OPTIMAL METHOD FOR MEASURING THE INTERIOR

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Abstract

The purpose of the work was to determine the optimal method for interior measuring. The study gives an overview of measuring instruments, then discusses metrology, tolerances in furniture manufacturing, multi-criteria analysis and software support related to Industry 4.0. For each type of measuring device, their properties were analyzed by using multicriteria analysis. In order to compare the time consumption of each method, results from a separate research study were used in the analysis. A methodology for the analysis is also included to allow modification to meet the specific requirements for particular users.
The result is a comparison of the different facilities and associated procedures, taking into account technical, time and economic influences.

Keywords: measuring, furniture, gauges, room, interior, software

INTRODUCTION

It can be said that every time a furniture manufacturer, whether a small joiner or a medium-sized furniture company, wants to make customized furniture, they need to measure the interior where the furniture is to be placed. To do this, they usually use either classic tape measures, which can be bought for a few crowns, or laser measure, which are a bit more expensive, but again much more accurate. These measurements produce data that must be processed. Once this data has been processed, a 3D model of interior should be created that is ready to design bespoke furniture. The advantage of such 3D software is that the furniture can be placed in precisely oriented interiors, and therefore at least partially eliminate any imperfections during the actual installation in the space.

MATERIALS AND METHODS

Tolerances in Furniture Production

Due to the nature of the product, it is necessary to determine what tolerances are permissible or necessary for proper operation or installation prior to manufacture. These may be tolerances in the opening of furniture doors, tolerances between drawer fronts or tolerances for convenient installation or tolerances permitted in terms of safety and design.

„A standard describes a rule or set of rules setting out requirements for human characteristics, things or behaviour that can be described as ‚normal', ‚usual' or ‚acceptable' [1]. On the basis of an analysis of the standards, it can be noted that, for example, the external dimensions of table, reclining or cabinet furniture can vary by up to ± 2 mm.

At the same time, the permitted deviations must not reduce the aesthetic standard of the product. At the same time, it is not permissible for non-conforming dimensions to cause poor product function, for example in doors, sliding glass or other movable or removable parts.

„Accuracy is particularly important when designing embedded parts to be manufactured off-site. Small discrepancies can lead to big problems on site. Drawings of the original building may exist, but their accuracy should always be questioned. Buildings are never built exactly as their original designer drew them" [2].

Tolerances that are not allowed for any piece of furniture are those that reduce its aesthetic level or even prevent the proper functionality of the product itself. Such furniture is not suitable for delivery to the customer, as it may cause injury during use or will not be accepted by the customer.

Tolerances in furniture assembly are a significant area of concern for designers, as well as tolerances in manufacturing. Any errors and flaws in the product can have a negative effect on marketing, reputation and brand in the long term. Hence, the risks in assembling products, both standardised and custom, should be identified before the product is launched. This can be achieved, especially for

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custom products, by proper measuring of the interior for which the products are designed. Here, the person carrying out the measurement has to verify what construction work has or has not been completed. This fact has animportant role when designing custom-made furniture. The dimensions of the interior without plaster/with plaster, the presence of the final floor covering, the presence of window sills are key. Therefore, the design and measurement of interior furniture should be done at the latest stage of renovation or construction.

For correct and high-quality interior measuring, it is advisable to use a suitable gauge and a suitable measuring procedure. Obviously, an inappropriate methodology using a 3D scanner will lead to lower quality results than using a suitable methodology with a tape measure. Thus, it is not only the gauges and its principle which is used that matter. Also the professional experience is crucial.

To avoid unsightly gaps that are associated with tolerance, there are several methods of masking. Some customers or manufacturers will not accept agap next to a wall, which may be caused by the finishing skirting board. For example, this problem can be solved with a false part, or a concealing trim. Small unsightly gaps are also solved for sloping upper cabinets. This can be solved by gluing and shaping a covering edge that is tightly bound into the joint between the furniture and the wall.

Analysis of Gauges Market

Tape Measure

When choosing a tape measure, the length and width of the tape measure play a major role. These are the basic key features that should be considered when buying a tape measure. Their price depends not only on their length or width, but also on the brand of the manufacturer (Prices are as of 25 February 2024 in CZK.) (Tab. I).

Laser Rangefinder

Three completely different types of laser rangefinders were found here. Their price here is mainly based on the features they can help with measuring. This could be the maximum distance that can be measured, the ability to target angles, or the ability to write data to a mobile app. These are all factors that should be considered when buying a given type of laser distance measuring tool (Prices are as of 25 February 2024 in CZK.) (Tab. II).

3D Scanners

When researching the market for 3D scanners, it is essential to allocate an appropriate category of products suitable for interior measuring. Exclude scanners used for mapping small objects for example for subsequent 3D printing. 3D scanners for surveying and mapping buildings are offered in a limited range and prices are usually not publicly available. An exception where pricing is publicly available is the Leica brand, which deals with 3D scanners on a professional level. For this reason, only scanners from this company are listed in the price overview table.

These scanners differ from each other not only in size but also in the possible scanning distance. While the Leica 3D DISTO deals with scanning rooms, the Leica ScanStation is for scanning outdoor objects such as buildings, dams or traffic junctions (Prices are as of 25 February 2024 in CZK.) (Tab. III).

I: *Analysis of the market for Tape Measure [3, 4]*

Name of product	Price (from-to) (CZK)	Seller
Tape Measure 2 m × 13 mm	28	www.briol.cz
Tape Measure Stanley 8 m × 25 mm	547	www.mall.cz

II: *Analysis of the market Laser Rangefinder [5, 6, 7]*

Name of product	Price (from-to) (CZK)	Seller
Asist LM030	499	www.asist.cz
Bosch GLM 120 C	6,719	www.dek.cz
Leica DISTO S910	38,398	www.shop.leica-geosystems.com

III: *Analysis of the market for 3D scanners [8, 9]*

Name of product	Price (from-to) (CZK)	Seller
Leica 3D DISTO	192,390	www.geoserver.cz
Leica ScanStation P50 3D Laser scanner	2,109,149	www.secure.fitgeosystems.com

Mobile Phones

For example, the technology company Apple has been implementing LIDAR technology in its PRO series mobile phones for several years. Each year, it improves these technologies to create a comprehensive device that is not just for making phone calls. To determine whether this technology can be fully exploited in a commercial setting, specifically for measuring spaces, it would be necessary to test the accuracy and speed of measuring. In any case, this possibility can be included in the market analysis research.

METHODOLOGY

Methods of Operation of Measuring Devices

Tape Measure

The first method that was investigated in this study was the method of measuring with a classical tape measure. The measure tape is produced in various lengths from one metre upwards.

The tape meter works on the principle of a coiled metal plate on which a measuring scale is printed. The measuring scale is indicated by commas, which are always separated by longer commas after five and ten millimetres for better orientation. Each line indicating ten millimetres is then given a number indicating the length in centimetres.

In this study, a conventional tape measure was used, which can be purchased at any home improvement store. In order to determine whether the tape measure was indeed measuring correctly it was subjected to a calibration check at M & B Calibr, spol. s. r. o., from which a record was made in the form of a calibration report.

Laser Measure Bosch Zamo

The laser measure used in this work was a Bosch rangefinder. Specifically, the Bosch Zamo was used here.

„Laser measure work by emitting an electromagnetic pulse in the form of a laser beam through an opto-electronic circuit. The beam of laser light is reflected from the area to be measured and returned to the measuring instrument. The rangefinder circuitry then processes the beam and determines the measured distance. The device circuitry performs the distance measurement by detecting the time of traversal of a section in two planes based on the phase shift of the transmitted and returning EM wave“ [10].

Again to verify the accuracy of the measurements, a calibration measurement was carried out at M & B Calibr, spol. s. r. o.

Technical data:
- measuring range: 0.15–20.00 m,
- measuring accuracy: ± 3 mm,
- smallest display unit: 1 mm,
- measuring time: 0.50–4.13 s,
- weight: 0.08 kg,
- dimensions: 101.4 × 38.0 × 22.3 mm.

The manufacturer lists two specifications that affect the quality of the measurement.

1. Caution on the measuring range:

The range increases the better the laser light reflects off the target surface (good scattering, no glare) and the brighter the laser spot is compared to the ambient brightness (indoors, dusk). Under adverse conditions, such as very intense indoor lighting or a surface with poor reflectivity, the measuring range may be limited.

2. Note on measurement accuracy:

Under adverse conditions, such as very intense indoor lighting, surfaces with poor reflectivity, or room temperature significantly deviating from 25 °C, the maximum deviation may be ± 5.00 mm at 20.00 m. Under favourable conditions, you must allow for an influence ± of 0.05 mm/m“ [11].

3D scanner

Another method that was used in this study was the 3D scanner measurement method. Here a 3D scanner from Leica was used - specifically the Leica RTC 360. This high speed scanner is used to collect accurate and clean data. Due to the advanced technology that can collect the data, high quality output data can be obtained.

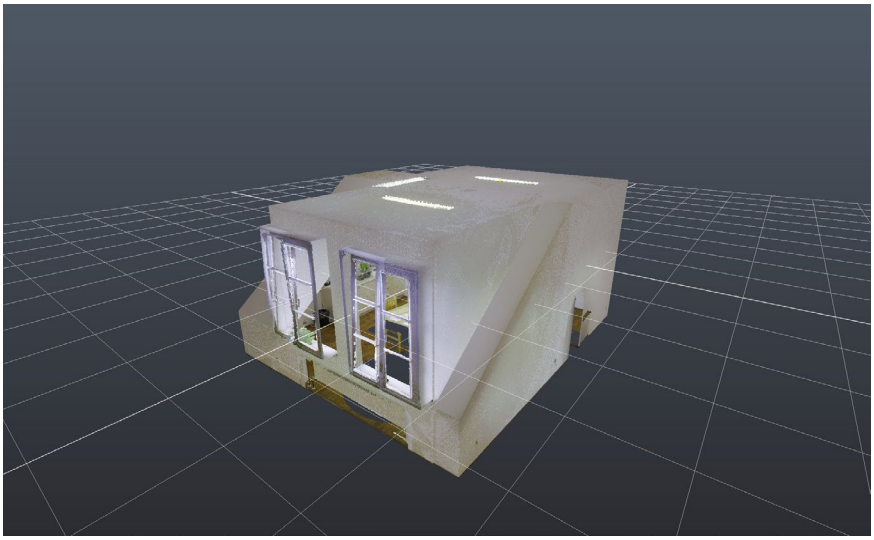
The scanner uses scanning up to 2,000,000 points per second to capture 3D reality (Fig. 1). Furthermore, thanks to its integrated cameras that allow HDR quality and panoramic photographs in 360°, a complete textured overview of the measurement can be obtained. The output of the whole measurement is a point cloud file, which is then ready for further use.

To get the best scan without further adjustments, e.g. removing moving people, it is best to leave the room and let the scanner work independently. Of course, in this case, the scanner can be controlled remotely using a tablet. If there is a need to be present at the scanner, a double measurement function can be used, where the scanner can remove moving persons.

„Virtual Inertial System - Automatic Scan Linking in the Field

The Leica RTC 360 scanner comes with the novelty of an integrated VIS system that works on the basis of five cameras and one integrated IMU unit. This robust system allows the positioning between two consecutive scans to be determined in real time and automatically links the two scans together without the need for user interaction.

Technical specifications:
Scanner dimensions: 120 × 240 × 230 mm
Weight: 5.35 kg



1: *Sample data from 3D scanner*

2: *Sample data from Leica BLK3D*

Scanning speed:
- Up to 2,000,000 points per second.

Resolution and scanning speed:
- 3 mm @ 10 m = 1:51 minutes,
- 6 mm @ 10 m = 51 seconds,
- 12 mm @ 10 m = 26 seconds,
- Panoramic 360° calibrated image in RAW quality - 432 MPx,
- 3 camera system 36 MPx.

Scan accuracy settings:
- Angular Accuracy 18°,
- length accuracy 1.0 mm.

3D point accuracy:
- 1.9 mm @ 10 m,
- 2.9 mm @ 20 m,
- 5.3 mm @ 40 m.

Operating temperature:
- 5° to + 40°.

Sensors:
- Altimeter,
- compass,
- GNSS“ [12].

Leica BLK3D

The last method used in this study is the measurement of 2D/3D dimensions using stereo photographs. The Leica BLK 3D was used for this purpose. This instrument allows the measurement of lengths in 3D space directly from a captured photograph (Fig. 2). To be able to make this measurement, the instrument combines the functions of a laser rangefinder and photogrammetry.

The instrument is small, compact allows the data to be manipulated directly after it has been acquired. Thanks to the touchscreen display, the edges to be measured and can be marked and the instrument calculates them immediately. The data can also be transferred to a computer, where it is much easier to work with the larger display and the computer mouse.

RESULTS

Sample of Data from 3D Scanner and Photogrammetric Instrument

Multicriteria Analysis

The multi-criteria analysis involves scoring on six different parameters relevant for evaluating. (Tab. IV) In this case, the multicriteria analysis will evaluate the time that was obtained using the Kruskal-Wallis test. We take this time into account because the occurrence of outliers during the corridor measuring, in the subjective opinion of the author, is not so frequent and therefore we can just use the results from the statistical evaluation. If the occurrence of these values were important for furniture manufacturers, the average values of the measuring times from the different methods have to be taken.

The second main factor that is an important part of multicriteria analysis is the data transfer time. If the measuring method saves enough time, but then we will lose it when when transferring data from the instrument to the computer, the instrument is unsuitable for further use.

Another evaluation criteria is the weight of the device itself. After all, lifting loads of, for example, five kilograms is very uncomfortable, so the lower the weight of the sight, the better.

The fourth evaluation criterion in this analysis is size. For a one-person carry, the size of the instrument is very important in terms of convenience during operation.

The fifth factor to consider is the number of people needed for measuring. After all, a 3D scanner can be assembled by one person, but with a tape measure, for example, a second person is sometimes desirable for convenience and accuracy.

Another factor that will be taken into account in this multicriteria analysis is the precision of the measurement. With the data obtained from the calibration measurements and the manufacturer's data, it is very easy to determine which device is the most accurate.

The last evaluation criterion in the multi-criteria analysis will be price. Price is a very important aspect that must be taken into account. Not every small enterprise has several hundred thousand, if not millions of crowns to spare to buy an expensive measuring instrument, because they would not be able to pay for such an instrument at all and would not pay it back.

DISCUSSION

First, it was necessary to find out whether there was interest in this issue among furniture manufacturers. The main objective of the study was to find out whether new measuring methods can save measuring time and thus money.

Other data were also taken from the surveying of the premises in the form of rough sketches of the premises on paper, scans and photogrammetric photographs. This data had to be transferred to AutoCAD 2023 software where it would be used for subsequent production preparation.

The work with individual data was different. While data from the laser rangefinder and the tape measure were manually entered directly into the software. The 3D scanner data were converted almost instantaneously. All that was needed was to select the correct file format type.

The data from the Leica BLK3D had to be first „extracted“ from the photogrammetric images taken. Here the limit of the instrument itself was found, which in low light and low colour contrast (e.g. white rooms) is not able to accurately determine the boundary anchor point. Due to this limitation, the oriented dimensions were very different from the dimensions oriented using the other three methods investigated. However, the data acquisition from the BLK3D software is not the final data processing. This data then had to be transferred to AutoCAD software, thus increasing the data conversion values considerably.

In order to compare not only the times, but also the compactness and cost of the individual devices, a multicriteria analysis was chosen. The factors of measuring time, data transfer time, weight, size, number of persons, labour cost, accuracy and price were compared.

The highest weighting was given to the accuracy of the individual gauges. The second highest weighting was given to measuring and data transfer times. The factors of cost, number of people and labour costs were ranked next. Price is important to most manufacturing companies - they want to know if the instrument will be worthwhile and if the payback on the cost will be within a reasonable timeframe. The number of people and labour costs are closely related to the financial costs of the company. It is very important for a company whether it sends two people to do the measuring or whether an individual can do the measuring. The last factors were weight and size. Both of these factors are important because of carryover.

According to the results found, which are presented in Tab. IV. Multicriteria Analysis, it was found that the best instrument for aiming is the classic tape measure. Although the roll meter came out higher in terms of sighting time and number of persons for sighting, yet the data transfer time, size, weight, cost and accuracy of the meter came out best. The second best measuring device was

IV: *Multicriteria Analysis*

	Measuring Time (s)	Data Transfer Time (s)	Weight (kg)	Size (mm)	Workers	Total Wages (CZK)	Device Presicions (mm)	Price (CZK)	
Tape Measure	594.5	574	0.2	70.0 × 70.0 × 25.0	2	102	± 0.7	128	
Laser Rangefinder	380.0	574	0.08	101.4 × 38.0 × 22.3	2	77	± 4.0	1,269	
3D scanner	722.0	85	5.35	120.0 × 240.0 × 230.0	1	47	± 1.9	1,499,900	
Leica BLK3D	133.5	1,251	0.48	180.6 × 77.6 × 27.1	1	80	± 3.0	120,000	
Weight	8	8	6	5	7	7	10	7	Total:
Tape Measure	15	10	10	5	10	20	5	5	580
Laser Rangefinder	10	10	5	10	10	10	20	10	650
3D scanner	20	5	20	20	5	5	10	20	730
Leica BLK3D	5	15	15	15	5	15	15	15	720

the photogrammetric device Leica BLK3D and laser rangefinder, and the least effective was the 3D scanner. The similar result for the laser rangefinder and Leica is surprising. Although the Leica is significantly better than the laser rangefinder in the factors of measuring time, number of people needed and labour costs, it is worse than the laser rangefinder in the factors of data transfer time, weight and price. The weight to be given to these factors according to the preferences of the manufacturing company must therefore be considered here. Changing the weights of the individual factors could change the overall ranking of the measuring instruments.

CONCLUSION

Conclusion of this study is assignment the optimal gauge for measuring interior. Four targeting instruments were selected and compared with each other. The first one is a classical tape measure, a laser rangefinder, a LEICA BLK3D and a 3D scanner.

From the evaluated data, the classical tape measure came out as the most effective targeting method. The second most effective device was the laser rangefinder, followed by the Leica BLK3D photogrammetric device and the 3D scanner.

The implication of these results is that modern measuring methods are only suitable under pre-specified conditions. However, they are neither the fastest nor the most inaccurate. Therefore, for any complicated targeting caused by large interior subdivisions, it is advisable to use classical targeting methods.

Every gauges have some benefits and downsides. For example, tape measure benefits are device presicions, size and weight, but downsides are total wages and workers.

The weight for only criterion is individual and everyone can change it along their preferences.

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