Measuring Produced Biogas Using Kinect Device

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Abstract: This article deals with automated measurements of produced biogas. In the National reference laboratory of biogas transformations, values are recorded manually into dairies, which are then archived and manually transcribed into a digital form. MS EXCEL, from which necessary charts are generated, is among the most widely used programs for that. The main objective of this paper is to develop automation solutions to this problem. The MS Kinect motion sensor was used for research and creating this application. This device was originally designed for applications that are controlled by motion. However, they can also be used just for taking individual pictures. Using this device, a picture of small biogas reactor is taken and then it is automatically processed using our software. The result is a digital record of the amount of the produced biogas. These values are then stored in an internal database, which can be accessed in real time using a VPN (virtual private network).

Keywords: Biogas station, kinect, automatic measuring, image recognition.

INTRODUCTION

Nowadays, the production of biogas is on the increase. Its use can be found mainly as a source of the production of electricity or the production of heat. Biogas is produced through anaerobic digestion, a complex of consecutive microbial processes [1]. It is very important to regularly monitor and check this process of fermentation to ensure the best possible conditions for microbial community. This allows us to reach the highest possible values of the biogas produced in the highest quality, which is also continuously looked into in our workplace [2].

At present, values are recorded into diaries in the National reference laboratory of biogas transformations (located at Mendel University in Brno) which are then again manually transcribed into a digital form (MS EXCEL) and after that archived. The disadvantages of the current situation are: a) the impossibility of online check of the biogas production b) complicated check of the correctness of the transcription c) impossibility to measure with the frequency of more than once a day (from personnel reasons). The proposed solution will enable us to measure the data continuously in the intervals which will be set in advance. This fact enables not only more frequent data readings, but also more frequent check of the measured data. It will be possible to access the measured data in real time and in case of finding an error, it will be possible to respond immediately. Since the data are stored online, they can also be directly processed and evaluated. This allows us to avoid human error during processing, for instance, because of inattention.

The data readings take place using the Kinect device by Microsoft. This device was originally designed for motion control but it enables us to take individual pictures as well (instead of video) and then to edit them. VisualStudio 2015 was used to create the application. C++ was chosen as the main programming language, not only for its compatibility, but also because of the number of already created applications and existing online support.

MATERIAL AND METHODS

Used hardware

The Kinect Device by Microsoft was used as a device for image sensing. This device was originally designed to be used as a motion control device for Xbox 360 video game console. However, compatibility with PC and USB port for connecting to the PC were added. Even though Kinect offers a whole range of options for image sensing, we will use it as a common webcam mainly because of easy interchange ability with other devices (for example a common webcam). When using Kinect, a wide range of options to improve the current system in the future opens up. On Fig. 1, we can see a diagram of the measurement system.
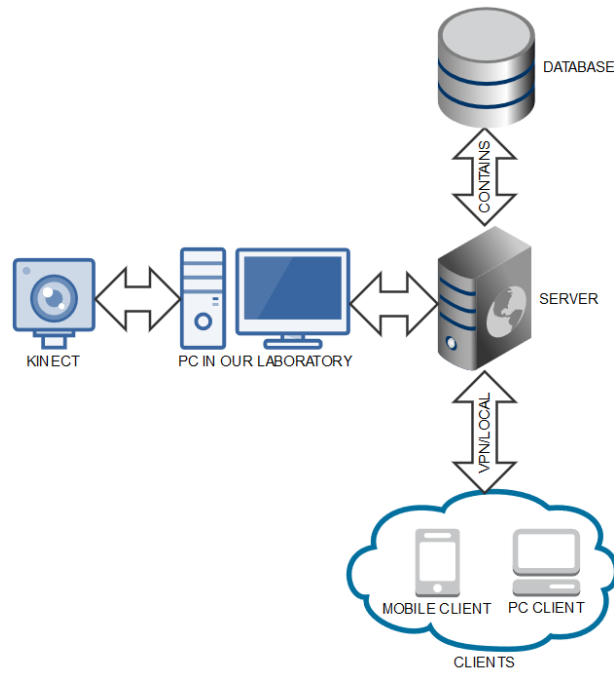
Fig. 1 Wiring diagram used system components

Kinect and PC

Kinect enables us to capture in two main modes (Fig. 2).The sensor has an angular field of view of 43° vertically and 57° horizontally. The horizontal field of the Kinect sensor at the minimum viewing distance is 87 cm, and the vertical field is 63 cm. At the given resolution of the depth camera, it can be easily calculated that one image pixel accounts for only 1.3 mm of the sensing area.

The accuracy decreases with the increasing distance of the object from our sensor. For better illustration, Fig. 2 shows maximum and minimum possible distances while maintaining accuracy. It is also necessary to take into account whether the sensor works in the mode of the standard or decreased distance. The mode of the decreased distance was added at newer models, which were designed primarily for PC.
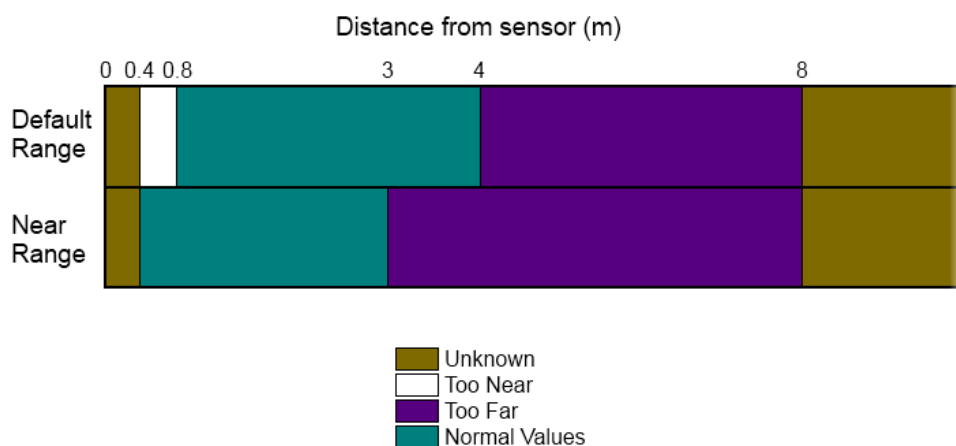

Fig. 2 Kinect sensor distance – taken from www.msdn.microsoft.com

For the received data processing, a standard personal computer placed in a biogas laboratory with OS Windows 8.1 was used.

Database

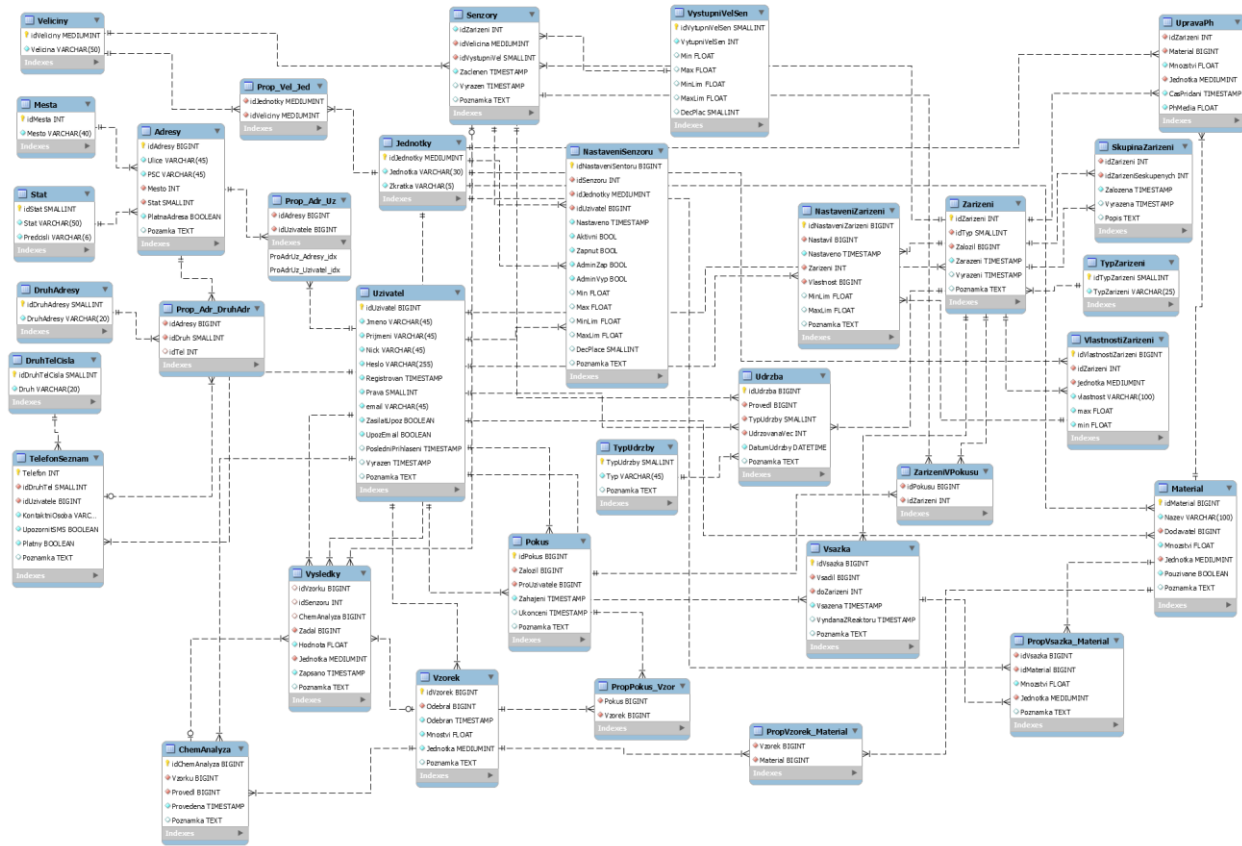For data storing is used MS SQL Server. On Fig. 3, we can see database ERD diagram.

Fig. 3 Database ERD diagram

Used software

VisualStudio 2015, development environment by Microsoft, was used to create our application. It can be used to develop console applications and applications with graphical interface along with Windows Form applications, websites, web applications and services.

VisualStudio supports programming languages through language services, allowing code editor and debugger to support any programming language. The embedded languages include C / C ++ (using Visual C ++), VB.NET and C#. Support of other languages such as for example Python, Ruby, etc. can be added using the language services.

C++, or visual C++ integrated in VisualStudio, was selected as the default programming language for creating our application. It is a multi-paradigm programming language, which was an extension of C language. Whereas C was a purely procedural language, C++ is formed as an object oriented language. The idea of OOP (object-oriented programming) is in the proposal of data classes which describe a certain set of properties and how to deal with them. Nowadays, this language is among the most widely spread programming languages.

To work with images, OpenCV(Open Computer Vision) was used. It is an open source set of libraries for working with real time computer vision. It is possible to develop and create applications for gesture and faces recognition, object identification and so on. It is therefore used mainly in robotics and for the implementation of applications in experimental interfaces for human-computer interaction (Human-Computer Interaction), etc. OpenCV is associated with Intel Company which implements its support directly to hardware – it uses Intel Integrated Performance Primitives technology which provides high performance for low-level routines (audio, video, speech recognition, coding, decoding and cryptography).

This library is very robust because it includes tools for a complete analysis of the image

(image filtering, object detection, motion analysis, image transformation, working with video, simple work with windows and user interface, camera calibration, support for stereo – involvement of multiple cameras), etc. Multiplatform is an advantage. This framework exists in versions for GNU/LINUX, Microsoft Windows and MAC OS X. A continuous development is another advantage. The library is still being worked on. The last version of OpenCV, which is also used for creating our application, was released in December 2015.

RESULTS AND DISCUSSION

It was necessary to additionally edit the photo after taking it, especially clip it down to a certain size. The next step was to detect the correct height level (Fig. 3) in the correct biogas reactor. Reactors are always marked with numbers in their upper part. Identifying a correct reactor is done through image recognition using the MatchTemplate method. A draft of the algorithm will be submitted (in our case the marker with number 9) and using the algorithm, we try to search the image and correctly detect the template.

After detecting the correct cylinder, we will draw in detail the height level (filled rectangle in Fig. 3) and using the algorithm for filling the cylinder we will fill it with a pre-defined colour, in our case black. In the following step, the image is converted into black and white using the method of thresholding (it can be seen in Fig. 3 as well). This step is important mainly because of determining the number of pixels, which needed to be coloured to fill the cylinder from its peak to the level. Our control cylinder is formed by a rectangle with a side A = 20 pixels and side B = 697 pixels. Thanks to thresholding and conversion to black and white (black colour in our cylinder determines the height level) and using algorithm for searching in the field (our picture in the internal memory is represented as a field of values where each field contains information about RGB model, that is red, green and blue) we can easily count the number of black pixels in the vertical direction. In our case it is 134 pixels. One pixel in our picture has a value of 0.86 mm. The level dropped by 115 mm.
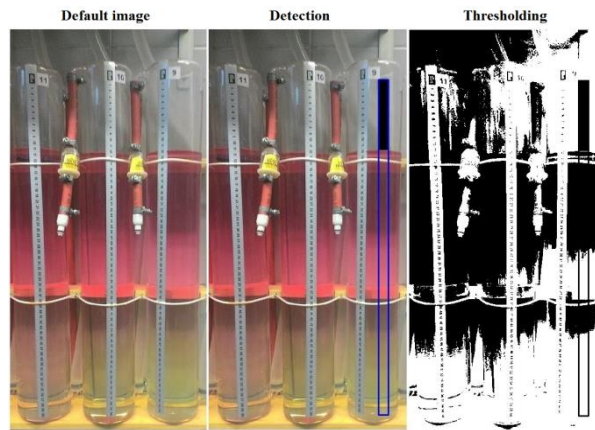

Fig. 4 Image processing and determining the height level

If the final height level is known, we can calculate the volume of produced biogas using the following equation:

$$V_n = \frac{T_0}{T_n} \cdot (k \cdot h_n) \cdot \frac{\left[\left(p_a + (h_k \cdot \rho \cdot g) + \left(\left(\frac{h_n}{100}\right) \cdot \rho \cdot g\right)\right)\right]}{p_a} \cdot 10^{-3} \quad [m3] \qquad (1)$$

Description of individual members of the equation (1) is shown in Table. 1.

Table 1 *The meaning of constants mentioned in the above equation*

Constant	Meaning	Unit
V_n	the volume of biogas at physically normal conditions	$[m^3]$
T_0	physically normal thermodynamic temperature	$[K]$
T_n	measured thermodynamic temperature	$[K]$
K	calibration constant of the measurement system	$[-]$
h_n	height levels	$[cm]$
Pa	atmospheric pressure	$[Pa]$
h_k	height constant of measured distance	$[m]$
ρ	the density of the fluid reservoir	$[kg/m^3]$
g	acceleration of gravity	$[m/s^2]$

Measured values are now stored in database. Database structure was described in previous chapter.

In Fig. 5 we can see the comparison between the direct measurement and the values obtained using Kinect. Measured values are indicated in cm.
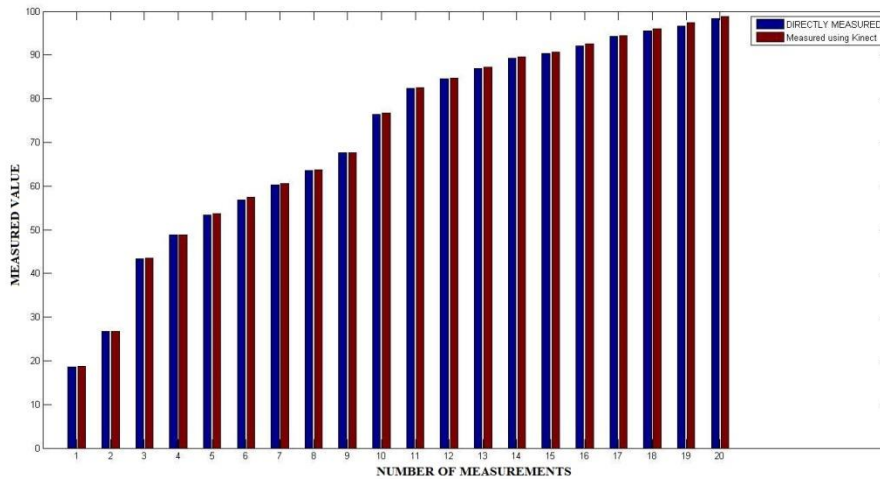

Fig. 4 Comparison between the direct measurement and the values obtained using Kinect

Nowadays, the development of applications for image recognition is widespread. Such applications are used for example for face recognition [2]. The image recognition is also used a lot in automobile industry where the aim of the system is to recognize licence plates of particular cars [3]. This is used for example for the search for a specific vehicle due to theft. Recently, image recognition has been shifted towards mobile devices. It is also for example because of still expanding augmented reality [4]. It is therefore obvious that image recognition is nowadays a widespread issue and in some fields it is a must.

On the contrary, our solution for reading of the values of produced biogas is very specific, mainly because of specific solution of biogas reactors inside the National reference laboratory of biogas transformations. Another important fact is that the above mentioned techniques are used mainly for object recognition, not for readings of values.

CONCLUSION

Automation of measuring of the produced biogas in small bioreactors was carried out. The main advantages include more accurate measurements and ensuring continuous measurement at given intervals – including weekends and holidays. Nowadays, the values are recorded manually into diaries, which are then archived. Currently, the resulting values are manually written in the equation. The possibility of errors in calculation will also be decreased with the introduction of the automated system.

Another undeniable advantage is that in case of the data export to a pre-prepared database, the results can be accessed anywhere on the internet after the user validation. It also give us an option of export in the data from the database using a pre-specified key (for example the date, the volume of produced biogas, used batch, etc.).

Our laboratory solution is very specific, for this reason it is hard to compare it with other solutions of biogas measuring. In industrial solution, biogas production is measured by certified gas meters. From this reason it is hard to find other articles on this subject from other authors.

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