# USING KINECT TECHNOLOGY EQUIPMENT FOR ERGONOMICS

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Analysis of human working postures designated for ergonomics can be performed by traditional measuring instruments – pen and paper. However, this method allows within a given period of time only a very limited count of ergonomic analyses with consideration of human error. Larger companies (especially automotive) have made considerable financial investments in Motion Capture (MoCap) devices in recent years. This device is well known, e.g. from the film industry, where we can animate a virtual character as a result of capturing real actor movements. Thanks to the expensive MoCap device, it is possible to acquire positions of points (called markers) on a character´s body in real time. The MoCap expenses can be significantly reduced with the aid of the KINECT device, which was originally designed for computer games. Although the potential is limited compared to traditional MoCap, for basic ergonomic analysis it represents a cheap and reliable alternative. The solution lies in connecting the software of the device with a professional tool for ergonomic analysis. This paper deals with usability analysis, financial and time demands of this new method of movement capturing (since September 2012). Every issue will be demonstrated in a case study.

***Keywords***

*Ergonomics, Motion Capture, KINECT, PLM, Siemens PLM Industry, Process Simulate Human*

## 1. Introduction

Digital production and virtual verification processes are increasingly being used not only by large companies, but they are penetrating into companies in the form of cheaper software packages that are destined for SME. Nowadays, the market offers besides this software also hardware which was originally designed for the entertainment industry – construction kits, wireless controllers for game consoles (e.g. Wii controllers, controller Razer Hydra, Asus Xtion PRO LIVE) etc. Some of these technologies can be used not only for entertainment, but they can be also very effective in production layout design, preparation of processes, etc.

The means of virtual reality are commonly used especially for the purpose of prototype verification mainly in larger companies. Formerly complicated projections can be now realized by financially accessible 3D projectors and controllers. This paper is focused on implementation of ergonomics verification (i.e. human positions regarding performance and health), where in larger companies there are used Motion Capture systems that are again well known from the entertainment industry. With the aid of this technology, it is possible to connect the virtual character with the movements of a real actor – in the case of production, of a worker. The technology for on-the-fly recording of these movements by Motion Capture is financially very demanding. Often, it is necessary to devote an entire room to this recording. The difficulties with portability are solved by e.g. Motion Capture suits, which enable recording movements directly for example during a manufacturing process in the workshop. However, we still encounter the financial restrictions of SMEs. A cheap solution (with certain inaccuracies compared to expensive classical Motion Capture solutions) can be found in the MS Kinect device.

There will be described an actual case study, where the time and financial demands of MS Kinect device use will be evaluated, compared to classical processing for ergonomic purposes. This action will be preceded by a demonstration of Tecnomatix Process Simulate software, in which the virtual environment is implemented. Moreover, the technical parameters of the Kinect device have to be defined.

## 2. Tecnomatix Process Simulate – Human module

**Tecnomatix** software is a package of products developed by **Siemens PLM Software.** This product range includes software tools suitable for different production areas that are mutually connected. Tecnomatix thus enables companies to use in practice the means of a digital factory: production designing and planning, optimizing processes in digital environment, etc. By accurate digital modeling and spatial visualization, the workers can develop future production processes. This fact enables the most important decisions in process design to be approved in time and based on a wider understanding. The effect represents the reduction of errors that could arise later during the production preparation phase. Digitization helps to prepare process quickly and precisely, while simulation and optimization ensures in the development phase that the product will be manufactured to high quality, without a need to additionally apply financial and time-consuming changes.

The Tecnomatix tool kit contains a simulation tool Process Simulate that enables planning of robotic and human based production systems of one product or of a product mix. This environment is used for realistic simulation: detailed simulation of manual processes regarding ergonomics, visibility of performed process, reach of a worker, process feasibility and worker´s load. By the use of 3D technology, it dynamically validates spatial restrictions and reduces physical assembly testing to a minimum. Users have at their disposal the whole range of predefined statistics, filters, graphic and tabular reports, images, videos and exports into different data formats can be generated. [Siemens 2012]

Regarding the fact that we will continue to scrutinize ergonomics, let´s focus in particular on the **Process Simulate – Human module**, which enables production planning, creating real human simulations and performing ergonomics evaluations. This module can evaluate human performance (e.g. to avoid injuries) and create effective ergonomic studies. Moreover, the module can be used for layout optimization and verification of manual assembly feasibility.

The human model in Process Simulate can be parameterized, i.e. defined:

- gender (male/female),
- nationality (in Process Simulate, they are represented by models),
- height,
- weight (version 10 enables obesity to be defined and its type),
- percentile (human average – if a human of an average height is tall or small),
- etc.

All these proportions affect human performance and effort in work activities. After defining the human model, a number of analyses can be performed (static, dynamic, back strain, strain of upper limbs, etc.). This digital modeling, simulation and ergonomic analysis enables avoiding some dangerous human health affecting factors, and thus the real workplace can be adapted to workers' abilities.

The analysis of human performance uses several tools provided by Process Simulate software. We are able to evaluate physical requirements with the NIOSH tool for lifting and carrying the load, with RULA analysis for quick evaluation especially of upper limbs, with OWAS analysis for evaluation of overall body position. Moreover, ergonomic reports can be generated and thus we gain access to a wide range of data related to virtual human model, including the angles of the body, load of articulations and performance. All this data can be used for generating our own analysis.

## 3. Microsoft KINECT for Windows

**Microsoft Kinect** (see Fig. 1), developed by Microsoft, is a device that records human movements and it was originally designed for the game console Xbox 360. On May 2012, Microsoft introduced to the market **Kinect for Windows** version, which is designated only for operating system Windows 7 (and Windows 8), which also includes new functions. Together with the new Kinect, Microsoft released SDK – Software Development Kit. This package allows developers to create applications for Kinect in programming languages C#, C++ or Visual Basic (using Microsoft Visual Studio application). This fact gives to Kinect a completely new dimension of usability.

Microsoft Kinect for Windows includes RGB camera that captures three basic color components and thus enables its human recognition ability. A depth sensor, an infrared projector combined with monochrome CMOS sensor enables three-dimensional space recording in any light conditions. It also contains a multi-directional microphone that is able to identify voices according to sounds and to distinguish noise from the surroundings. Furthermore, the Kinect device includes a 3 axis motor that can tilt Kinect accordingly.

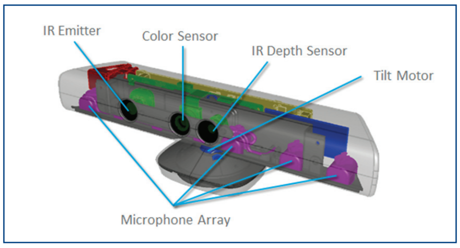


***Figure 1.*** *Microsoft Kinect [Catuhe 2012]*

In practice, the real or potential use of KINECT is connected with (for instance) health care, chemical industry, or wherever there is a need to maintain a sterile environment and any kind of manipulation e.g. with a keyboard can lead towards contamination. Toyota has tried to introduce robot control system using the KINECT device [Siradjuddin 2012]. This device allows a complete scan of the human body or it recognizes the human face. Other possibilities for using KINECT lie in virtual sales, marketing and education.

## 4. Interconnection between MS KINECT and Tecnomatix Process Simulate Software

Almost immediately after launching the new MS Kinect on the market, Siemens introduced a trial version of a tool that connects MS Kinect with the software package Process Simulate. The **Skeletal Tracking** application (See Fig. 2) is used for transferring movements from a real human to a human model in the digital environment of Process Simulate software. Skeletal Tracking constitutes a part of software development package (SDK) and it is modified in order to communicate with Tecnomatix. A plugin was installed into Tecnomatix software, which interconnects Kinect, or more precisely Skeletal Viewer, with a digital human model. The Skeletal Tracking application is able to recognize a human from data provided by KINECT.

MS Kinect can recognize up to six persons in its field of vision. Two of these six persons can be closely monitored. The Skeletal Tracking application is able to recognize the key joints of a scanned person and it can monitor his/her movements in real time (See Fig. 3).

This application can also recognize standing or seated users and then match them with appropriate number of joints. When Kinect

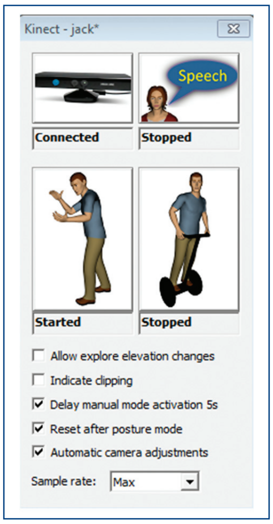


***Figure 2:*** *Plugin for Tecnomatix [Siemens 2012]*

tracks a standing figure, the Skeletal Tracking application assigns 20 joints to this figure. A seated figure has only the upper 10 joints (See Fig. 4). Furthermore, the application can recognize a user´s face. The Skeletal Tracking application, together with Tecnomatix Process Simulate software, enables creation of accurate movement and visualization of human activity in real time.

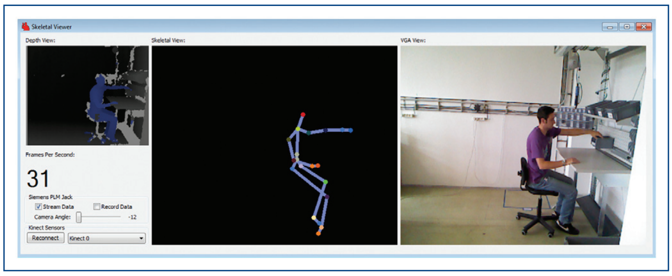


***Figure 3:*** *Skeletal Viewer Application*

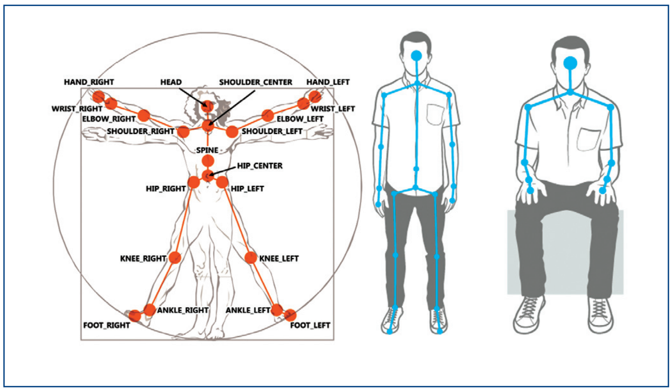


***Figure 4.*** *Skeletal Viewer – recognition of joints [Catuhe 2012]*

## 5. Case Study

The case study discusses financial and time costs of the work performed on the Kinect device in comparison to manual settings of the virtual human model. A simple action has been chosen for this pilot testing and evaluation: bending and grasping a container with products. First, the process was simulated conventionally (manually) in Process Simulate Human module and then with the aid of MS Kinect. In both cases, it is necessary to primarily create a digital workplace model in Process Simulate SW. Therefore, this time sequence will not be included in the final evaluation. The main monitored time criterion is thus the time required for simulating the human position and ergonomic evaluation of this position by an experienced worker. Figure 5 illustrates the simulated and real situation.

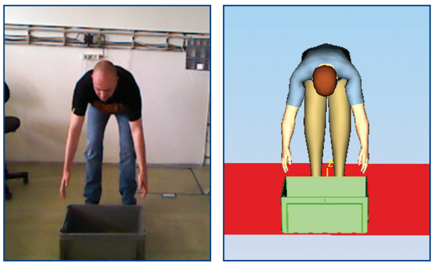

***Figure 5.*** *Real and simulated human position*

***Simulation using tools in Process Simulate Human***

Primarily, the working position was simulated manually, using commands and functions of Process Simulate Human SW, thus the position of a human was created by keyboard and mouse. Working position was generated by **Reach target** function and subsequently simulated in detail by **Man Jog** function. To set the model into working position took 1:40 minutes on average. Finally, the position was analyzed by OWAS analysis (which means a few mouse clicks).

***Simulation using Kinect***

MS Kinect was attached to the stand and placed at the required distance from the place of performing the operation. The choice of placement is very important because if the controller is located too close, the movements may be distorted. Optimal placement is as follows: the controller records the position from approximately the same height as the person moving in front of it. The actual time required for settings needs to be taken into consideration (when defining the results), however when you gain some experience with measuring, it is possible to connect and set up the device within a couple of minutes.

Simulation itself requires one figurant and one technician, who manipulates the software and hardware. A figurant performs the requisite operation and a technician "stops" the transferred virtual image, i.e. he creates a virtual reference figure.

Skeletal Viewer application transfers human movements through MS Kinect to Process Simulate Human (See Fig. 6). In Process Simulate, OWAS analysis is activated and it returns the results in real time, as shown in the figure. The time required for creating the working position is equal to the time of real movement (in this case, only 2 seconds) – See Fig. 7.

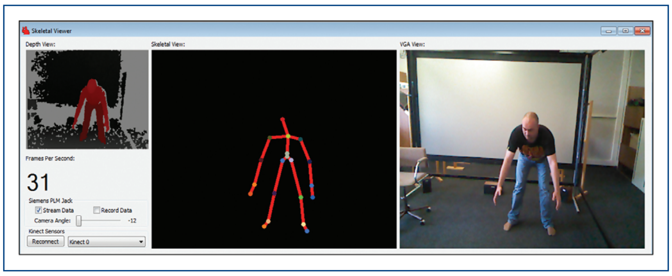

***Figure 6.*** *Recording movements – grabbing a box*

## 6. Case Study Evaluation

The box that is lifted up by the reference virtual (and also real) figure is too heavy. From an ergonomic point of view, this position is not suitable (See Fig. 7) and it would be necessary to consider a lighter box or to lift it from a greater height. However, this result is not the subject matter of this study. Let´s focus on the use of the MS Kinect device with the possibility of position analysis in real time.

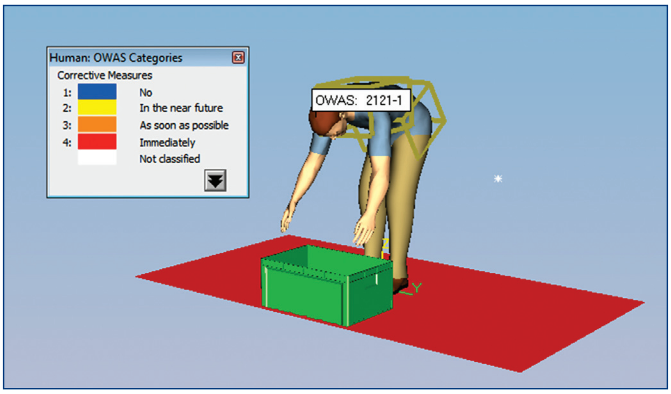


***Figure 7.*** *OWAS analysis evaluation*

The advantage of using MS Kinect is the immediate discovery of the optimal working position, since the analysis is based on real time. In Process Simulate Human, the adjustments of working positions performed in the conventional way are time-consuming.

Although capturing performance with MS Kinect is in some cases less time-consuming than simulating in the conventional way, the Kinect calibration (location) into optimal position may require more time. There are several obstacles that complicate the location and settings of the controller and thus it may need more time than the convenntional manual simulation of a given working operation. The obstacles are for example: lack of space required for the placement of the controller or there are more objects around the scanned person.

| Way of Simulation | Time(sec) | Price |
|---|---|---|
| **Manual Simulation** | 100 | Price SW Process Simulate |
| **Simulation with MS Kinect** | 2 | Price SW Process Simulate + Price KINECT (215 USD – 10/12) |

***Table 1:*** *Evaluation*

It is advantageous to use MS Kinect, especially if we want to record more positions at one workplace. In other words: wherever you consider single device calibration and use of several working positions of a figurant in one environment, which is a relatively common situation in practice. As we can see in Table 1, one working position can be evaluated by MS Kinect within a few seconds. This fact decreases costs. Another advantage is the portability of the device. The positions can be measured and handled directly in the production process, without any production cut. Thus, it would be possible to monitor the activity of an operator over a long time period and to analyze which working sequence during the day was the best for him, in terms of time, effort and consumption of metabolic energy.

The KINECT device **costs about 250 times (!) less** than conventional Motion Capture technology. The main disadvantage is lower accuracy, compared to conventional Motion Capture. To increase the accuracy, two MS Kinect will be used in the future (to record from the front and from the side). Of course, a combination with haptic gloves is suitable (for accurate grasp recording); this problem is, in terms of Process Simulate SW, solved. Unfortunately, there is not a "cheap" variant of data gloves so far and the cheapest one costs approximately 2000 USD.

The use of MS Kinect is not beneficial in every situation. If some body parts overlap with obstacles, the skeleton may be deformed, leading to deformation of movements in Process Simulate. Another important factor is lighting. Accent lighting, or light environment in general, causes the deformation of the virtual skeleton. The MS

Kinect camera is not able to identify all the figurant´s parts in front of the controller. In extreme cases, when the device was tested under full outdoor lighting, the work was almost impossible. However, contrasting clothes is helpful, i.e. if the background is bright, the clothes must be dark, and vice versa.

## 7. Conclusions

This technology, together with Process Simulate software, is an ideal and modern way to improve production processes and product designs. Users can simply, quickly and cheaply create human simulations and develop the best design and procedure with regard to a human. This technology enables quick identification of the factor of human failure and find an alternative. The movements can be saved and re-used for another design. Using this technology and Process Simulate software users can significantly reduce the time required for ergonomic workplace analysis.

**Acknowledgements**

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