Development of a new multi-touch system

This paper describes a multi-touch system based on laser radar technology. The author explains the components and functions of the so-called "radarTOUCH" System and outlines possible applications. The system was developed within the context of a bachelor thesis at the Institute for Media and Imaging Technology, part of the department of Information, Media and Electrical Engineering at the Cologne University of Applied Sciences.

Introduction

Normally computers are operated with a keyboard and a mouse. Today, however, advances in technology offer the opportunity to switch for many applications to systems that are touch-sensitive, obstacle-sensitive or movement-sensitive. These systems are commonly referred to as "touch systems", even though the term "touch" is not quite correct as many of these techniques do not really involve physical contact. One of the reasons for operating a computer via touch systems is that communication with mouse and keyboard is frequently unsatisfactory or inappropriate.

Systems that recognize user gestures and interpret them are especially beneficial for simple, rapid and successful communication between operator and computer. These systems are in most cases multi-touch capable, meaning that they are able to simultaneously evaluate a number of "touches".

In these days of even-larger displays, high-quality projections, and increasing enthusiasm for interactive transactions and digital signage, market demand for especially large touch systems is growing. There is a need for such applications, for example, in museums, public areas, control centres and industrial facilities. Great potential also exists in the event sector or in TV studios. Touch systems will be given an additional boost by the new Microsoft operating system, because Windows 7 comes standard with multi-touch support [5].

System requirements

The objective of this thesis was to develop a multi-touch system enabling new and different types of operator/computer interaction. On the one hand this system should respond to the trend towards increasingly large screens (display, projection, etc.) and on the other hand it should offer the possibility of interacting with it from anywhere in the room.

In order to establish itself on the market, the system would have to meet the following criteria:

- Flexibility in use, especially with respect to the size
- True multi-touch capability, i.e. more than two "obstacles" can be recognized
- Coverage of larger areas, through which the operator can move freely
- Universally applicable, with small dimensions
- Reliable functioning even with changing light conditions, temperature variations, humidity
- Priced comparably to, or lower than, similar systems
- Low latency rate between user action and software/ visualization reaction

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The basic idea behind this bachelor thesis was to realize these objectives using so-called laser radar technology. Measurement equipment based on this technology supplies data from its surroundings, which is then processed by software developed within the scope of this thesis.

The multi-touch system

The product "radarTOUCH" consists of hardware and associated newly developed software, which establishes an Ethernet connection based on the TCP/IP protocol and then processes the received data. The hardware comprises a measurement instrument and the corresponding connection cables.

Hardware

The measurement device used is a distance sensor working in a two-dimensional measurement transmission mode. Inside the sensor is a laser diode whose light beam is fed onto a rotary mirror via an optical system. This deflection unit is moveable and rotates, whereby the laser can be guided over a certain angular field. The laser generator transmits light pulses at certain intervals. If these pulses strike an obstacle, they are remitted and detected by a receiver inside the device.

We should not confuse remission with reflection here. With remission, light is reflected diffusely. An ideal remission surface would distribute the light striking it equally in all directions, like a Lambertian radiator. Using the delay of the light pulses from when they are transmitted to when they are received back and the effective angle setting of the deflection unit, the measurement instrument is able to determine the exact coordinates of the object. This measurement principle is known as time-of-flight measurement (TOF) [1].

The measuring device fulfils the requirements for Laser Protection Class 1 and is therefore graded as not dangerous [2]. The generated

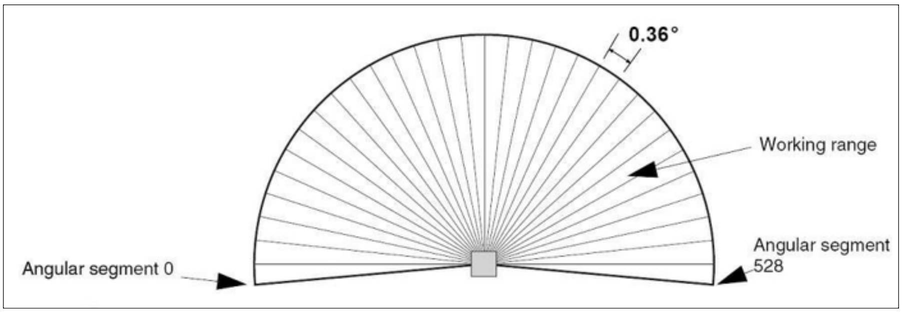


Fig. 1: Working range and angular resolution

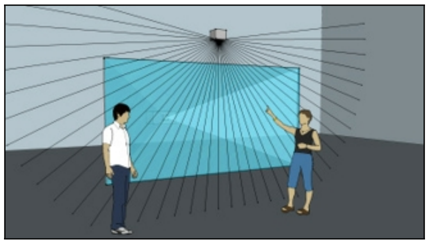


Fig. 2: Possible installation of the radarTOUCH in front of a rear projection screen

and transmitted laser light propagates with a wavelength of 905 nm and is hence in the infrared range.

The measurements made by the scanner cover an angle range of up to 190° at a minimum angle step of 0.36°. Consequently, one measurement consists of a maximum of 529 values and is carried out 25 times per second. Fig. 1 schematically shows the importance of these parameters.

The external dimensions of the measurement instrument are approximately 130 mm x 170 mm x 170 mm (WxHxD) and it weighs 2.3 kg. The power consumption is a maximum of 20 W. It meets the requirements of Protection Class IP65 and can optionally be ordered with integrated heating so that ambient temperatures down to -20°C do not interfere with operation.

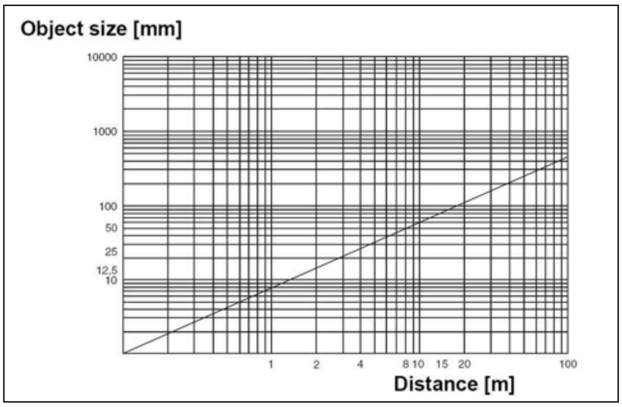
The measuring device can be mounted and adjusted via various ceiling brackets or truss mounting systems. These holder systems can, for example, be mounted above or below the area in which interactive operation takes place. Fig. 2 shows a possible installation option for the "radarTOUCH" system. Here the measurement resolution of the scanner is shown much smaller for better visualization.

The maximum theoretical distance at which the system is able to detect objects is 50 metres. However, with increasing distance to the measurement object, the distance between two consecutive measurement points also increases. This situation is partly compensated by a laser spot size that increases with distance. All the same, the system cannot always detect objects that are too small, especially at greater distances.

The reliability of object detection is furthermore strongly dependent on the object's remission capability. The remission factor is determined by the ratio of the remitted radiation energy to the impinging radiation energy [6]. If the remission factor is too small, the object cannot be detected. Furthermore, the power of the remitted light received is dependent on the distance of the object to be detected. Here, amongst other things, it is of significance that the received power reacts inversely proportional to the square of the distance [1]. These different factors influence the capability of the system to detect obstacles.

Fig. 3 shows the minimum object size as a function of the distance. This diagram always relates to the minimum remission still detectable and therefore depicts somewhat of a worst-case

Fig. 3: Minimum object size with increasing distance



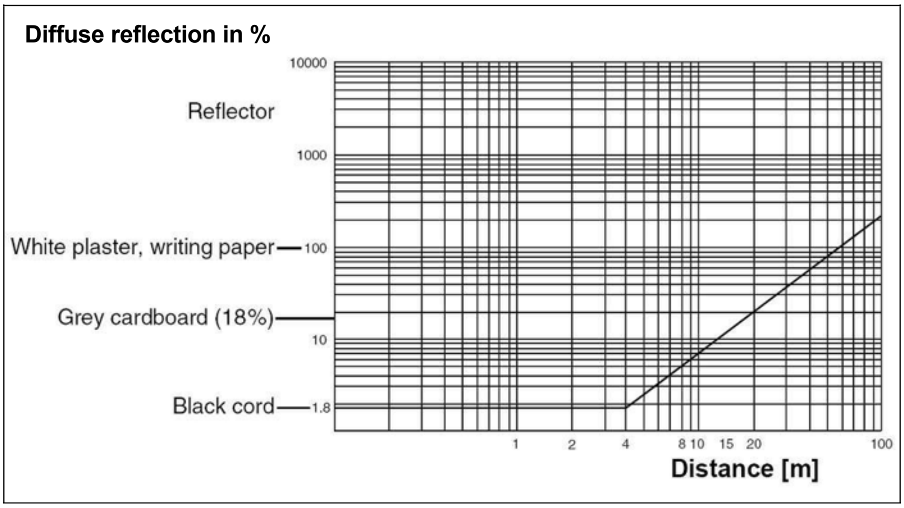


Fig. 4: Minimum reflectance with increasing distance

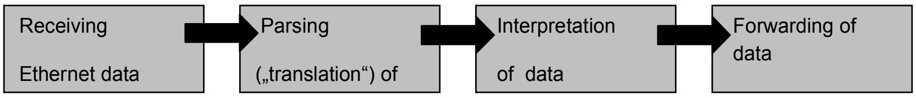


Fig. 5: Software construction principle

scenario for the system. Fig. 4 shows exactly this minimum remission as a function of the distance, assuming objects of a sufficient size. It is to be noted here that these diagrams only serve as reference. Normally, the remission value, e.g. of a hand, is far greater than the minimum remission value, and consequently the minimum object size also decreases.

In order that the power of the remitted light be as high as possible, the laser has a power of up to 15 W for the duration of a pulse. Owing to the short pulse duration of only 3 ns, an average power of 12 µW is not exceeded. The measuring device is therefore able to meet the requirements of Laser Class 1.

Software

For communication with the measuring device, evaluation of the measured values and to start (activate) a possible reaction, software was developed based on Java and was programmed with the JDK 1.6.

When creating the program, considerable importance was attached to modular design. This means that the tasks to be solved by the software are contained in various modules. These can then simply be exchanged. Amongst other things, we drew on known Java design patterns here, e.g. the “observer pattern”.

Software design

The following describes the principle design of the software (Fig. 5). The first module of the software receives the detected measurement data via the configured network link. Once all the data has been received for one measurement, this raw data is transferred to the parser. Parsing puts the data in the right format to be used simply in the following process at a high degree of performance. The information is interpreted in the following step. If the interpreter determines that the data should activate a reaction given the current settings, it will then be formatted and transferred to the last module. This then transmits the data to the receiver via the corresponding interface.

The software does not have any determinable latency in the millisecond range, meaning that the reaction time of the radarTOUCH system is less than 40 ms – depending on the duration of the measurement sequence.

Fig. 6: Graphical user interface

The user is provided with a graphical user interface (GUI) with which a wide variety of settings can be made and saved. As an example, Fig. 6 shows the interface for setting the basic parameters. One task of the GUI is the configuration of the so-called active area. Its position and size define the range in which the system detects and further processes obstacles. Furthermore, various filters for noise reduction or other functions can be adapted depending on the version used.

A second window (Fig. 7) presents the measurement data in the form of a contour representing the surroundings of the measuring device. This visualization enables the user to set the radarTOUCH system and to quickly detect possible errors. The red line forms the measurement contour and the blue square represents the active area. In the visualization, the measurement instrument is positioned at the centre of the white semi-circles.

Various “interpreters” are available for data interpretation depending on which function the user wishes to connect with the radarTOUCH. For example, there are interpreters that offer mouse control or that transmit differently formatted data via different interfaces.

For our purposes, the most practical and common interface for data transmission is OSC (Open Sound Control) [3], which communicates via a UDP connection. Some clearly defined protocols are shown in the TUIO

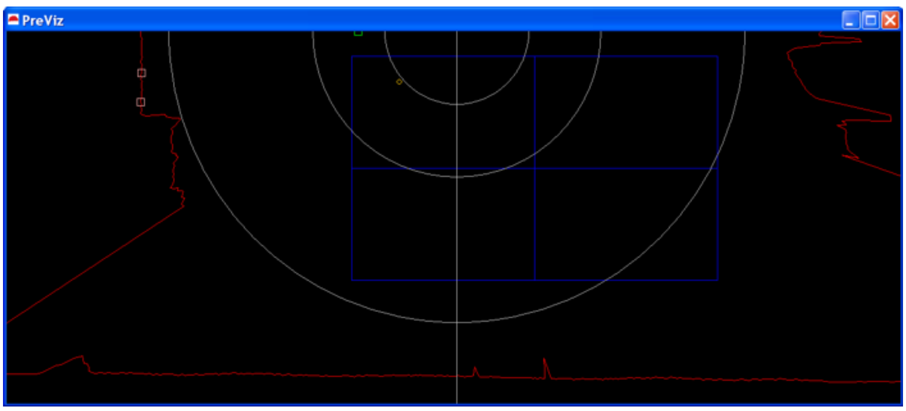


Fig. 7: Visualisation of the measurement contour and the active area

framework [4], which has developed into something of a standard in the area of multi-touch. Here there are different profiles that determine which data from detected obstacles (coordinates, acceleration, movement vectors, ID etc.) are to be transmitted and in what form. With TUIO the previously mentioned OSC is used for transmission.

Amongst other things, radarTOUCH supports the 2Dcur profile (TUIO specification) and a specially developed protocol for the transmission of data via OSC. Other interfaces (e.g. DMX, MIDI and Artnet) are already implemented or can be implemented in the future. Furthermore, it is possible to use the system in connection with the touch functions from Windows 7.

Possible applications

Owing to the flexibility with respect to the size of the active area, alignment and assembly of the compact measurement instrument as well as the manifold useable interfaces and protocols for data transfer, the radarTOUCH system lends itself to many fields of application. However, it is not suitable as an adequate control for classically designed operating systems such as Windows XP, Vista etc. This is partly due to the fact that many of the areas to be activated would simply be too small.

The following briefly describes some possible practical applications:

- Generally it can be said that the multi-touch system introduced here functions in front of any presenting medium (displays, LED panels, back projections etc.) or even functions in the room completely on its own.
- It would be conceivable to combine a number of measurement instruments with each other to cover very large interactive areas, or to use only one measurement instrument for a number of active areas. This might for example involve a number of displays mounted on a single plane on which varying applications could be used and controlled.
- With its true multi-touch support, the system can be used in areas where a number of users should be able to call up information simultaneously on corresponding displays.
- At events and exhibitions radarTOUCH can be used as an innovative presentation system. Simple as well as complex applications are conceivable here with which, for example, newly introduced products can be presented as 3D models and, by rotating, scaling etc., be put into the spotlight.
- In the field of digital signage, quite a few practical applications can be realized: for example at a special point of interest (PoI).
- Even a shop window, equipped inside with a projection or displays, can be an interactive area and supply potential customers with information. Of special interest here are the weather resistance (IP65) previously mentioned as well as the optional heating unit.
- The equipping of TV studios is a further promising field. Here for example a system could be integrated with which the presenter need not take his gaze away from the camera but could simply convey information by moving through space.

Planning and installation

Before installing a radarTOUCH system, the user should clarify which interfaces and protocols are to be used. The type of use is also important. There are two basic variations:

- Directly in front of a display, projection, LED panel or similar
- Freely placed within the room

The latter demands mainly gestural control because it will otherwise be difficult for the user to accurately operate a button, for example. In terms of the amount of effort required for installation, particularly with respect to the precision of the setup, gesture-based control is easier to achieve.

If a higher degree of precision is desired, in order to reliably influence components by touch, then care must be taken when mounting the measurement instrument. There are various mounting systems available for this purpose with which good results can be achieved. As a rule, high precision also requires that the plane covered by the laser is as close as possible to the presentation area (e.g. projection screen). Generally, minimum distances between one and two centimetres can be achieved.

When designing the user interface, sufficient object size should always be observed. This varies depending on the size of the active area and must be tested in case of doubt. With precise mounting and a diagonal screen size of approximately 100 inches, an object size of 3 x 3 cm is a good reference value.

The measurement values are reliably determined by the system. As opposed to many other touch systems, radarTOUCH is robust with respect to fluctuating lighting conditions. However, focussed light should be avoided directly on the front screen. Owing to the fact that the measuring device determines the distance of an object using remitted light, strongly reflective or transparent surfaces can significantly interfere with the measuring process. Such materials should therefore be kept out of the active area or its direct vicinity. Mist or a dirty front screen can likewise fundamentally interfere with function.

Final remarks

The radarTOUCH system and the corresponding software afford a low latency between the action of the user and the reaction of the corresponding visualization. The programming structure furthermore offers future-ready system configuration and rapid and reliable software operation.

Comparing the product created for this bachelor thesis with other touch systems, we can basically conclude that it is a special solution using special technology. The flexible range of applications in particular makes it difficult to draw parallels with other touch systems. radarTOUCH can be regarded as a simple, reliable and affordable solution for a wide variety of creative ideas and projects. In order to implement practical applications with this new technology, it will now take not only creative hardware and software developers, but also people with artistic and creative vision to bring it to life.

Reference literature

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