A REVIEW STUDY ON HUMAN POSE ESTIMATION USING KINECT SENSOR

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Abstract*—With the invention of the low-cost Microsoft Kinect sensor, high-resolution depth and visual (RGB) sensing has become available for widespread use. The complementary nature of the depth and visual information provided by the Kinect sensor opens up new opportunities to solve fundamental problems in computer vision. Estimating the pose of a human in 3D given an image or a video has recently received significant attention from the scientific community. The main reasons for this trend are the ever increasing new range of applications (e.g., human-robot interaction, gaming, sports performance analysis) which are driven by current technological advances. Although recent approaches have dealt with several challenges and have reported remarkable results, 3D pose estimation remains a largely unsolved problem because real-life applications impose several challenges which are not fully addressed by existing methods. For example, estimating the 3D pose of multiple people in an outdoor environment remains a largely unsolved problem. In this paper, we review the Study on Human Pose Estimation Using Microsoft Kinect Sensor.

***Index Terms*—Digital Image Processing, Human Pose Estimation, Microsoft Kinect Sensor.**

I. Introduction

An image could also be outlined as a 2D function, f(x, y), where x and y are plane coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or grey level of the image at that time. When x, y, and the amplitude values of f are all finite, discrete quantities, we say the image a digital image. The field of digital image process refers to processing digital pictures by suggests that of a computing machine. Note that a digital image is composed of a finite number of components, each of that has a explicit location and worth. These components are referred to as image elements, image elements, pels, and pixels. Pixel is the term most generally used to denote the element of a digital Image.[1]

Vision is the most advanced of our senses, so it is not stunning that pictures play the only most vital role in human perception. However, unlike Humans, who are restricted to the visual band of the magnetic spectrum, imaging machines cover nearly the entire EM spectrum, ranging from Gamma to radio waves. They can treat pictures generated by sources that humans aren't aware of associating with pictures. These include ultrasound and computer-generated images. Thus, digital image processing possess a great and varied field of applications.

Human motion analysis is gaining a lot of and more attention in the field of human machine interaction. On one side, such popularity is caused by the reality that, existing devices become more subtle and combined with growing procedure power has allowed to solve critical issues. On the other way, recently appeared number of a lot of affordable devices which can be used as ainexpensive good systems. Main areas of human motion analysis are medicine, surveillance, man-machine interface, games and animation.

The major area of research are motion analysis, tracking and human gesture recognition. Present work principally focuses on human body tracking and aims to use the talents of Kinect XBOX 360 device to develop an MATLAB program which provides us human skeleton joint's (X, Y) coordinates. These coordinates can be used to extrapolate next step of human gesture or human motion. Further this project will inspire several applications that might be utilized in the world of real time controlled systems, i.e. robots,robotic arms, medicine robotic arms, medicine robots and reconciling robots, home automation systems, gesture recognition systems obtained with markers.

Human pose estimation is one of the key issues in Image process that has been studied over fifteen years. The reason for its importance is that the abundance of applications that may get pleasure from such a technology. For example, human pose estimation permits for higher level reasoning in the context of human laptop interaction and activity recognition. It is alsonone of the fundamental building blocks for marker-less motion capture (MoCap) technology. MoCap technology is useful for applications starting from character animation to clinical analysis of gait pathologies.

Despite many years of analysis, however, pose estimation is very difficult and unsolved problem. Among the most important challengesare: (1) change in human visual appearance in pictures, (2)changes in lighting conditions, (3) differences in most human physique, (4) partial occlusions due to self-articulation and layering of objects within the scene, (5) complexity of human bone or skeletal structure, (6) high dimensionality of the pose, and (7) the loss of 3d information that results from taking the pose from 2D planar image projections. Till now, there is no approach that may produce satisfactory ends up in general, unconstrained setting while dealing with all of the aforesaid challenges.

II. Microsoft Kinect Sensor

The Kinect sensor has been developed and patented by Microsoft Company originally under a project Natal since 2006. The intention to create a revolutionary game controller for Xbox 360 was initiated by the unveiling of the Wii console at the 2005 Tokyo Game Show conference. The console introduced a new gaming device called the Wii Remote which can detect movement along three axes and contains an optical sensor that detects where it is pointing. This induced the Microsoft's Xbox division to start on a competitive device which would surpass the Wii. Microsoft created two competing teams to come up with the intended device: one working with a PrimeSensetechnology and other working with technology developed by a company called 3DV. Eventually, the final product has been named Kinect for Xbox 360 and was built on the PrimeSense'sdepth sensing technology.[3]

At this time, Microsoft offers two versions of the Kinect device. The first one, Kinect for Xbox 360, is targeted on the entertainment with Xbox 360 console and was launched in November 2010. After the Kinect was hacked and many various applications spread through the Internet, Microsoft noticed the existence of a whole new market. On the basis of this finding Microsoft designed a second version of the sensor, Kinect for Windows, targeted on the development of commercial applications for PC. Technically, there are only slight differences between both versions; however, the official Software Development Kit from Microsoft limits the support of Kinect for Xbox 360 for development only. The most important difference between Kinect for Xbox 360 and Kinect for Windows is especially in an additional support of depth sensing in near range that enables the sensor to see from 40 centimeters distance instead of 80 centimeters.

Inside the Kinect

Kinect is a line of motion sensing input device by Microsoft for Xbox 360 video game consoles and Windows PCs. It is an add-on peripheral device similar to webcam. This sensor enables users to control and interact with their console/computer without the need of a game controller, through a natural user interface using gesturers and spoken commands.

The device features an "RGB camera, depth sensor and multi-array microphone running appropriate software", which provide full-body 3D motion capture, facial recognition and voice recognition capabilities. Depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, which captures video data in 3D under any ambient light conditions. The novelty and attraction of the kinect sensor lies in its infrared camera, which is comprised of two distinct devices. An infrared projector sends out a 640x480 grid of infrared beams, and an infrared detector is used to measure how long the reflection of each beam takes to return to the sensor.[1] This data is known as “point cloud”. The point cloud is a three dimensional vector comprised of data points between 40 and 2000, which correspond to distance from the device of each beam. The data in this array can then be studied to construct a 3D image. Kinect is capable of simultaneously tracking up to six people, including two active players for motion analysis with a feature of 20 joints per player.[5][3]

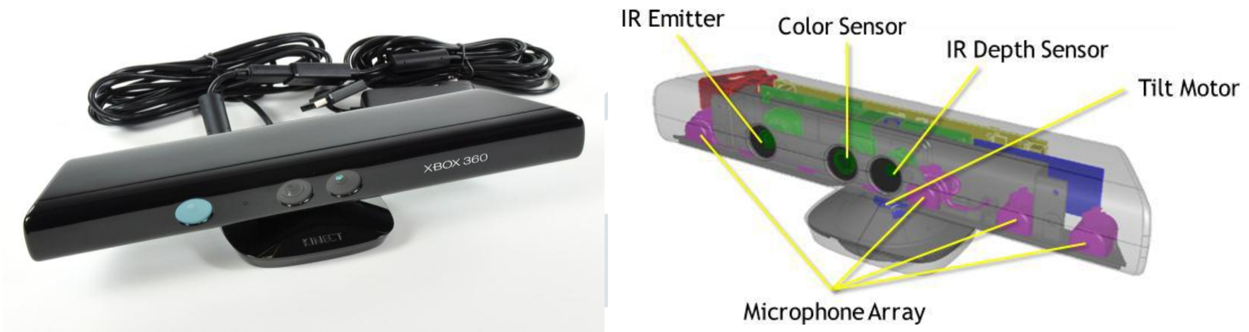


Figure 1 Kinect (XBOX 360) for Windows Sensor Components

Field of View

Because the sensor works in many ways similarly to a camera, it also can see only a limited part of the scene facing it. This part of the scene that is visible for the sensor, or camera generally, is called Field of View (FOV) [8]. The sensor’s FOV for both depth and color camera is described by the following vertical and horizontal angles in . The horizontal angle is 57.5 degrees and the vertical angle is 43.5 degrees. The vertical angle can be moved within range from -27 to +27 degrees up and down by using the sensor tilt. Additionally, the depth camera is limited in its view distance. It can see within range from 0.4 meter to 8 meters but for the practical use there are recommended values within 1.2 meter to 3.5 meters. In this range the objects are captured with minimal distortion and minimal noise. The sensor’s FOV is illustrated by the Figure [9]

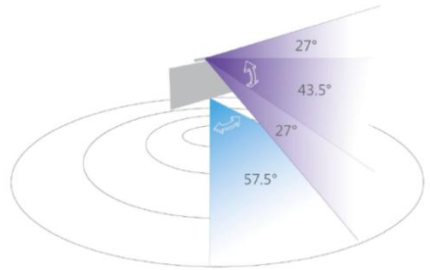


Figure 2 Kinect for Windows sensor field of view [9]

III. WINDOWS MICROSOFT KINECT FOR SDK

Microsoft published an official SDK after it had realized the Kinect’s potential in opening a new market. The first final version of the SDK was officially released in February 2012 as a Kinect for Windows SDK along with unveiling a commercial version of the sensor, Kinect for Windows. The SDK supports a development in C++, C#, VB.NET, and other .NET based languages under the Windows 7 and later operating systems. The latest version of the SDK is available for free on its official website [3].

The Kinect for Windows SDK started by its very first beta version that was released in July 2011. The beta was only a preview version with a temporary Application Programming Interface (API) and allowed users to work with depth and color data and also supported an advanced Skeletal Tracking which, in comparison with an open–source SDKs, did not already require T–pose to initialize skeleton tracking as is needed in other Skeletal Tracking libraries. Since the first beta Microsoft updated the SDK gradually up to version 1.7 and included a number of additional functions.

The first major update came along with the 1.5 version that included a Face Tracking library and Kinect Studio, a tool for recording and replaying sequences captured by the sensor. The next version 1.6 extended SDK by the possibility of reading an infrared image captured by the IR camera and finally exposed the API for reading of accelerometer data. The currently latest Kinect for Windows SDK version 1.7 was released in March 2013 and included advanced libraries such as Kinect Fusion, a library for 3D scanning and reconstruction, and a library for hand grip detection which has opened doors for more natural way of interaction.

The API of the Kinect for Windows SDK provides sensor’s depth, color and skeleton data in a form of data streams. Each of these streams can produce actual data frame by polling or by using an event that is raised every time a new frame is available. The following chapters describe particular data streams and their options. [3]

Depth Stream

Data from the Kinect's depth camera are provided by the depth stream. The depth data are represented as a frame made up of pixels that contain the distance in millimeters from the camera plane to the nearest object as is illustrated by the Figure 3.

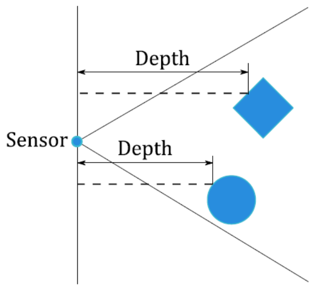


Figure 3 An illustration of the depth stream values.[10]

The pixel merges the distance and player segmentation data. The player segmentation data stores information about a relation to the tracked skeleton that enables to associate the tracked skeleton with the depth information used for its tracking. The depth data are represented as 16–bit unsigned integer value where the first 3 bits are reserved for the player segmentation data and the rest 13 bits for the distance. It means that the maximal distance stored in the depth data can be up to 8 meters. The depth data representation is illustrated by the Figure 4.

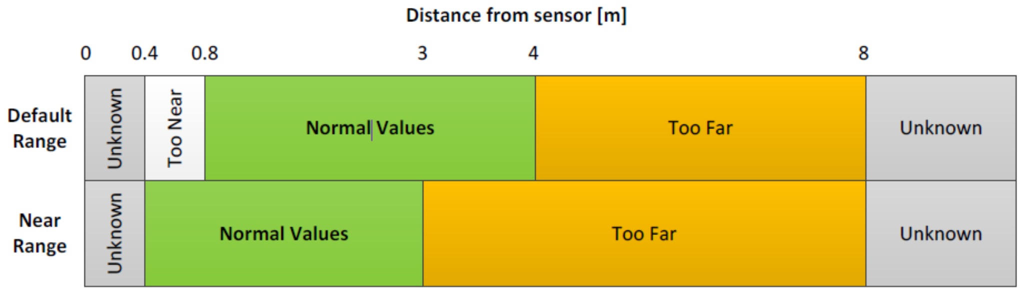


Figure 4 – An illustration of the depth space range.[3]

The depth frame is available in different resolutions. The maximum resolution is 640x480 pixels and there are also available resolutions 320x240 and 80x60 pixels. Depth frames are captured in 30 frames per seconds for all resolutions.

The depth camera of the Kinect for Windows sensor can see in two range modes, the default and the near mode. If the range mode is set to default value the sensor captures depth values in range from 0.8 meter to 4.0 meters, otherwise when the range mode is set to near value the sensor captures depth values in range from 0.4 meter to 3.0 meters. According to the description of depth space range described in the maximal captured depth value may be up to 8.0 meters in both range modes. However, quality of the depth value exceeding a limit value of 4.0 meters in default mode and value of 3.0 meters in near mode may be degraded with distance.

Color Stream

Color data available in different resolutions and formats are provided through the color stream. The color image's format determines whether color data are encoded as RGB, YUV or Bayer.

The RGB format represents the color image as 32–bit, linear X8R8G8B8–formatted color bitmap. A color image in RGB format is updated at up to 30 frames per seconds at 640x480 resolution and at 12 frames per second in high–definition 1280x960 resolution. [10]

The YUV format represents the color image as 16–bit, gamma–corrected linear UYVY–formatted color bitmap, where the gamma correction in YUV space is equivalent to standard RGB gamma in RGB space. According to the 16–bit pixel representation, the YUV format uses less memory to hold bitmap data and allocates less buffer memory. The color image in YUV format is available only at the 64x480 resolution and only at 15 fps.

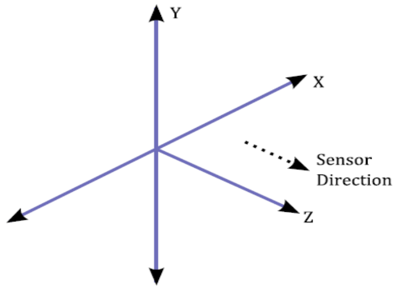
The Bayer format includes more green pixels values than blue or red and that makes it closer to the physiology of human eye . The format represents the color image as 32–bit, linear X8R8G8B8–formatted color bitmap in standard RGB color space. Color image in Bayer format is updated at 30 frames per seconds at 640x480 resolution and at 12 frames per second in high–definition 1280x960 resolution.

Since the SDK version 1.6, custom camera settings that allow optimizing the color camera for actual environmental conditions have been available. These set-tings can help in scenarios with low light or a brightly lit scene and allow adjusting hue, brightness or contrast in order to improve visual clarity.

Additionally, the color stream can be used as an Infrared stream by setting the color image format to the Infrared format. It allows reading the Kinect's IR camera's image. The primary use for the IR stream is to improve external camera calibration using a test pattern observed from both the RGB and IR camera to more accurately determine how to map coordinates from one camera to another. Also, the IR data can be used for capturing an IR image in darkness with a provided IR light source.

Skeletal Tracking

The crucial functionality provided by the Kinect for Windows SDK is the Skeletal Tracking. The skeletal tracking allows the Kinect to recognize people and follow their actions. It can recognize up to six users in the field of view of the sensor, and of these, up to two users can be tracked as the skeleton consisted of 20 joints that represent locations of the key parts of the user's body (Figure 6). The joints locations are actually coordinates relative to the sensor and values of X, Y, Z coordinates are in meters. The Figure 5 illustrates the skeleton space. [3][10]



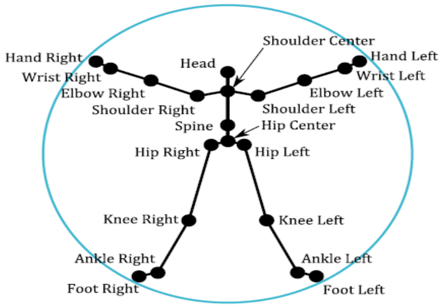


Figure 5 An illustration of the skeleton space. Figure 6 Tracked skeleton joints overview

The tracking algorithm is designed to recognize users facing the sensor and in the standing or sitting pose. The tracking sideways poses is challenging as part of the user is not visible for the sensor. The users are recognized when they are in front of the sensor and their head and upper body is visible for the sensor. No specific pose or calibration action needs to be taken for a user to be tracked.

The skeletal tracking can be used in both range modes of the depth camera, see also 3.1. By using the default range mode, users are tracked in the distance between 0.8 and 4.0 meters away, but a practical range is between 1.2 to 3.5 meters due to a limited field of view. In case of near range mode, the user can be tracked between 0.4 and 3.0 meters away, but it has a practical range of 0.8 to 2.5 meters.

The tracking algorithm provides two modes of tracking. The default mode is designed for tracking all twenty skeletal joints of the user in a standing pose. The seated mode is intended for tracking the user in a seated pose. The seated mode tracks only ten joints of upper body. Each of these modes uses different pipeline for the tracking. The default mode detects the user based on the distance of the subject from the background. The seated mode uses movement to detect the user and distinguish him or her from the background, such as a couch or a chair. The seated mode uses more resources than the default mode and yields a lower throughput on the same scene. However, the seated mode provides the best way to recognize a skeleton when the depth camera is in near range mode. In practice, only one tracking mode can be used at a time so it is not possible to track one user in seated mode and the other one in default mode using one sensor.

The skeletal tracking joint information may be distorted due to noise and in-accuracies caused by physical limitations of the sensor. To minimize jittering and stabilize the joint positions over time, the skeletal tracking can be adjusted across different frames by setting the Smoothing Parameters. The skeletal tracking uses the smoothing filter based on the Holt Double Exponential Smoothing method used for statistical analysis of economic data. The filter provides smoothing with less latency than other smoothing filter algorithms.

Face Tracking Toolkit

With the Kinect for Windows SDK, Microsoft released the Face Tracking Toolkit that enables to create applications that can track human faces. The face tracking engine analyzes input from a Kinect camera to detect the head pose and facial expressions. The toolkit makes the tracking information available in real time.[9]

The face tracking uses the same right–handed coordinate system as the skeletal tracking to output its 3D tracking results. The origin is located at the camera's optical center, Z axis is pointing toward a user and Y axis is pointing up. The measurement units are meters for translation and degrees for rotation angles. The coordinate space is illustrated by the Figure 7.

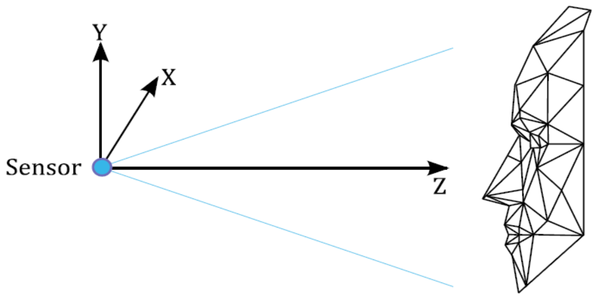


Figure 7 – An illustration of the face coordinate space.[9]

The face tracking output contains information about 87 tracked 2D points illustrated in the Figure 8 with additional 13 points used for 3D mesh reconstructions, information about 3D head pose and animation units that are mentioned to be used for avatar animation. The 3D head pose provides information about the head's X, Y, Z position and its orientation in the space. The head orientation is captured by three angles: pitch, roll and yaw, described by the Figure 9. [10]

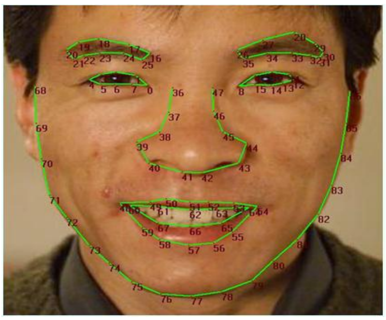
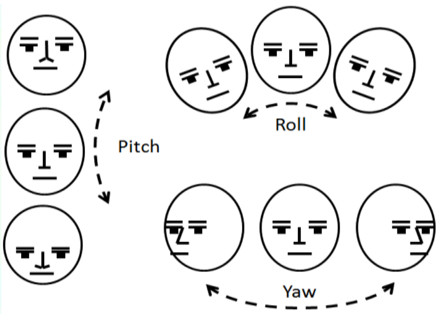



Figure 8 Tracked face points.[9] Figure 9 Head pose angles.[9]

Interaction Toolkit

The latest Kinect for Windows SDK version 1.7 came up with Interaction toolkit. The interaction toolkit can detect a hand interaction state and decides whether the hand is intended for interaction. In addition it newly includes a pre-defined Physical Interaction Zone for mapping the hand's movement on the screen for up to 2 users.[10]

The Interaction toolkit provides an interface for detecting user's hand state such as grip and press interaction. In the grip interaction, it can detect grip press and release states illustrated by the Figure 3.8. The grip press is recognized, when the users have their hand open, palm facing towards the sensor, and then make a fist with their hand. When users open the hand again, it is recognized as the grip release.

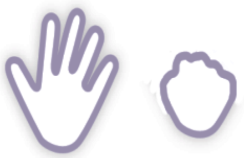


Figure 10 Grip action states (from the left: released, pressed).[11]

According to the known issues published by Microsoft, the grip detection accuracy is worse for left hand than it is for right hand. There is a noticeable delay in grip recognition. The grip does not work as well with sleeves or anything that obstructs the wrist. Grip should be used within 1.5 to 2 meters away from the sensor, and oriented directly facing the sensor.

In the press interaction, the users have their hand open, palm facing towards the sensor, and arm not fully extended towards the sensor. When user extends the hand toward the sensor, the press is recognized.

All information about the current interaction state is provided through the Interaction Stream similar to the stream model of the other data sources.

IV. Applications of Kinect in the Real World

Teleimmersive Conferencing

With increasing economic globalization and workforce mobilization, there is a strong need for immersive experiences that enable people across geographically distributed sites to interact collaboratively. Such advanced infrastructures and tools require a deep understanding of multiple disciplines. In particular, computer vision, graphics, and acoustics are indispensable to capturing and rendering 3D environments that create the illusion that the remote participants are in the same room. Existing videoconferencing systems, whether they are available on desktop and mobile devices or in dedicated conference rooms with built-in furniture and life-sized high-definition video, leave a great deal to be desired mutual gaze, 3D, motion parallax, spatial audio, to name a few. For the first time, the necessary immersive technologies are emerging and coming together to enable real-time capture, transport, and rendering of 3D holograms, and we are much closer to realizing man's dream reflected in Hollywood movies, from Star Trek and Star Wars to The Matrix and Avatar.[14]

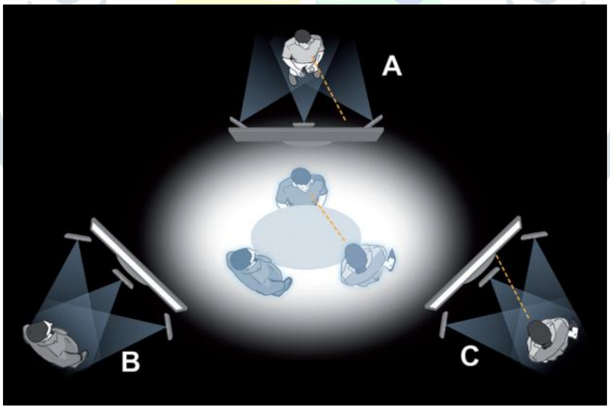


Figure 11 Virtual Video Conferencing[14]

The Immersive Telepresence project at Microsoft Research addresses the scenario of a fully distributed team. Figure 5.1 illustrates three people joining a virtual/synthetic meeting from their own offices in three separate locations. A capture device (one or multiple Kinect sensors) at each location captures users in 3D with high fidelity (in both geometry and appearance). They are then put into a virtual room as if they were seated at the same table. The user's position is tracked by the camera so the virtual room is rendered appropriately at each location from the user's eye perspective, which produces the right motion parallax effect, exactly like what a user would see in the real world if the three people met face to face. Because a consistent geometry is maintained and the user's position is tracked, the mutual gaze between remote users is maintained. In Figure 10, users A and C are looking at each other, and B will see that A and C are looking at each other because B only sees their side views. Furthermore, the audio is also spatialized, and the voice of each remote person comes from his location in the virtual room.

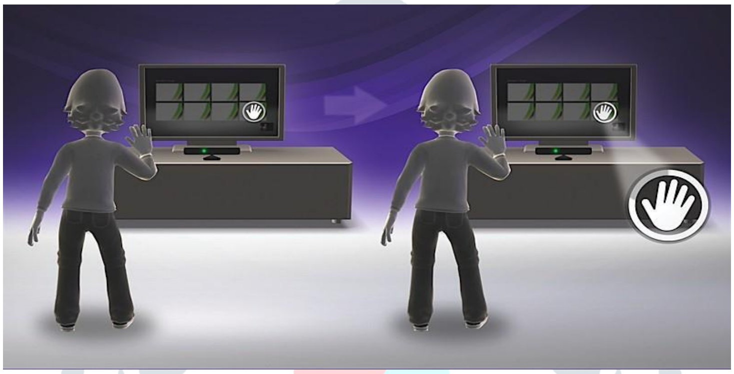
The display at each location can be 2D or 3D, flat or curved, single or multiple, transparent or opaque, and so forth—the possibilities are numerous. In general, the larger a display is, the more immersive the user's experience. Because each person must be seen from different angles by remote people, a single Kinect does not provide enough spatial coverage, and the visual quality is insufficient. Cha Zhang at Microsoft Research, with help from others, has developed an enhanced 3D capture device that runs in real time with multiple IR projectors, IR cameras, and RGB cameras.

Figure 12 A screen shot of two remote people viewed from a third location.[14]

Figure 12 illustrates the quality of the 3D capture we can currently obtain with that device. A similar system is being developed at the University of North Carolina at Chapel Hill that uses multiple Kinect sensors at each location.

Virtual Controllers

For systems where the act of finding or acquiring a physical controller could require too much time, gestures can be used as an alternative control mechanism. Controlling secondary devices in a car or controlling a television set are examples of such usage. Users can also play a virtual piano by tapping their fingers on an empty desk.



Figurer 13 Controlling PC with hand gesture[15]

Ultimate Battlefield Simulator 3

Using advanced surround sound, lighting, and video technology, paintball guns, a portable omnidirectional treadmill, with full 360 degree view and a Kinect for motion control duties, the team of uber geeks constructed the first person shooter simulator that, prior to this, only existed in our dreams.
The online fight feels like a geography lesson (in a good way). Depending on the game mode, each map utilizes a different area or shifts wider and wider as gameplay progresses. This simulator can be used to train shoulders.

Kinect in Hospital

Kinect also shows compelling potential for use in medicine. Kinect for intraoperative, review of medical imaging, allowing the surgeon to access the information withoutcontamination.In medical it is used to measure a range of disorder symptoms inchildren,creating new ways of objective evaluation to detect suchconditions as autism, attention-deficit disorder and obsessive-compulsivedisorder.

Figure 14 Kinect in medical imaging

A Lip Reading Application on MS Kinect Camera

Hearing-impaired people can read lips and lip reading applications may help them to improve their lip imitation skills. Speech of normal people can be recognized by even cellular phones but lip reading systems using only visual features remain important for hearing-impaired people.Predefined lip points are located with depth information by the MS Kinect Face Tracking SDK. Words are segmented from the speech and the angles between the lip points are used as features to classify the words. Angles are computed using the 3D coordinates of the lip points.[16]

Using a Kinect WSN for Home Monitoring

In medical fields to assist ill people are emerging saw the attractions it represents. In addition, given their small size and low cost, sensors can fit easily and unobtrusively into the environment of a patient or any person requiring continuous monitoring, like elderly or disabled persons. Collecting various measurements on the state of a person and supervising any change in its environment are very advantageous solutions for several reasons. Economically, monitoring an elderly person in his natural environment would reduce the assistance charges by remote diagnostic and treatment with specialized staff at the hospital or a nursing home.[17]

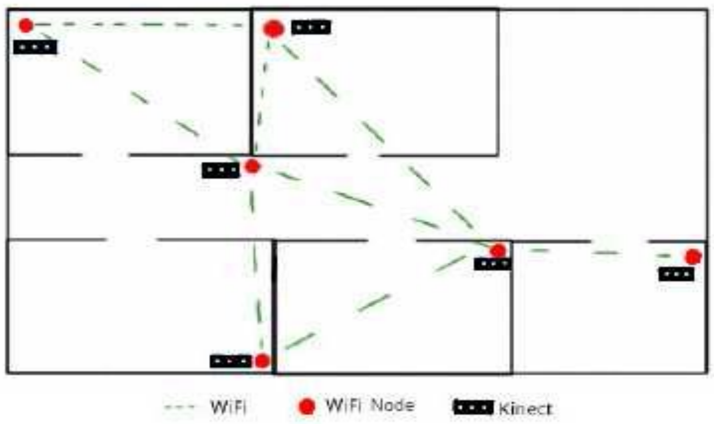


Figure 15 Kinect wireless sensor network[17]

There are more applications of Kinect like

- Hand gesture of dumb people can be recognized and can be translated in speaking language.
- As a dance trainer who could find out errors in your dance action and also shows correct action by collecting data from dance video.
- +Video surveillance system that combines multiple kinect devices to track group of people even in complete darkness.
- Building of robotic arm which mimics the motion of human arm of the user.

V. Conclusions

The Kinect sensor offers an unlimited number of opportunities for old and new applications.Present research belongs to the area of human-machine interaction. The main goal of this report is to find skeleton joint coordinates using MATLAB, present different interfacing techniques which allow the user to interact with electronic machine or computer equipped with Kinect sensor and avoiding the usage of keyboard, mouse or any other device requiring physical contact.

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