Wireless Access to Numerous Destinations (WAND)-Pointer for museums

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***Abstract*—In this work we present a concept of interactive guiding in a museum. A pointer is used to identify different exhibits with minimum equipment. The so called "Wireless Access to Numerous Destinations" (WAND)-Pointer is an electronic device with an integrated inertial, distance measurement and localization unit. The pointer is combined with an audio guide, that gives the visitors information about the selected object. The WAND-Pointer identifies the specific exhibit by aiming the pointer at the desired object. Visitors can select an object from a distance and do not have to stand right beside it. The exhibits can be chosen from different angles of view. There is no need to install identification-chips (RFID) at the objects. Only the wireless infrastructure, with a minimum of four receiving nodes is needed for localization. An Extended Kalman Filter algorithm is used to reduce errors that occur due to multipath propagation.**

***Index Terms*—Inertial Measurement Unit, Indoor localization, Museum guide**

I. Introduction

Many museums offer audio tour guides to hear facts about the exhibits. Mostly the sequence of this service is static, because it is only an audio band. Novel audio guides are combined with a keypad. The visitors can enter a number from the specific exhibition piece. For the visitors this is very uncomfortable. In [1] a more comfortable audio guide is presented, which uses an RFID-Reader. The reader scans a tag near the exhibits and identifies the object. For this, the visitor should touch his reader which is combined with the audio guide, to the installed RFID tag on the exhibit. If the exhibits are changing very fast for new exhibitions or the place is not fixed, then this solution is inconvenient. A better solution is to save the coordinates from an exhibit in a database and then let the visitor choose the specific object with the help of the select button on a remote. This can be realised with a pointer device which is combined with an audio guide: A Wireless Access to Numerous Destinations (WAND)-Pointer.

II. Working principle of WAND-Pointer

The basic idea of WAND-Pointer is presented in [2] where a robot is directed in the pointed direction of the pointer. For this application the orientation of the pointer was measured by an Inertial Measurement Unit (IMU).

The method of identification of the WAND-Pointer is shown in Fig. 1. The information about orientation and localization of the pointer together with the distance of the object is used to identify the exhibit.

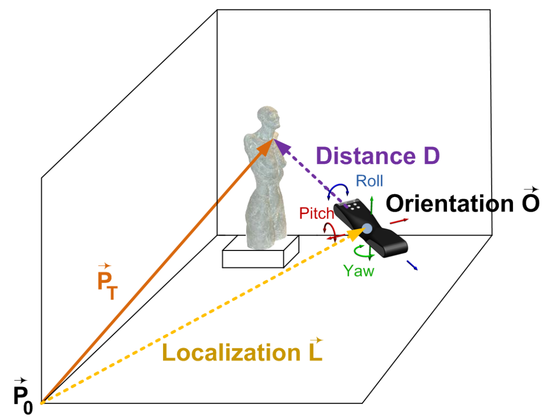

Fig. 1. The operational concept of WAND-Pointer

The WAND-Pointer calculates the absolute coordinates $\vec{P_T}$ of the targeted exhibit using equation (1). The localization vector $\vec{L}$ is calculated with an indoor localization system. Orientation angles $\vec{O}$ are detected with an inertial measurement unit. In the last part, the distance information D is measured by a infrared distance sensor.

$$\vec{P_T} = \vec{L} + \vec{O} \cdot D \tag{1}$$

$$\vec{O} \cdot D = \begin{pmatrix} L_{distance} \cdot Cos_{pitch}(\beta) \cdot Cos_{yaw}(\alpha) \\ L_{distance} \cdot Cos_{pitch}(\beta) \cdot Sin_{yaw}(\alpha) \\ L_{distance} \cdot Sin_{pitch}(\beta) \end{pmatrix} \tag{2}$$

A. Localization

For the localization of the WAND-Pointer an indoor localization system is needed which is robust against multipath propagations. In this example an electromagnetic system from Nanotron was used. This system is easy to install and works with a time of flight measurement at 2.4 GHz. The system uses the Chip Spread Spectrum (CSS) modulation scheme. To determine the distance between the tag and the anchor the ranging methodology Symmetrical Double-Sided Two Way Ranging (SDS-TWR) is used [3]. To measure the position in a 3D environment, minimal four anchors are required to calculate the relative position of the Pointer. The anchors should be installed at the corners of the ceiling with the position $a_{x,n}$, $a_{y,n}$ and $a_{z,n}$. Each anchor calculates the distance r_n to the tag inside the Pointer.

Equation (3) shows the dependence of the distance and the localization. The actual position can be calculated with the help of multilateration [4].

$$\begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{pmatrix} = \begin{pmatrix} \sqrt{(p_x - a_{x,1})^2 + (p_y - a_{y,1})^2 + (p_z - a_{z,1})^2} \\ \sqrt{(p_x - a_{x,2})^2 + (p_y - a_{y,2})^2 + (p_z - a_{z,2})^2} \\ \sqrt{(p_x - a_{x,3})^2 + (p_y - a_{y,3})^2 + (p_z - a_{z,3})^2} \\ \sqrt{(p_x - a_{x,4})^2 + (p_y - a_{y,4})^2 + (p_z - a_{z,4})^2} \end{pmatrix} \quad (3)$$

The terms p_x, p_y and p_z present the actual position of the pointer $\vec{L}$. The equation can be solved using least mean squares, however measurements are subjected to errors and noise. Multipath propagation and Non Line of Sight (NLOS) are the major sources of measurement errors which have a non-uniform distribution surface. Only with an Extended Kalman Filter (EKF) a localization with a minimum divergence in indoor environments is achievable.

To determine the accuracy of the system with (EKF) a test setup was used where a model railway is equipped with the tag that should be localized. Four nodes at the corners of an elliptic track (dotted line, as shown in Fig. 2) were used to capture the distance to the tag. The straight blue line in Fig. 2 shows the calculated position. The localization accuracy is 40 cm in an indoor scenario.

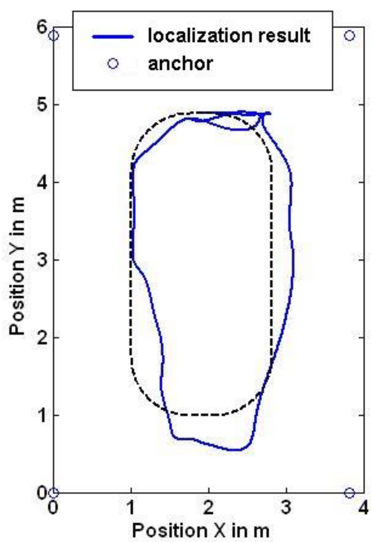

Fig. 2. Localization result

B. Orientation

The orientation of the WAND-Pointer is detected with an Inertial Measurement Unit (IMU) having a 3-axis magnetic sensor, 3-axis acceleration sensor and a 3-axis gyroscope. The sensors are implemented inside the pointer. For this task a small Micro-IMU with dimensions 18 mm x 16 mm x 4 mm was developed and is shown in Fig. 3. All three sensors are digital. In this case neither the generation of an analog reference nor an analog to digital converter are ecessary. The selected full scale range is ideal for hand applications, where the speed and the acceleration are not high. The three axis accelerometer measures the pitch angle and the three axis magnetometer measures the yaw angle.

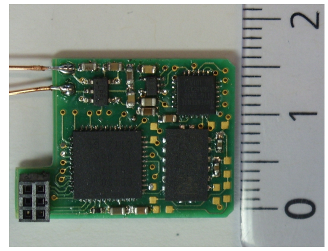

Fig. 3. Micro-IMU with radio cell

The IMU provides a port for connecting the switch button to the pointer. An analog port detects the sensor data from the distance measurement. In the development of the IMU a radio cell has been implemented to transfer the data to a receiver wirelessly.

C. Distance measurement

To measure the distance between the remote control and the exhibits an infrared sensor is used which allows a reliable distance measurement between 20 cm to 150 cm. The analog voltage output from the sensor is independent of the distance to the object. The output voltage is nonlinear and the distance is calculated in the receiver unit using nonlinear polynomial regression. The measurement error was experimentally evaluated. Using this sensor, it is possible to measure the distance with an accuracy of 5 cm.

III. Conclusion and Future Work

The WAND-Pointer provides a promising way to have a comfortable audio guide. The visitors have more degrees of freedom. For the museum, it is easy to install the system, because no RFID-Tags are necessary. In this work the detailed requirements are analyzed and a hardware platform was designed and built. In the current system all the components are working on their own. The localization part was analyzed with a test scenario where a model railway was tracked. The accuracy was 40 cm. The next step is to improve the localization with data fusion from the gyroscope.

References

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