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## CAVE Design Using in Digital Factory

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### Abstract

Therefore, in order we are to better orient and introduce the future workplace, it is very useful tool of immersive technologies CAVE. It is a device which creates virtual reality. The device CAVE as the product does not offer any manufacturer. The device is necessary to design with the components from different suppliers. The article deals with the experience of CAVE design and using CAVE in cooperation with the Tecnomatix Jack or Process Simulate and the Microsoft Kinect tracking system. In the article are used the results of their own research of CAVE designing with the active and passive projections and with the creation of the 3D view.

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*Keywords:* CAVE; Workplace design; Tecnomatix; Microsoft Kinect; Immersive technologies

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### 1. Introduction

The changing customer demands put great emphasis on the flexibility of production, innovation and flexibility to respond to changes. It is needed to quickly modify the structure and organization of production, which is often time consuming and costly. The classic approaches using real models are time consuming and unnecessarily prolong the rise time of a new production. Technologies such as augmented reality, virtual reality, and digital factory contribute to the optimization and verification of the proposal already in virtual form. The proposal for changes we can verify not only statically but also dynamically through simulation. Through special software we can test the operation of the automated elements of workplaces, but also modularity and the ability of the new organization of the entire workplace.

Therefore, in order we are to better orient and introduce the future workplace, it is very useful tool of immersive

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technologies CAVE. It is a device which creates virtual reality and embeds observers in this virtual environment. The device consists of one or more walls, which using the technology back-projected 3D image. When there is more active walls, the impression of embeds into the virtual environment is more convincing. The device CAVE as the product does not offer any manufacturer. The device is necessary to design with the components from different suppliers. The article deals with the experience of CAVE design and using CAVE in cooperation with the Tecnomatix Jack or Process Simulate and the Microsoft Kinect tracking system. In the article are used the results of their own research of CAVE designing with the active and passive projections and with the creation of the 3D view.

## 2. CAVE

When creating CAVE is a key decision how large the device we want to create. It is necessary to define how many active walls the device will have. Then their dimensions are specified and the ratio of individual walls is given. First CAVE devices were built mostly in a wall-to-wall ratio of 3:4, similarly as the majority of screens used in that period. Currently, the wall-to-wall ratio of 16:9 or 16:10 is preferred. The walls can be made from various materials in dependence on the manufacturer. They are mostly made from either plastic or glass. They have a diffusing surface which enables displaying a visualised environment which is projected onto them; the projectors should not dazzle the user. The number of projectors is chosen in dependence on the number of active walls of the device and on the technology of 3D image display. If we use active projection, the number of projectors displaying an image with a frequency of 120 Hz is equal to the number of active walls. In the case of passive projection, the number of projectors with a frequency of 60 Hz is twice as large as the number of active walls.

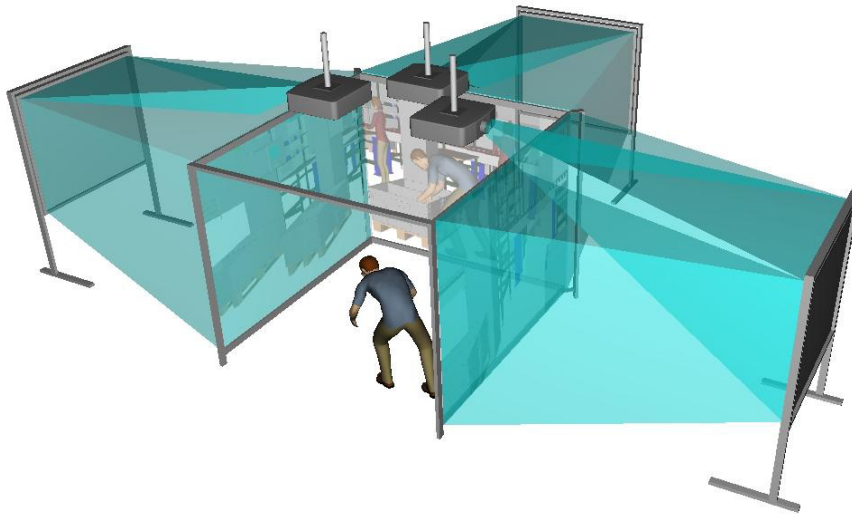


Fig. 1. CAVE with active projection using reflecting mirrors.

Depending on the dimension of the space to be used for the CAVE building, we can choose either direct lighting of the walls or indirect lighting using reflecting mirrors. Mirrors are usually made of polished sheet. The importance is to be put one their placement and clamping. Any visible corrugation should be avoided because due to a double distance, the reflection on the projected surface is outstandingly distorted. The mirrors should be placed very exactly so that the projector would light the whole surface of displaying area and any unlighted places on the edges, shift in an image display on individual walls should be avoided.

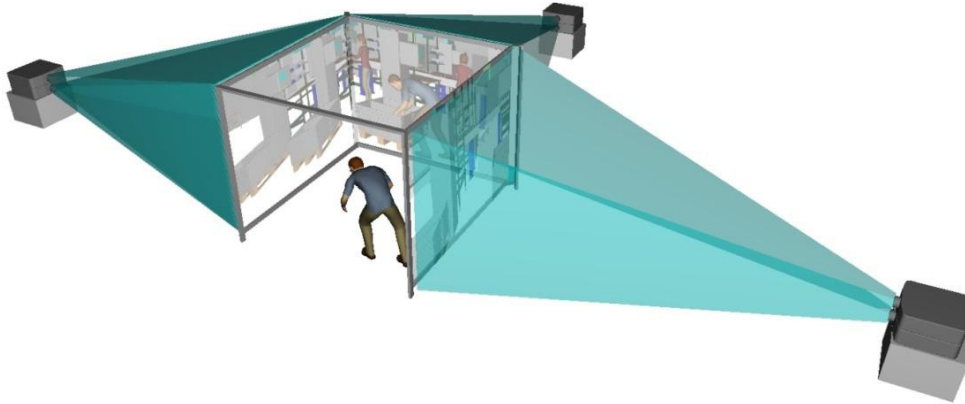


Fig. 2. CAVE with passive projection and direct lighting of walls.

Another important part of the device is a tracking workstation. Simple said, it is a set of power graphic cards and a program distributing an image onto individual walls. It means that thanks to this device the image is not cloned; it is spread onto all the walls of the device which surround the user; this is what causes the effect of a complete immersion into the virtual environment.

The final important part of the hardware is a tracking system. It ensures that the CAVE user's movements are tracked. When the user's position is changed, the system determines a new tilting of the virtual environment as if the user found himself / herself in a real environment. Various technologies can be used for the movement recognition in the CAVE environment. The most frequently used is optical or ultrasound tracking. The principle of movement tracking was dealt with in more detail in the chapter Tracking Systems. These solutions are costly and must be precisely calibrated. Various activators and joysticks represent a simpler alternative; they enable the movement in a virtual environment also directly from the user's position. These devices operate mostly on the principle of a gyroscope. Another alternative is the use of Kinect. The device has a free SDK, in which application for particular use can be programmed. At the same time, it is possible to use the existing plug-ins of concrete software. As already mentioned in the previous chapters, Kinect can be connected, for example, with modules of Tecnomatix Process Simulate and Jack. When using Kinect, the spacing of approx. 2 metres from the sensor is needed to enable the user to get completely to the visual field of the device.

The device has to be placed in the upper part of the CAVE construction so that it could not be placed in the user's field of vision in which the virtual environment is being drawn. From this reason the sensor has to be tilted under a sharp angle of approx. 20°-25°, which partially influences the scanned data quality [1].

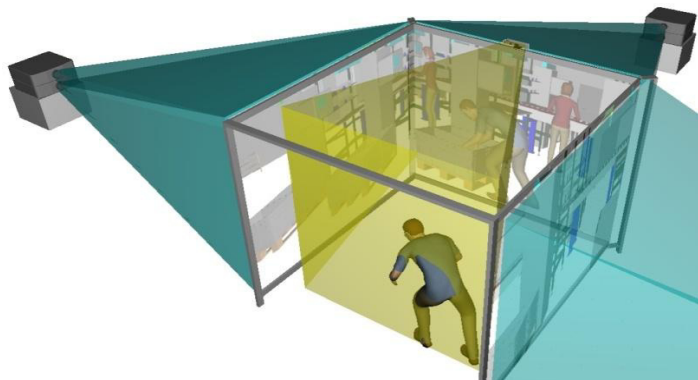


Fig. 3. Sample of interactive modelling of work positions in the CAVE environment using software of Tecnomatix Jack and device Kinect.

As for software solutions, there are more alternatives. The first alternative are simple 3D model viewers that are able to display a 3D image. The second alternative are software programmed primarily for the CAVE environment, as, e.g. VDP developed by the company ICIDO. These software products are very costly. The third alternative are graphic programs which are able to general stereo display. These programs include also modules of Tecnomatix Teamcenter Visualization MoCup and Jack. They contain various display settings for display of stereo image [4].

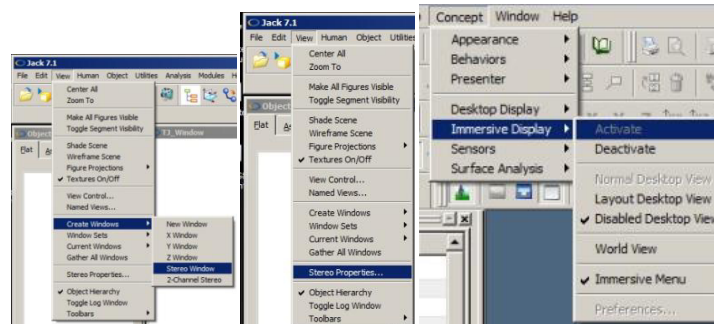


Fig. 4. Possibilities of modules Jack with Vis Mockup for stereo display.

To distribute the generated 3D display on all the walls of the CAVE device, it is also necessary to specify more precisely the image resolution and its exact position and tilting in the space. This position of individual walls in the space is defined via a text file in .vcd format. This file is to be read in Teamcenter Vis MockUp in the bookmark Concept / Immersive Display / Preferences [1].

The setting of immersive display for one wall is as follows:

```

versionNumber 0.1
initCommand ""
view CAVE
{
  units feet
  designEyeOffset 0,0,0
  display MiddleDisplay
  {
    pipe           ":1.0"
    border         BORDER_OFF
    stereo         STEREO_ON
    channel        MyMainChannel
    {
      #           WidthxHeight+Xoffset+Yoffset
      framebufferGeometry 1440x1080+240+0
      #           WidthxHeight+Xoffset+Yoffset
      virtualGeometry 900x1000-450-500
      projectorRotation 0
      #           yaw, pitch, roll
      viewRotation 0, 0, 0
      #           Left, Right, Top, Bottom, Distance
      physicalDimensions -4.5, 4.5, 4.5, -5.5, 4.5
    }
  }
}
exitCommand ""
Nastavenie zobrazenia na tri steny a podlahu je :

versionNumber 0.1
initCommand ""

view CAVE
{
  units feet
  designEyeOffset 0,0,0
  display LeftDisplay
  {

```

```

pipe                ":0.0"
border              BORDER_OFF
stereo              STEREO_ON
channel             MyMainChannel
{
#                   WidthxHeight+Xoffset+Yoffset
frameBufferGeometry 1280x1024+0+0
#                   WidthxHeight+Xoffset+Yoffset
virtualGeometry     900x1000-1350-500
projectorRotation   0
#                   yaw, pitch, roll
viewRotation        -90, 0, 0
#                   Left, Right, Top, Bottom, Distance
physicalDimensions  -4.5, 4.5, 4.5, -5.5, 4.5
}
}
display MiddleDisplay
{
pipe                ":1.0"
border              BORDER_OFF
stereo              STEREO_ON
channel             MyMainChannel
{
#                   WidthxHeight+Xoffset+Yoffset
frameBufferGeometry 1280x1024+0+0
#                   WidthxHeight+Xoffset+Yoffset
virtualGeometry     900x1000-450-500
projectorRotation   0
#                   yaw, pitch, roll
viewRotation        0, 0, 0
#                   Left, Right, Top, Bottom, Distance
physicalDimensions  -4.5, 4.5, 4.5, -5.5, 4.5
}
}
display RightDisplay
{
pipe                ":2.0"
border              BORDER_OFF
stereo              STEREO_ON
channel             MyMainChannel
{
#                   WidthxHeight+Xoffset+Yoffset
frameBufferGeometry 1280x1024+0+0
#                   WidthxHeight+Xoffset+Yoffset
virtualGeometry     900x1000+450-500
projectorRotation   0
#                   yaw, pitch, roll
viewRotation        90, 0, 0
#                   Left, Right, Top, Bottom, Distance
physicalDimensions  -4.5, 4.5, 4.5, -5.5, 4.5
}
}
display BottomDisplay
{
pipe                ":3.0"
border              BORDER_OFF
stereo              STEREO_ON
channel             MyMainChannel
{
#                   WidthxHeight+Xoffset+Yoffset
frameBufferGeometry 1280x1024+0+0
#                   WidthxHeight+Xoffset+Yoffset
virtualGeometry     900x1000-450+500
projectorRotation   0
#                   yaw, pitch, roll
viewRotation        0, 90, 0
#                   Left, Right, Top, Bottom, Distance
physicalDimensions  -4.5, 4.5, 4.5, -4.5, 5.5
}
}
}
exitCommand " "

```

These two displays are primarily used. It is also possible to create any other 3D display on the basis of changes of parameters in the text file.

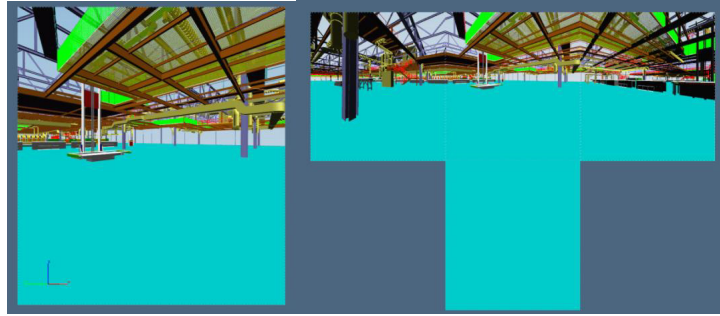


Fig. 5. Immersive display into one and four walls of the CAVE environment.

### 3. Arrangement of proposals and choice of the final proposal

When the user is surrounded by a virtual environment and can see displayed elements of the future workplace in the real dimensions, he or she can very exactly imagine the work space and reveal possible limitations and disadvantages of arrangement of components. Individual software packages also offer tools for detecting collisions, generating outreach zones and many other ergonomics analyses with the use of which we can efficiently and quickly assess the proposal of component placement in the workplace. Thanks to these tools we arrange the placement of basic component in the workplace and specify their precise dimensions. If there is no CAVE environment at our disposal, we can make arrangements with the support of a 3D projector or 3D monitor [9] [12].

HMD displays can also be used for displaying individual variants in the virtual environment and for decision making support. In the past, these devices were relatively defective; however, at present they offer a convincing experience and are visibly smaller. Currently, one of the best solutions present the glassed Oculus Rift developed by Oculus VR®. The company started selling the first version of glasses under the name “Development Kit“ and currently offers a new version with HD resolution. The company also offers accessible development environment and users can test new possibilities of the device and prepare their own applications [8].



Fig. 6. Placement of components in the workplace using the CAVE.

The device consists of two circular displays which are set in the glass frame. The distance of displays is within



the eyes' width. The frame is arranged so that the displays are in close vicinity of the eyes. The images for each eye are sent individually and are mutually shifted to create impression of a three dimensional space. The first version displays had a resolution of 1280x800, new version displays feature HD resolution. The use can walk in the virtual environment using a keyboard or joystick. The device contains a gyroscope; thus it can interactively react to head movements and automatically recalculates an image in the displays as if the user moved his/her head also in a virtual environment[5] [7].

The device is connected via HDMI or a DVI cable and is considered to be an external monitor. When the device is used, the monitors have to be set to image cloning. This is the reason why the generated image can be seen also on the monitor screen. There are two separate windows with a shifted image. 3D impression and immersion into a virtual environment can be achieved only with the support of a HMD device [5] [10].



Fig. 7. HMD display Oculus Rift.

If all the proposals for the workplace arrangement have been optimised in the previous design step, we choose the best variant. With more complex projects it is necessary to take into account different aspects of proposals and, therefore, a multimember team is to be created. The decision-making team consists mostly of the project team members, but it is possible to add a specialist from a particular area of activity. The resultant variant then moves to the stage of detailed design, in which a detailed placement of all – also less important – workplace elements is done: placement of tools, visual management, maintenance, working and assembly procedures, etc. This variant can be visualised before the detailed design phase with the use of AR in real size and real position in a layout where it will be placed in the future. Such display can be used as visualisation of the final concept solution presented to the company management, etc. [2] [3] [6].

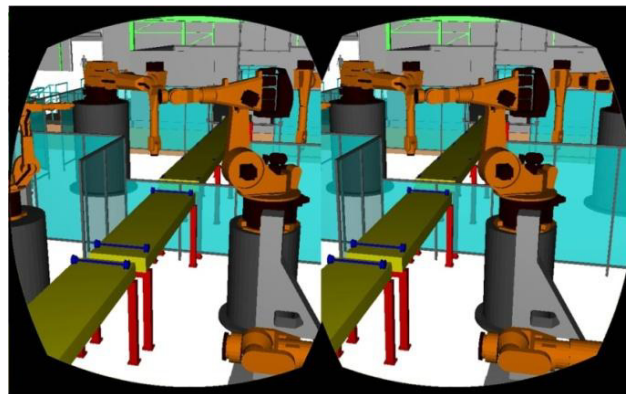


Fig. 8. Virtual view on the monitor screen using Oculus Rift.



Fig. 9. View of the future workplace using AR in 1:1 scale.

## Conclusion

In the time of rapid changes in demand it is necessary to flexibly react to customer requirements. Because of that it is necessary to rebuilt and change existing working and assembly workstations. Modern information technologies and software solutions give a range of possibilities to try new ways how to design or evaluate a workstation. I introduced one possible software solution Tecnomatix Jack and its features in the CAVE environment. The aim was to design and implement the CAVE environment with the possibility of special using software Tecnomatix Jack. The new solution was adding plug-in for possible cooperation between the CAVE and Tecnomatix Jack. To be able to implement the new solution, we propose to use Kinect for Windows device.

These technologies are not without defects or disadvantages, but they are constantly developing. The assumption is that these technologies will become more and more common and widely used. They will be very helpful because already the current versions shorten time of designing and significantly reduce costs.

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