AR) is a rather new form of the HMI [8]. AR can replace the common installation manual, e.g. by showing virtual instructions directly in the technician's field of view [4]. Boeing, BMW and Volkswagen are well known for conducting the first pilot studies incorporating augmented reality in their assembly lines in order to improve their manufacturing and assembly processes [9].

In order to make that – assembly module – less dependent of the specific knowledge of an operator, one solution is the implementation of a "Mixed Reality (MR) assistance system" to assist the operator performing manual operations. The aim of this research and technology development (RTD) work is to showcase the development of such system.

2. Supporting Technologies for Mixed Reality Assistance Systems

2.1. Virtual, Augmented and Mixed Reality

VR usually uses screens as displays to show the virtual environment, but when it is desired to show a set of instructions projected directly on the workspace it is also required the use AR techniques. MR systems – are systems that combine real and computer-based information. Table 1 presents a comparison of the advantages of three visualization techniques that currently exist for real and virtual environments. Almost all tools used to interact with the virtual world are separated from those used to interact with the real world, so it forces their users to switch between operation modes and therefore resulting in a discontinuous interaction [10].

Table 1. Visualisation Techniques for Real and Virtual Environments

Advantages	AR (Glasses)	VR (Fixed Display)	MR (Fixed Projector)
Real Environment Integration	X		X
Multiple Viewers (Individuals)	X	X	X
Head Orientation/Detection Possible	X	X	X
Requires to Wear a Device		X	X
Portability	X		

2.2 Projection Mapping

Projection Mapping (PM) is a technique to project images or videos to surfaces of any kind of shapes, turning them into interactive displays [11]. Some of the simplest projections are made onto geometric shapes that can be flattened without stretching their surfaces [12]. Furthermore, factors such as geometry, image blending and warping, color and brightness uniformity, latency, and image retention must be considered when designing a high performance simulation using this technique [13] such as an assembly sequence simulation.

PM technologies can be software-driven or camera-based systems that automatically align and blend with high accuracy. However, most of the software-driven solutions are programmed for flat screens using screen points for quick geometric calibration based on the authors' experience.

Furthermore, there is a large variety of tools (software and devices) which are useful for creating MR solutions using PM. Nevertheless, there is still a lack of integration and interoperability between them according to authors' experimentations. In many cases, it is desired to interact with other external devices (e.g. external sensors for detecting workflows and context data), which requires specific implementation efforts tailored to the used software to achieve this integration. Available software solutions are often not designed for the specific needs of PM-based assembly assistance and come from different domains, requiring adaptations to make them usable for the mentioned use case of sequential assembly processes. Furthermore, most software solutions have either no external communication foreseen or provide only very simple communication interfaces, as for example *VPT7*, which includes socket-based communication for interacting with external devices.

3. A Mixed Reality Assistance System Development based on Project Mapping Technology

The mixed reality assistance system proposed in this RTD work will provide virtual assistance to the operator by projecting instructions onto the workstation environment. The chosen set-up was a projector mounted in a fixed position over the assembly workstation.

For benchmarking purposes, an existing case based also on AR technology was used as a reference [14]. In the benchmark case, Google Glass and Epson Glasse (BT-200) were used as the AR technology to display the instructions as a video-stream in their screen displays.

The main advantage of the PM technique over the previous modality using smart-glasses is that there is no need for wearing any device, requiring a specific angle of view, and is integrated into the real environment. Furthermore, smart-glasses are currently limited by their computing power.

The case of this RTD work refers to the manual assembly of a business card holder assembled in a poke-yoke, where the worker choses the correct parts and the proper tools for each step as following: Slide the clip in the glass piece, then put a distance plate and a steel piece on the glass piece, finally use a hammer and a chisel to apply pressure.

Fig. 1 shows the difference between a traditional manual assembly and a manual assembly assisted by a mixed reality assistance system based on projection mapping technology for one exemplary process/instruction step.

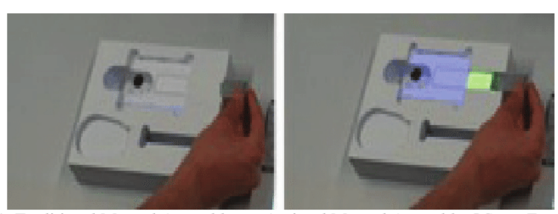

Fig. 1. Traditional Manual Assembly vs. Assisted Manual Assembly ©SmartFactory^{KL}

For the proposed mixed reality assistance system, it was necessary to gain full knowledge of the business card holder assembly sequence and its surrounding environment, and to have a clear idea of the operational instructions for each assembly task to be assisted during the performance of the manual operations, so that the mentioned success factors for projection mapping of the assembly sequence be properly considered when mapping the working area and parts to be assembled.

Furthermore, the modeling and rendering of the list of parts and tools involved in the manual assembly sequence of the business card holder, as well as the workstation (assembly module) as a 3D virtual world was made by a set of image computations of abstract and mathematical 3D-models describing the real world [15]. However any image of the parts and tools involved can be used for the projection instructions. Fig. 2 presents the existing assembly workstation at SmartFactory^{KL} that will be enhanced with the mixed-reality assistance system.

Fig. 2. Business Card Holder's Manual Assembly Workstation ©SmartFactory^{KL}

3.1 Assisted Manual Assembly Sequence

The manual assembly workstation is basically equipped with an assistance system and a recognition system [16]. The assistance system provides real-time instructions streaming from the Manufacturing Execution System (MES) on a screen in front of the operator. This assistance system was extended (augmented) by/with the projection mapping solution proposed, so that the instructions can now be visualized directly on the workplace and the operator be assisted in a natural way. While operations are performed, the workflow recognition system determines the actual work context, e.g. If the operation has been finished, the recognition system automatically displays the next instruction. Alternatively, the system can completely be controlled in a manual fashion way with a click.

- Step 1 – Take part instruction displayed: *Take glass piece from the box.*
- Step 2 – Assembly instruction displayed and highlighted by the projection mapping (where the part should be assembled): *Place glass on the base with the groove facing up.*
- Step 3 – Take part instruction displayed: *Take clip from the box.*
- *S*tep 4 – Assembly instruction displayed and highlighted by the projection mapping (where the part should be assembled): *Slide clip into the groove.*
- Step 5 – Take part instruction displayed: *Take the distance plate from the box.*
- Step 6 – Assembly instruction displayed and highlighted by the projection mapping (where the part should be assembled): *Put the distance plate on the glass piece.*
- Step 7 – Take part instruction displayed: *Take the steel piece from the box.*
- Step 8 – Assembly instruction displayed and highlighted by the projection mapping (where the part should be assembled): *Place the steel piece over the assembly.*
- Step 9 – Take part and rotation instructions displayed: *Take the assembly and rotate it 90 degrees and place it into the slot.*
- Step 10 – Take tool instruction displayed: *Take the hammer from the tools area.*
- Step 11 – Take tool instruction displayed: *Take the chisel piece from the tools area.*
- Step 12 – Hammer instruction displayed and highlighted by the projection mapping (where the hammer should hit): *Gently hit on the three small openings on the top of the assembly.*
- Step 13 – Take part, rotation and placement instructions displayed: *Rotate the assembly 180 degrees and place it into the slot.*

- Step 16 – Hammer instruction displayed and highlighted by the projection mapping (where the hammer should hit): *Gently hit the other side with the hammer.*
- Step 18 – Put back the tools instruction displayed: *Put back the hammer and the chisel into the tools area.*

"The Sequence was successfully completed"

3.2 Operator Perspective

In order to make the projection mapping instructions more realistic, it was required to implement a set of best practices for the proposed mixed reality assistance system:

- Perspective – The beamer was properly positioned so it can cover the required projection mapping area for each image (workstation, part, and tool). According to the operator's angle/point of view, the image perspective view was adjusted. The 3D modelling and rendering was done with Autodesk 3DS MAX software.
- Meshing – In order to display an image in an irregular area, e.g. *a groove.* The image was divided into sections; each section was deformed to cover the different objects (parts and tools) in the workstation.
- Calibration – Once the image is meshed; the control points of the mesh are adjusted.

Fig. 3 shows the sequence to create the image adjustment to the worker perspective angle.

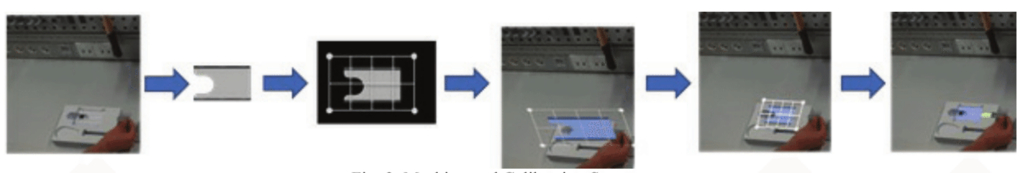

Fig. 3. Meshing and Calibration Sequence

3.3 Software Solutions

For the given environment of a manual assembly workstation, the following software solutions have been chosen:

- CAD software for 3D modeling of parts and tools e.g. to be shown in any sequence of any instruction to be followed by an operator – e.g. Autodesk 3DS MAX.
- PM software for projection environment calibration – e.g. Video Projection Tool (VPT7).
- A communication protocol to allow the interaction among computers and other multimedia devices, optimized for networking technology – e.g. Open Sound Control (OSC).

3.4 Hardware Solutions

For the selection of the hardware components of a mixed reality assistance system, diverse hardware solutions can be chosen depending on the working area and the surface that should be covered by the projection mapping. For the given environment of a manual assembly workstation, the following hardware solutions were chosen:

- A laptop for 3D modeling and execution of a/the projection mapping solution.
- A projector and its mounting solution for covering the target projection mapping surface as well as to mount at the proper position and distance of the projector.
- A line of motion sensing input device for automatic detection of hands movement.

3.5 Automatic Detection/Recognition System

The automatic detection of hands movement was implemented using a recognition system based on the Microsoft Kinect sensor motion controller. Fig. 4 depicts the workflow of the recognition system.

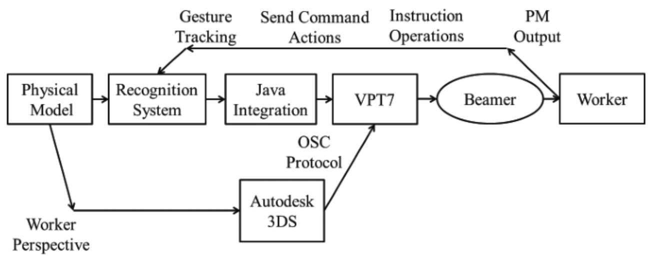

Fig. 4. Recognition System Workflow

3.6 System Integration with Java

Once the recognition system identifies the environment and movements, the next step is to use the information gathered by the Microsoft Kinect to integrate it to the assistance system. In other words, the running Java code determines when the operator successfully finished a step, so the assistance system can send a command for projecting the next step to the VPT through the OSC protocol (see Fig. 4).

3.7 Send Command Actions

The communication between the workflow recognition system and the projection mapping solution chosen was VPT7, and it was realized with a socket-based communication. Since VPT7 is capable of different types of communication, including the Open Sound Control (OSC) protocol, the commands sent by the Java code were in the OSC protocol, e.g. /presetprev t

3.8 Instructions Operations (VPT7)

For the meshing and calibration, in each step it is required to make a 'preset'. A 'preset' is an array of layers and images that saves the correct deformation, so when the image is required; it is already adjusted for correct visualization. To display an image it is necessary to first *Load* the image, e.g. the clip, to the VPT7 and then assign it to a Layer. A *Layer* is a section area where the instructions are displayed; it can cover a small area or the entire surface; however the larger area, the more complex it will be, in this case, the layer of the clip. The layer is distorted with meshes to correct the image projection to adapt it to the workstation and assembly shapes as shown previously in Section 3.2. In Fig. 3 the system was developed as simply as possible, using only the three commands:

- /preset i
- /presetprev t
- /presetnext t

4. Limitations & Further Work

A limitation of the proposed mixed reality assistance system is the reflectiveness on some materials, e.g. when projecting over a plastic transparent surface, the image quality decrease. The same occurs when projecting on surfaces at high degree field of view from the projector, a pixel stretching cause a poor quality image. The projection can be calibrated, but the quality is limited by the projection angle, the bigger the angle the worse the image. Also, the entire environment has to be manually calibrated, for each implementation its required knowledge of diverse software solutions involved. Also it still requires a lot of authoring effort.

Further work improvements include using a calibrating system with depth sensors and integrating it to the mixed reality assistance system so it can track the environment, which means optically identifying real objects and making possible layers auto-calibration. A recommend device is the Microsoft Kinect, because it already includes many sensors for depth and color as well as a microphone array and is Microsoft Windows friendly.

Another interesting system upgrade can be to make use of a multi-projector array to increase area coverage and therefore reduce image distortions on the surface or specific angles.

5. Conclusions

In this paper authors presented the development of a mixed reality assistance system based on projection mapping technology to assist manual operations at assembly workstations. The system was successfully able to provide information (instructional guidance) directly at the place of action. To use it, any operator has to choose the required assembly task and then the PM solution projects the instructions directly onto the workstation environment, which will guide the user step-by-step until the whole assembly sequence is completed successfully. In conclusion, the mixed reality assistance system makes possible to enhance a typical manufacturing execution system.

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Appendix 3. Tutorial of the Projection Mapping Software (VPT7)

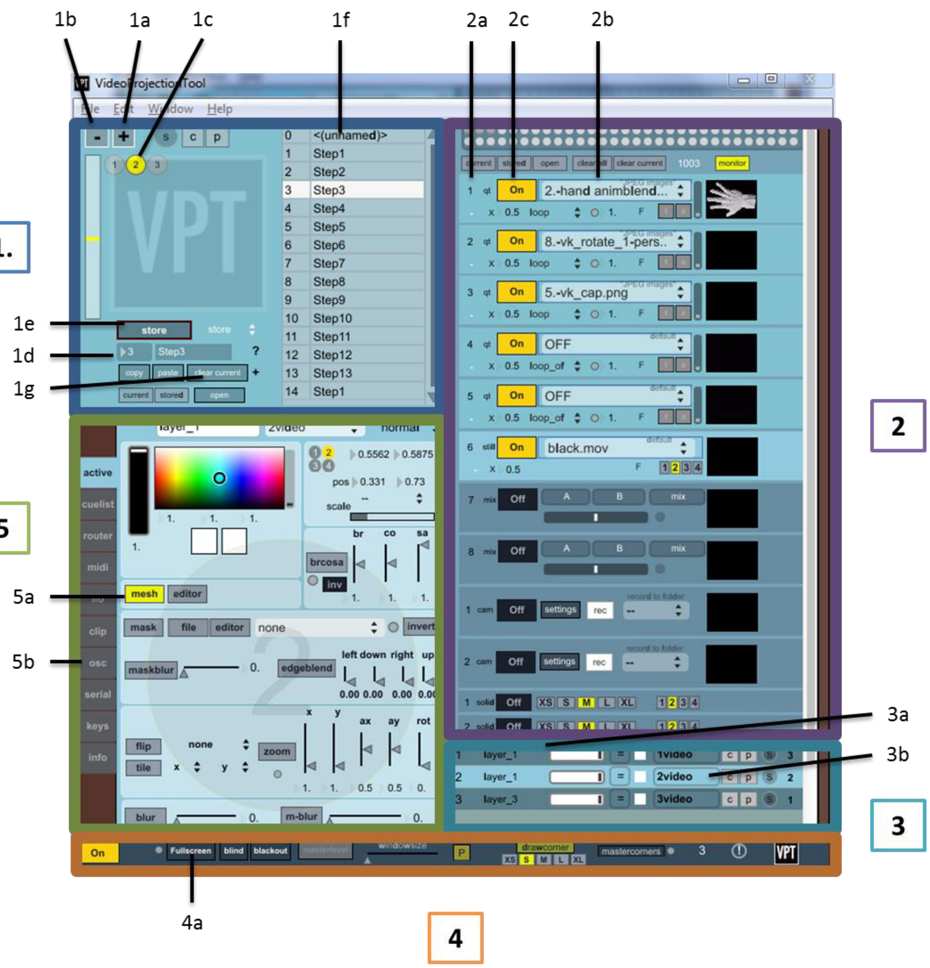
System Requirements

Windows XP, Vista, or Windows 7 machine with a Pentium 4® or Celeron® compatible processor or higher and one GB RAM. Jitter requires QuickTime 7.1 (or later), an OpenGL-compatible graphics card, and OpenGL 1.4 (or later).

Interface of VPT7 Software

The most important commands of software VPT7 used for the system development.

1. Create Layers & Presets
   a) Create Layer
   b) Delete Layer
   c) Select Layer
   d) Preset number
   e) Save a Preset
   f) Preset List
   g) Clear Preset
2. Load Image & Videos
   a) Slot Number
   b) Slot
   c) Active source
3. Assign Layer
   a) Layer
   b) Slot
4. Control Bar
   a) Full screen
5. Control Tabs
   a) Mesh a Layer
   b) OSC Control Tab



Tutorial of a Projection Mapping Setup using software VPT7 for “A Mixed Reality Assistance System Development based on Project Mapping Technology”

I. - Introduction

In this tutorial you will find information regarding how to setup the projection over different kinds of irregular surfaces. The software used is the Video Projection Tool (PT7) and is used for projection mapping solutions.

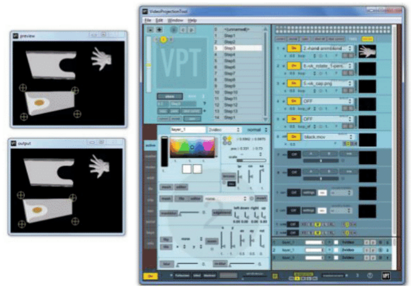
Basically VPT is real-time projection software that adapts a projection to a particular space/surface. The software works with layers which are loaded images or videos. Each layer is projected in a specific section and calibrated according to the surface of the environment.

The tutorial is divided in 2 groups: "Top Frequent Instructions" and "Creating a new project". The first section will cover a list of specific instructions in order to modify an existing project. And the second section "Creating a new project" will give you a set of steps to start a new project.

II. - VPT Overview

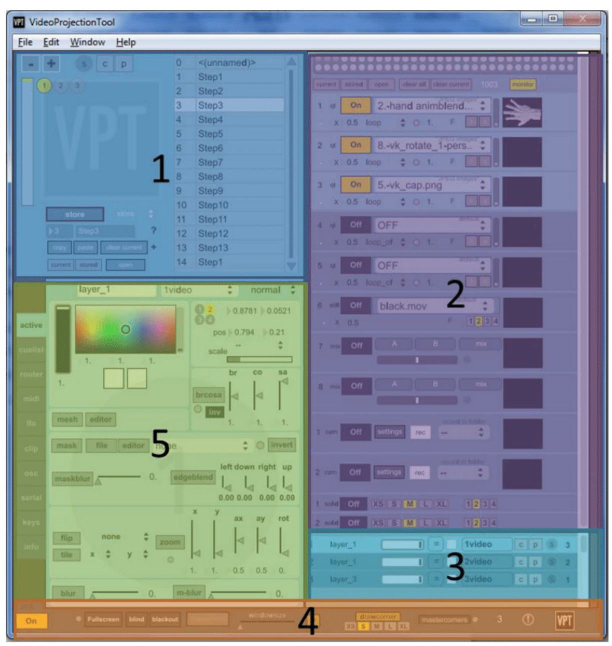
Before start giving instructions how to perform a setup, first we will take a overview of the sections and some button functions. Using VPT7 is easy to make a new project or a modification however is not so simple. For that reason is strongly recommended to take a general overview before start using it.

VPT 7 consists of three windows: Interface, Preview and Output. The **output window is** the window that should be on your projector output. In the **Preview window** you can make modifications to calibrate the images according to the surface. But of them can be controlled from the lower part of the Interface Window.



And finally the **Interface window** is the main window and it is divided in 5 sections:

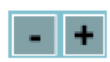
1. Create Layers and Presets (Mapping)
2. Load Images and Videos (Source)
3. Assign Images to Layers
4. Control Bar (Output)
5. Control tabs (Advanced functions)



To make the Output windows full screen click the fullscreen button at the bottom of the VPT interface (in the VPT control bar) or hit the [esc] key on your keyboard to go to fullscreen.

VPT Section 1: Create Layers and Presets (Mapping)

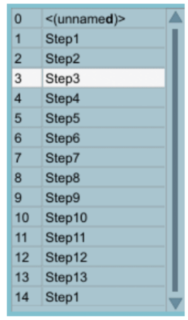
1. ***Create Layers.*** The buttons "+" and "-"creates and delete a new layer respectively.



2. ***Select Layers.*** To select a layer just press over the number of layer.

3. Create a Preset (save). A preset is an array of layers and sources. To save a preset it is only necessary to write the number of preset to save and press the button "Store". Additionally you can add a description for each preset.

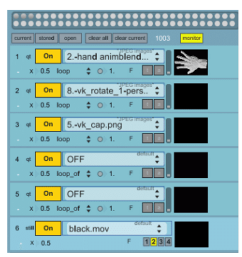
4. Select Preset



VPT Section 2: Load Images and Videos (Source)

In this part you can **load images or videos to VPT**. Each image or video have to be loaded **in a "Slot"**, that can be achieved dragging the image or video file and then selecting it from the dropdown list.

Unfortunately, there is only a total of 12 "slots", but you can only use the first 6 of them. That means, you can only have 6 images per preset. The slots are **called "Video#"**, e.g. the first slot is called "Video1".

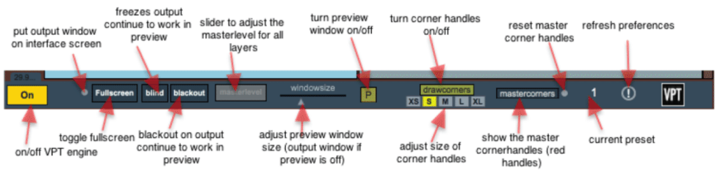


VPT Section 3: Assign Images to Layers

This section acts as an interface between the sources and the Layers. Here you **setup each layer to assign what Slot (from the Source section) will be displayed**. That means, for each layer you have to select the number of slot.

VPT Section 4: Control Bar (Output)

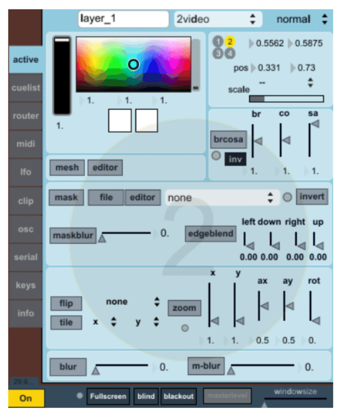
This section is used to control the Preview and Output windows.



Usually, for general use, you will only need the **Fullscreen** button.

VPT Section 5: Control tabs (Advanced functions)

At last, but not less important is the Control Tab Section. This is the most complex section on VPTA. It can be say it is the section to develop **advanced functions**. This tutorial doesn't cover all the functions but a general overview. For further information please check the VPT7 documentation.



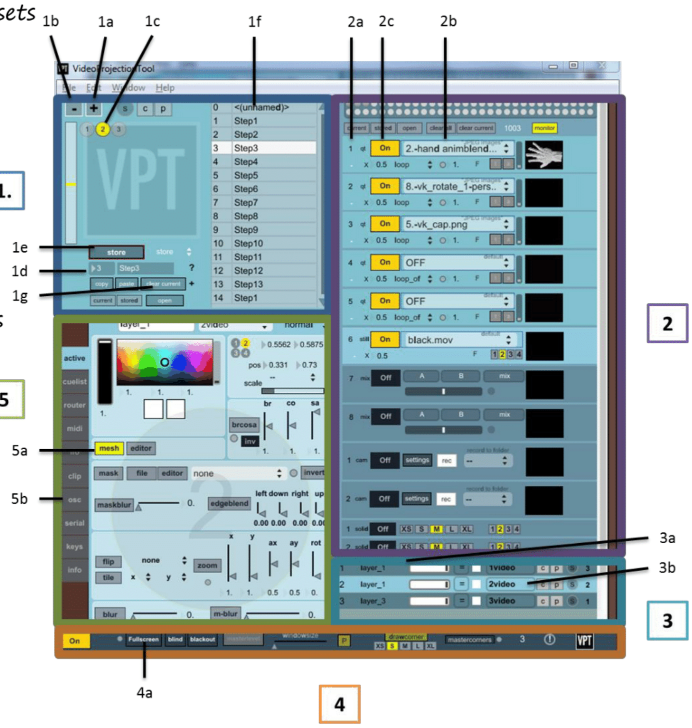
The Control Tab section consist of 10 tabs: Active, Cuelist, Router, Midi, IFO. Clip, OSC, Serial, Keys and Info.

The **Active** tab, basically are settings to modify the active Layer. The **Cuelist** let you make a playlist interacting between presets and the ***OSC*** tab makes possible to stablish an external communication with another network using port 6666 using the Open Sound Control (OSC) protocol.

Command Summary

As a summary of the most important or most used commands of VPT7 to develop a Projection Mapping for an Advanced Instruction System to Perform Manual Operations, it was created a "code" to refer them.

1. Create Layers & Presets
   a) Create Layer
   b) Delete Layer
   c) Select Layer
   d) Preset number
   e) Save a Preset
   f) Preset List
   g) Clear Preset
2. Load Image & Videos
   a) Slot Number
   b) Slot
   c) Active source
3. Assign Layer
   a) Layer
   b) Slot
4. Control Bar
   a) Fullscreen
5. Control Tabs
   a) Mesh a Layer
   b) OSC Control Tab



III. – Starting a New Project

In this section it will be explained the steps to be follow to setup up a projection mapping in the easiest way. The steps to follow are:

1. Create a New Project
2. Create layer
3. Load image
4. Assign image to a Layer
5. Layer calibration
6. Layer adjustments
7. Saving steps (Presets)
8. External Communication
9. Communication commands

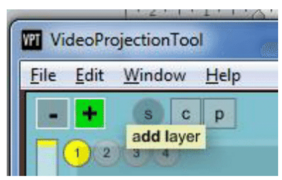
Layers

Once you have all the instruction files, it is necessary to choose a surface in which part of the environment it have to be displayed each instruction. *E.g. if it is necessary to press a button, a <Hand> image can be displayed over the button.* The surface required to project the <Hand> have to be ~~manually~~ calibrated. **For each different surface it is necessary to create a new layer.**

The larger the surface, the more complex the layer calibration will be.

Create New Layer(1)

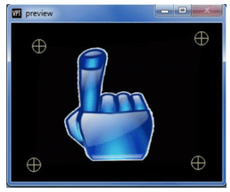
In this section will find useful information about how to create a new layer in a specific software environment. Each time you open the software VPT7, it also opens 2 display windows: Preview & Output. To create a new layer you only need to press <+> button. You can add as many layer as you need, they will be auto-named in ascendant numbers.



Automatically when you create a new layer the last one appears at the front. So in case one or more layer is overlapped you may not see part or a complete layer. You can also setup the layer position.

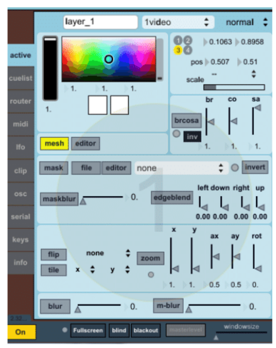
Calibrate Layer (4)

Once you have created a new layer, you may want to add an image to the layer, feel free to skip to the <Image> Section. To calibrate the layer to the surface, first, you have to select the properly layer. May sure your projection solution is working properly and working in the final position, otherwise you will have to calibrate each layer every time the projector moves. In the <Preview Window> the layers are displayed, to adjust them is only necessary to select and drag the 4 points to the real scenario area.

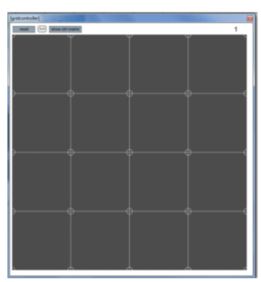


Complex Layer Calibration

For complex surfaces 4 corners may be not enough, in these cases it is required to add more control points to the output, it can be achieved by meshing the layer. In the <Active> Tab, select <Mesh>.



Now, you can vary the meshing size from 2x2 up to 10x10. To this, it is suggested to take a photo in from point of view which will be located the worker and try to adjust the most photo into the real environment.



Layer-Image Adjustment (5)

In some situations you may find useful to modify the original image. e.g. If is necessary to modify the size, color as well a rotation. This functions are part of the "Active" tab, they are displayed in the lower-left part, of the main VPT windows.

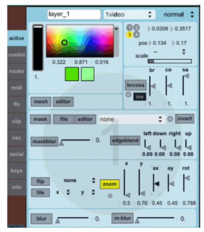


Image-Video

You should already have your own images and videos to display, which will be show to the worker in order to assist him to perform the manual operations. if something is missing, or you need to modify the, or well, the perspective is not the adequate, you can use the software Autodesk 3ds to assurance the best image quality. However some details can be done with the same software.

As soon as you start working with the VPT tool you may notice you can only be able to load 6 different images in each step. That means you will be only able to highlight or use six images sources for each step or well scenarios, however you can have as many layers ass you need in each step, and the image source can be shared.

To display an Image or Video in a layer, it is necessary to make 2 steps: **Load an image-video to VPT7 and then assign the image-video to a layer**.

Create Image Files

First, have to make sure you already have all the images-videos you will need to display. If is something missing you can easily create your own image or video to show to the user in order to assist him to perform his manual operations. It can be an Image or a Video file. It can be generated using NX8 and Teamcenter or well, any other editor as well Autodesk 3ds. Just make sure to save them in JPEG or PNG format file.

Load Image-Video to VPT (2)

In the upper-right section of the main window of VPT7 there are six slots to adding image-video, each slot receive the name Video followed by a number

"Video#". To load an image-video to VPT7, you have to drag the folder which contains the images or videos files to the dropdown list. In the Dropdown list select the file. It is also necessary to press the On-Off button to active it. Does not really matter in what position Video-Slot they are saved.

Assign Image-Video to a Layer (3)

In the lower-right section of the main window of VPT7 it can be found the layer section. Here you can assign a previously loaded image-video to each layer. You may choose from <Video1> to <Video6> according to the file you want to display. You can use the same image for multiple layers.

Saving Options

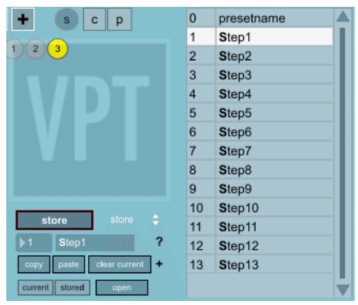
There is not such a thing to save the whole works as a file. The route File->Save and File->Save as will always be de-activated.

You will need to save your progress for every step that means for every scenario you have. **It is saved as a preset by clicking on <Store>.** You can not specify where to save it, it is only saved and the next time you open VPT, this automatically load the presets. For further instructions see the official VPT documentation.

Presets

A preset defines the layer position, calibration and the images or videos associated to each layer. A preset contains the total numbers of layers. You can customize any layer for each preset, but you cannot add or delete layers for a specific preset. If you delete or add a new layer in a preset, it will be added and deleted respectively in all presets.

To save a preset you have to name it as a number and press the "Store" button. Additionally it is possible to assign a description for each preset.



Processing Instructions

In the deployment of an advanced instruction system to perform manual operations, for many advantages it is desired to control the instructions remotely.

For personal customized assistance it can also be remotely controlled.

External Communication (6)

The software used for the projection mapping, is capable to stablish communication by serial, with a USB input or by a network, listening from port 6666.

In order to stablish a communication among other computers, it is necessary to use the Open Sound Control (OSC) protocol. As an advantage of using the OSC protocol is, it gives you freedom to use any programming language such as python, Java or C++.

Communication Commands

Once the presets for the Advanced Instruction System have been setup, some of the most useful tools using the OSC protocol are the commands which modify the Presets:

- */preset i*
- */presetprev t*
- */presetnext t*
- */store0*

In order to display the properly step, it is necessary to receive an input from a port, it can be done with any language as Python, Java, C++.

IV. - Frequently Instructions

For this section, in order to improve the instruction understanding it was created a "**Code**" as reference to VPT7 most used buttons. You can find this code in the "**Command Summary", in the VPT Overview (at the end of the section 2 of this tutorial).**

To make **a reference to that code, its used brackets "[ ]"**, and to make a reference to another "**Frequent Instructions" it's used braces "{ }"**

FI1. - Create a New layer

1. Press the add layer button [1a]

FI2. - Load an Image or Video to VPT7

1. Select the folder where is located the image or Video file
2. Drag the folder to a Slot [2b]

If it doesn't works, probably is because you also need to assign that Image-Video to a Layer.

FI3. - Add a comment or Text

VPT is only capable to display images and videos. So, if it is necessary to add a text, first must be created an image with the text to display.

1. Create an image file with your "text".
2. Follow the steps to {"Load an image to VPT"}

FI4. - Assign an Image-Video to a Layer

1. First, make sure to {"Load an Image or Video to VPT7"}

2. Choose the Layer [1c] where you want to display the image. (No press anything, only decide which layer)
3. Press the dropdown list [3b] of the corresponding layer [3a] you choose, assign the correct Source Slot [3b]

FI5. - Identify which Slot is the source of an image assigned in a Layer

1. Make sure to select the corresponding Preset [1e] you want to modify
2. Identify in which layer [1c] is assigned the image you want to replace
3. Go to the "Assign images to layer" VPT section [3a] and check which Slot [3b] is select.

FI6. - Change an image of a Layer

1. First, you must {"Identify which Slot is the source of the image assigned in a Layer"}
2. Identify in which layer [1c] is assigned the image you want to replace
3. Identify which slot [3b] is loaded to that layer
4. Load a the new image to VPT in the correct [2a] slot [2b]
5. Make sure the source [2c] is active as "On"

FI7. - Save (Preset)

You only save Presets. A Preset is an array of Layers and Sources, so it can be say a Preset is an Instruction Step. To save a Preset:

1. Press the Button Store [e1]

FI8. - Save As… ("Save a New Preset")

1. Write the number of Preset [1d]
2. Write a comment (Optional)
3. Press the button Store [1e]

If you write an existing Preset number, it will overwrite it

FI9. – Delete a Preset

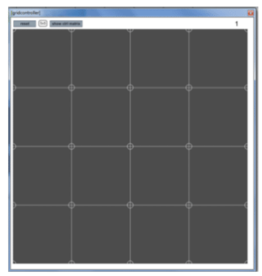
Select the Preset to delete in the "Preset Number" [1f]

Press

FI10. - Calibrate a Layer

1. Select the Layer [1c]
2. In the Preview Window of VPT7 select a corner and move until it fits.
3. If you need more precision, press the "Mesh button" [5a]
4. It will open a new window, select the array size for the meshing e.g. 5x5

5. Move each control point of the meshing until it fits to the surface



6. Close the window
7. Save the Preset

FI11. - Calibrate an image

To calibrate an image in VPT to adapt it to the surface of the environment, you actually have to calibrate a layer, and for that layer you assign an image to be display.

1. Follow the steps in the {Calibrate a Layer}

FI12. - Create a new Project

1. Close the program VPT7
2. Open the "vpt7_win" folder which contains the program.
3. Make a copy of the Folder "Blank_Project"
4. Re-name the folder without spaces, e.g. NewProject

You have already created a new project. However, to open it, you have to do something similar to specify VPT which project.

FI13. - Create a new Project in another location

1. Follow the steps to {Create a New Project}
2. Move the folder to the location you want to save it.

FI14. – Open a Project

1. Open the "vpt7_win" folder which contains the program.
2. Open the projectpath.txt file
3. There would only be a single file text with the format "project xxxx #" without quotes, where "xxxx" is any previous project
4. Rename the second word "xxxx" with your "NewProjectName" e.g. NewProject
5. Make sure in the third part of the text line "#" is a cero "0".
6. Verify the line is similar to this "project NewProject 0"
7. Save the file
8. Close the file
9. Run VPT7

It will automatically open the Project specified in the projectpath.txt file

FI15. – Open a Project from another location

1. Open the "vpt7_win" folder which contains the program.
2. Open the projectpath.txt file
3. There would only be a single file text with the format "project xxxx #" without quotes, where "xxxx" is any previous project
4. Rename the second word "xxxx" with your NewProjectName e.g. NewProject
5. Make sure the third word from that line is the number "1"
6. Verify the line is similar to this:
   "project C:\Users\HIWI\Desktop \vpt7\vpt7_win\NewProject 1"
7. Save the file
8. Close the file

FI16. – Save a Project

VPT7 Automatically saves your Project, you only have to make sure to save your Presets correctly.

1. To save Presets, follow the steps in {Save}

FI17. – Save a Project As…

It is not possible to do that. The most similar function is to make a copy of the project you want to "Save As" and then, open the Project.

1. Save your Presets {Save}
2. {Create a New Project}
3. Open the Project you just created {Open a Project}

FI18. - Receive Instructions from a Network

In order to receive instructions from a Network you have to follow the Next Steps:

1. Do nothing.

You don't have to do anything with VPT7, just to make sure the computer is in the same network.

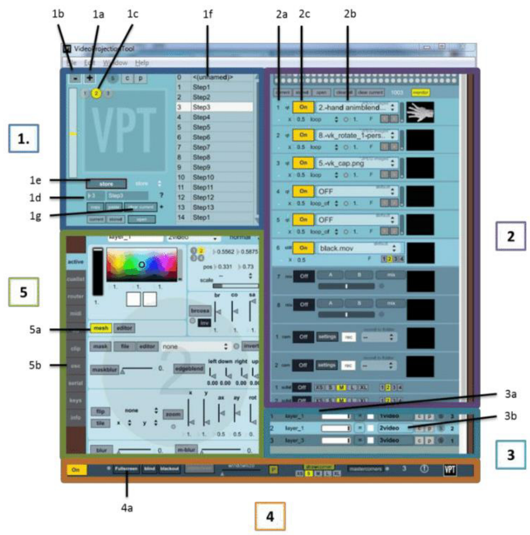
FI19. - How to Receive Instructions from a Network

1. Make sure the computer is in the same Network
2. Run an external patch that send commands in the OSC protocol through port 6666

VPT only listen from the port 6666. For further instructions check official VPT documentation.

FI20. – What means the Code inside brackets e.g. "[1a]"?

Is a Code it was created to make reference to some sections or buttons from the software VPT7



You can find more information in the "VPT Overview" Section from the Tutorial