Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 1, 2015, vol. LXI
article No. 1992

Jan CRHA[*], Ondřej ŤUPA[**]

MOBILE GAIT TRACKING USING MS KINECT AND ROBOTIC PLATFORM

SLEDOVÁNÍ CHŮZE S POUŽITÍM SENZORU MS KINECT A ROBOTICKÉ PLATFORMY

Abstract

Computer vision is a fast developing field of science. Activity monitoring and analysis belongs to this topic. Our application is focused on gait monitoring and analysis. The novelty of this attitude is in the combination of the MS Kinect v2 sensor for capturing the gait pattern and mobility of such sensor thanks to placing this device on a robotic platform.

Crucial part of this project is the hardware solution and autonomous function of this recording set. The designed platform is a six-wheeled robotic platform controlled by a micro controller using the depth information from the Kinect sensor and the distance driven by robot provided by encoders attached to every motor.

The following research is devoted to the proposal of methods for a precise and as narrow as possible control of the platform and post processing of records for a features selection and a classification of physical activities and early diagnostics of gait disorders, primarily the Parkinson's disease.

Abstrakt

Počítačové vidění je rychle se vyvíjející odvětví vědy, kam patří i monitorování a analýza pohybu. Naše aplikace se zaměřuje na zaznamenávání a analýzu chůze a využívá nový přístup v kombinaci senzoru MS Kinect v2 pro sledování pohybových vzorů a robotické platformy jako nosiče, který umožňuje mobilitu senzoru.

Stěžejní částí tohoto projektu je samotné hardwarové řešení a autonomní funkce nahrávání. Navrhnutá platforma je šestikolový podvozek řízený jednočipem s využitím hloubkových dat ze senzoru Kinect a ujeté vzdálenosti, která je získávána z šesti enkodérů upevněných na každém motoru.

Následujícím úkolem je nelézt a aplikovat metody pro přesné a co nejkomplexnější řízení platformy. Získané nahrávky budou následně podrobeny analýze fyzické aktivity a použity k včasné diagnostice poruch chůze, primárně způsobených Parkinsonovou nemocí.

Keywords

Robot control, MS Kinect, gait tracking, activity analysis

1 INTRODUCTION

Robotic motion platforms in combination with computer vision systems are commonly used in medicine today. For example, systems that enable observations and early diagnostics, even more with

[*] Ing., Ústav počítačové a řídicí techniky, Fakulta chemicko-inženýrská, VŠCHT Praha, Studentská 5, 166 28 Praha 6, tel: (+420) 22 044 4099, email: jan.crha@vscht.cz, web: uprt.vscht.cz

[**] Ing., Ústav počítačové a řídicí techniky, Fakulta chemicko-inženýrská, VŠCHT Praha, Studentská 5, 166 28 Praha 6, tel: (+420) 22 044 4099, email: ondrej.tupa@vscht.cz, web: uprt.vscht.cz

non-invasive methods, are important and interesting. One of these non-invasive computer vision systems is a motion sensing input device Microsoft Kinect.

A Kinect navigated robotic platform is used in [1] to follow elderly people. The authors Stone E. and Skubic M. proposed an application of the Kinect sensor for an in-home gait measurement to prevent people with Parkinson's disease from falling [2]. Kinect is also used for tracking speed skaters [3] to collect data for their trainers. The authors use a standard RC car as a carrier for their equipment, including the Kinect sensor. All aforementioned authors use infra-red and/or depth data provided by Kinect for their tracking algorithms. Another way to track people is in [4,5] where a stereoscopic camera is used and in [6] even combined with a Laser Range Finder (LRF). The authors use feature detection to extract individuals from captured images. After that, position of the selected region, colour and texture of their clothes are used for improving the recognition in subsequent images. LRF is also used as an obstacle avoiding system and its data are fused with the camera system data to obtain even more precise results.

Kinect was originally developed as a console for Xbox, wherefore it can provide not only depth and infra-red images, but also skeletal data of the tracked people to application, because there is a people detection algorithm included. New Kinect v2 can track up to six people at once and provide two persons' 25 major joints position. This feature is often used during rehabilitations to record the progress of the healing process. Several papers [7,8] discussing Kinect as a sensor of gait patterns have been written at our department. In these papers Kinect provides skeletal data that are processed for specific features like co-movement of legs and arms. These features are unique for every person, just like a finger print, but some neural diseases are able to change the gait patterns in a specific way common for most patients.

The previously mentioned papers are very interesting and we were inspired by them while creating our system. One of our innovations lies in the fact that we use Kinect v2 on our mobile robotic platform, which provides more precise depth and infra-red data. Another difference lies in the approach of positioning the moving robot in front of the patient with usage of cameras viewing backwards, thus providing a more natural and unobstructed recording environment.

2 MOTIVATION

The gait analysis involves a measurement, an extraction of the well-describing features and an interpretation of the results leading to a conclusion about the health of the subject. The process of measurement is highlighted in this paper. There are several techniques how to observe the gait pattern. There are two main categories of the features that have to be observed during the gait tracking.

Temporal and spatial measurement provides features such as walking speed or stride length. This process is usually carried out by a stopwatch and marks on the ground, walking on a pressure mat, laser sensors placed few centimetres above the ground or inertial sensors (gyroscopes and accelerometers).

Measurement of Kinematics could be performed by following methods:

- Chronophotography is using strobe lighting at a known frequency and capturing the images
- Cine film or video recordings from a single or multiple cameras to measure joint angles and velocities. This method allows analysis in three dimensions.
- Passive marker systems consist of reflective makers and multiple cameras (up to 12) sensitive to the reflection of used materials (usually red, infrared or near infrared).
- Active marker systems are based on a similar philosophy as the passive markers with the exception that the markers are triggered by the incoming signal.
- Inertial systems do not need any camera and the movement is captured by a set of sensors. Each sensor is a combination of a gyroscope and an accelerometer. The gait tracking is inferred according to a biomechanical model and a fusion of information from all sensors.

All these methods need some special equipment, wearable sensors limiting the movement or sensors dedicated to one purpose. Our method of capturing the gait pattern is using the MS Kinect sensor providing the skeletal tracking function. The skeletal tracking function enables to determine the position of the 25 main body joints derived from the depth frame (algorithm by J. Shotton and others). The disadvantage is the limitation of the Kinect sensor field of view, enabling reliable tracking of people only at distances between 0.5 m and 4.5 m. Therefore the combination of the cost-effective Kinect sensor and the mobile robotic platform is opening new possibilities to track the gait pattern.

In the previous studies [7,8] the Kinect device was placed stationary on a table to track people in its field of view. MS Kinect that was used for data acquisition was installed approximately 60 cm above the floor. Each individual repeated a straight walk of approximately 4 m (five steps) back and forth 5 times. The experimental portion of this study was devoted to the analysis of the gait of the following two sets of individuals: 18 patients with Parkinson's disease and 18 healthy age-matched individuals. From the acquired records 5 features were extracted – walking speed, stride length, center of mass deviation in the horizontal and vertical projection and limb synkinesis. The results were obtained by a combination of these characteristics by a neural network and the accuracy of decision of this system was up to 91.7 %.

3 EQUIPMENT OF PLATFORM

The platform was developed as a six wheeled remote controlled robotic platform. Each wheel is equipped with a motor with an encoder and a driver. The motors are high power and their maximal rated consumption is about 4 amps with 7 V supply each. Each motor has also a gearbox attached with a 75:1 gear ratio; together they provide enough torque to climb a 60° slope. The maximal speed is about 3.5 km/h and it is measured by quadruple encoders attached directly to the motor shafts. Each encoder provides 24 pulses on each channel per revolution, so there are approximately 3600 pulses per revolution of a wheel.

Each motor has our custom full H-bridge driver, which is controlled via the SPI. The driver can supply the motor with up to 5 amps continuously without any additional heat sink. [9]

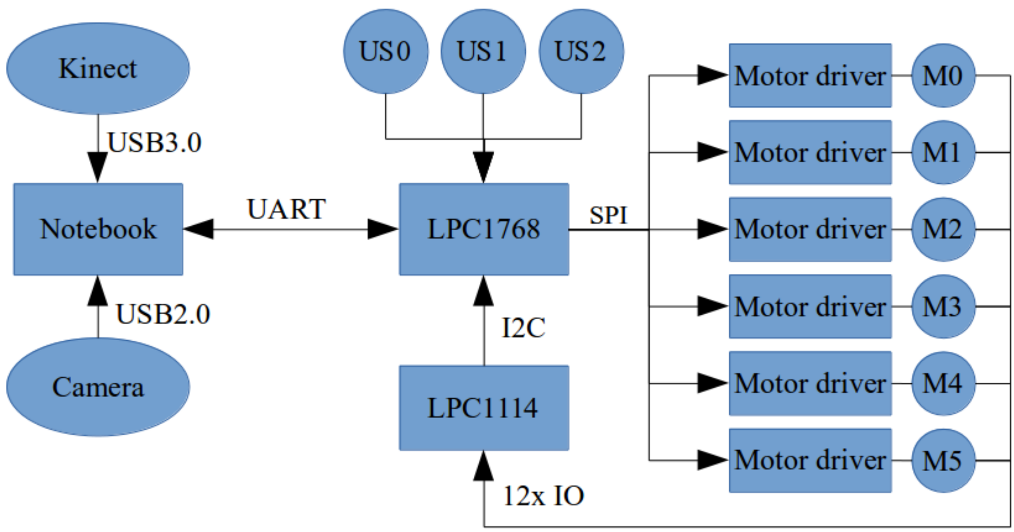


Fig.1 Scheme of the connections and the modules

Due to the usage of many pins for the SPI, there must be an auxiliary processor to handle all the encoders. For this reason the platform is equipped with an LPC1114, which is an ARM Cortex-

M0+ processor, running at 48MHz and in a user-friendly DIP28 package. The LPC1114 is providing information to the main microprocessor on request via the I2C. The main microprocessor is the LPC1768, which is an ARM Cortex-M3 processor, running on 96MHz and with a 512kB FLASH and a 64 kB RAM.

To avoid obstacles there are three ultrasonic sensors connected directly to that processor. All of them are triggered together to avoid cross echo detection. The ultrasonic sensors can measure the distance in a range from 2 cm to 400 cm and 20 times per second.

The image processing is done using a notebook, while both the images from Kinect and also from the camera are processed. The notebook is an Asus zenbook, which is a very lightweight laptop and it can run for prolonged periods of time only on the battery power. The attached camera can provide 720p images at 30fps and no additional power supply is needed.

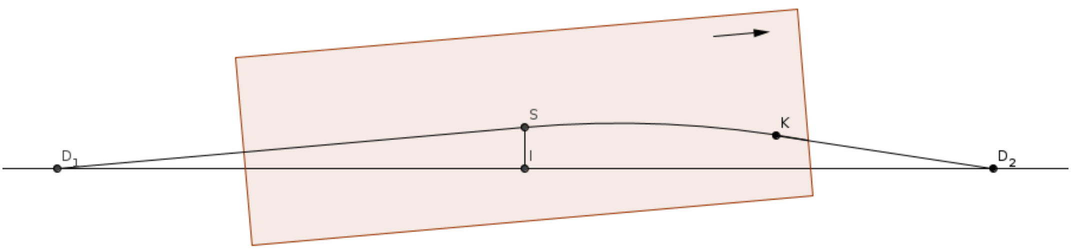
MS Kinect v2 is connected to the notebook and also to the special power supply via USB3.0, which is providing stable 12V 3A for the sensor from the Li-Po battery pack. The Kinect sensor provides RGB images, depth data image, infra-red image and it can also locate the 3D position of the 25 main skeletal joints. Kinect can track up to six people at once and in a range between 1m and 4.5m.

4 CONTROL OF PLATFORM

The goal of the control is to drive in front of the tracked patient with the least amount of changes in direction possible and in a specific distance with only a small divergence. For this reason the control is realized as a cascade computing many input variables, and for even more precise navigation in corridor, there are coloured marks placed on the floor.

The depth data and the skeleton information from Kinect are processed with the notebook (which also contains the main control loop) to obtain accurate distance between the patient and the platform. From the measured distance and from the driven distance speed deviation and then a new speed set point for the platform are computed.

Front camera images and Kinect RGB images are both used for computing the divergence in direction. Based on both the speed and the direction divergence new track is computed. The algorithm for returning to the path is quite simple. If the divergence is smaller than 5°, the platform is only controlled by different speeds on the right and the left side. When the direction divergence is



greater, the platform has to change the direction back to the path more smoothly. This is done by a circle path. When the platform is pointing back, it drives straight to the path. When he platform is near the original path, a differential way of control is used again to correct the direction.

Fig.2 the platform path corrections

In figure 2 the platform is shown as a brown rectangle. The centre of the platform is marked with letter S and the original path is line D_1D_2. The position deviation is |SI| and the angle divergence is equivalent to angle [SD_1I]. In the first stage, the platform drives in a circular path between the points S and K. For a correct circular path, there is a custom script that computes speed for each wheel. When the platform reaches point K, it drives straight to point D2, where it corrects the direction to the original line.

The second control loop is in the LPC1768 that obtains short commands specifying the type of the movement needed – differential control, straight movement or circular movement. Each type has its own parameters that are a part of the message. The LPC1768 computes the speeds for all the wheels and then it uses the data from all the encoders to cruise at the desired speed.

There are several ways how the speed divergence of one wheel is compensated. During the two second start of the movement all the speeds are slowly increased from zero to the desired speed. When the platform is already moving, there is an axle compensation active, which means that if one wheel is slower by more than 5 % of its speed, the second wheel on the same axle also slows down. The third possibility of compensation is used when a big divergence occurs in a short time. The reaction to this scheme is increasing the speed of the other wheels on the particular side. The speed of the wheel itself is controlled by a PI controller, whose model was tested in MATLAB, to avoid any overshoot and for a smoother start-up.

5 GAIT RECONSTRUCTION

The next step in the process of gait tracking is to reconstruct the gait pattern from the captured raw data. For the recording purpose a C# application was written to store the recorded skeleton data from Kinect and the information about the distance driven by the robot.

The data from Kinect contain a 3D position of the 25 joints returned by the skeletal tracking function and a time stamp of each frame. In the application to the data recording this is a procedure that (after the frame is returned from Kinect) sends a request to the ARM micro controller and the answer is the distance travelled by each of the six wheels. This distance driven by each wheel is necessary to compute the overall robot movement and figure out the exact direction the MS Kinect device is facing at this frame. For modelling the gait pattern the movement of the robot is subtracted in the processing.

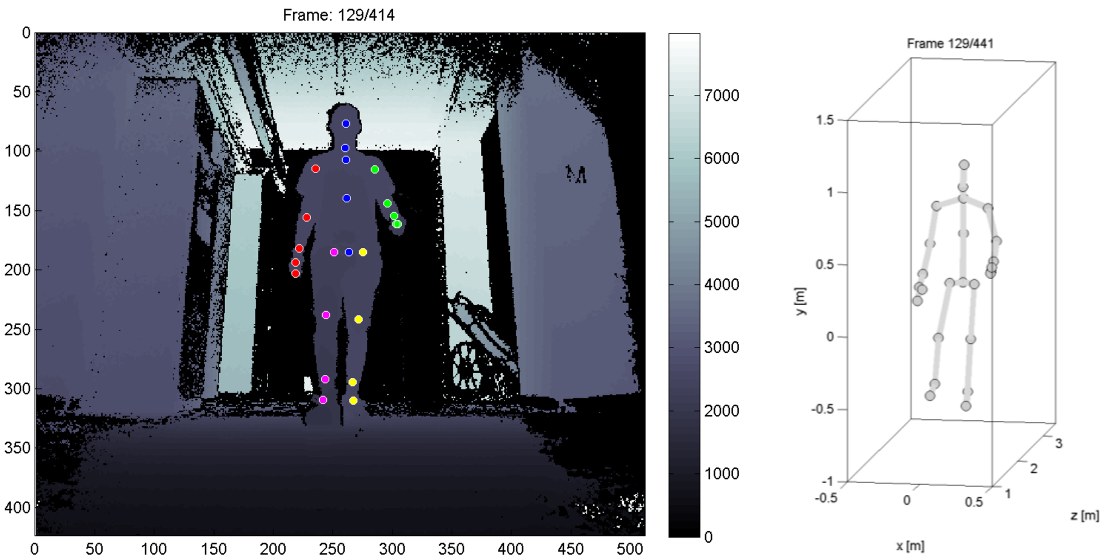


Fig. 3 Projection of tracked joints on depth data (left) and 3D visualization of entire skeleton(right)

The most common and the most required case is movement of the robot only in one axis. If there is an operational interference of the ARM processor, it is necessary to alter the absolute 3D position of the joints. For verification of the correct process of the gait reconstruction it is possible to observe a centre of the mass (COM) movement. If the processing is successful, the COM position is fixed, only with the regular deviation corresponding to the swings of the legs. On the other hand, there will be a discontinuous movement of the COM if the reconstruction is wrong.

After the reconstruction of the gait pattern feature extraction follows. The temporal and spatial gait characteristics are the walking speed and the stride length. The features describing the kinematics of the gait pattern are computed on the static skeleton. The static skeleton refers to the situation, where the general movement – mean distance travelled by all joints – is subtracted. On the static skeleton it is possible to reveal the limb synkinesis, COM deviation and other details different from the periodic gait pattern.

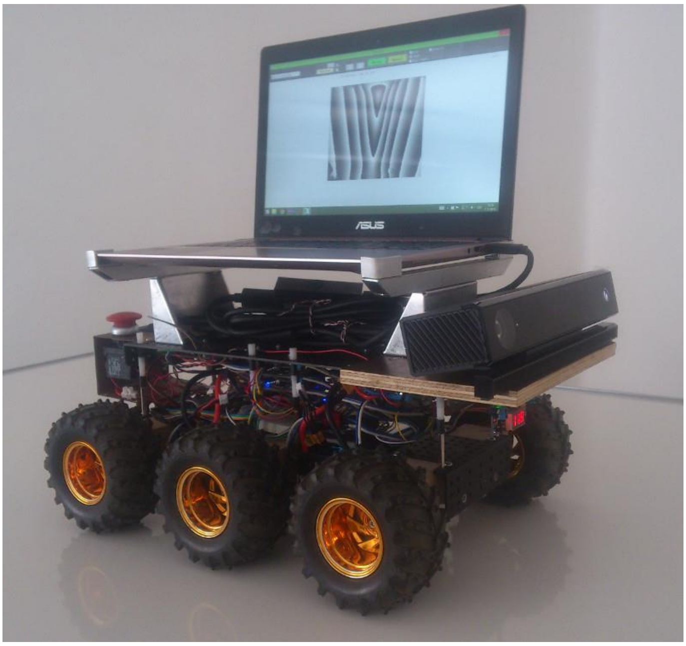


Fig.4 Image of robotic platform showing current depth data on screen.

6 CONCLUSION

Contemporary result of this project is the hardware solution of the robotic platform. This platform can perform autonomous measurements that are used for gait analysis. The platform can alter the behaviour in different scenarios to avoid possible problems during the measurements. The control of the platform is still in progress and there are some details waiting for more precise and specific solutions and to generalize the overall control.

The project is now in testing phase in the laboratory settings at our university. We are setting different situations and scenarios that will probably occur in the future in the neurology department of University Hospital in Hradec Králové. We are trying to automatize the control to achieve precise pathing of the platform. Another goal is to create a user-friendly program for recording, which will be handled by staff of the hospital.

Financial Support from Specific University Research (MSMT No. 20/2015)

REFERENCES

[1] Machida E., Cao M., Murao T. and Hashimoto H., Human Motion Tracking of Mobile Robot with Kinect 3D Sensor, SICE Annual Conference, p.2207-2211, 2012

[2] Stone E. E. and Skubic M., Unobtrusive, Continuous, In-Home Gait Measurement Using the Microsoft Kinect, IEEE Transactions on Biomedical Engineering, 60, 2925–2932, 2013

[3] Boyd, J.E., Godbout, A., Thornton, C., In Situ Motion Capture of Speed Skating: Escaping the Treadmill, Computer and Robot Vision, p.460-467, May 2012. ISBN: 978-1-4673-1271-4

[4] J. Satake and J. Miura, "Robust stereo-based person detection and tracking for a person following robot," in *ICRA Workshop on People Detection and Tracking*, Kobe, Japan, May 2009

[5] Z. Chen and S. T. Birchfield, "Person following with a mobile robot using binocular feature-based tracking," in *International Conference on Intelligent Robots and Systems*, San Diego, CA, October 2007, pp. 815–820.

[6] T. Sonoura, T. Yoshimi, M. Nishiyama, H. Nakamoto, S. Tokura, and N. Matsuhira, "Person following robot with vision-based and sensor fusion tracking algorithm," in *Computer Vision*, X. Zhihui, Ed. Vienna, Austria: InTech, 2008, ch. 27, pp. 519–538.

[7] Procházka A., Vyšata O., Vališ M., Ťupa O., Schätz M., Mařík V., Use of the Image and Depth Sensors of the Microsoft Kinect for the Detection of Gait Disorders. Springer: Neural Computing and Application, 2014. DOI 10.1007/s00521-015-1827-x. ISSN 0941-0643

[8] Ťupa O., Multi-Dimensional Data modelling and Analysis Using MS Kinect. Diplomová práce, VŠCHT Praha 2014.

[9] Crha J., Control of mobile robotic arm chassis. Diplomová práce, VŠCHT Praha 2014