Dynamic Tests of Robot Stations

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ABSTRACT

The integrated tracking module of the robot stations offers the possibility to observe and monitor cinematic processes. Application of robot stations under cinematic conditions is connected with the dynamic loading of their components. Accuracy characteristics of measured values (lengths and angles) given by producers describe the static conditions by measurement only. Dynamic conditions going by cinematic measurements can be describe by new accuracy characteristics only. Determination of these characteristics by dynamic tests of robot stations. Theoretical model of tests. Instrumentation and results of laboratory tests.

ZUSAMMENFASSUNG

Das integrierte Tracking-Modul der Robotstation ermöglicht die Messung von kinematischen Prozessen. Der Einsatzt von Messrobotern unter kinematischer Bedingungen ist mit der dynamische Belastung ihrer Komponenten gebunden. Genauigkeitscharakteristiken der gemessene Werte, die bei Hersteller gegeben sind, beschreiben nur die statischen Bedingungen der Messprozess. Für die Beschreibung der dynamischen Bedingungen bei kinematischer Messungen braucht man neue Charakteristiken. Dynamischer Test der Robotstationen für Bestimmung der neuen Charakteristiken. Theoretisches Model des Tests. Instrumente und teilweise Ergebnisse der Laborteste.

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1. INTRODUCTION

Motorization and automation of the robot stations starts a new faster and more effective way for measured data obtaining. Development of the automated robot stations with automatic searching and tracking of the reflected system opened new possibilities of their utilisation in all areas of surveying, first of all in the area of the engineering surveying. Robot stations with automatic searching and tracking of the reflected system offer with help of the integrated tracking module a possibility to track and order cinematic processes as movement and deformations of the building structures as well as deformations of the industrial robots and their trajectories.

2. CHARACTERISTIC OF ROBOT STATIONS

Characteristic component of the robot stations (RS) are stepping motors (eventually servomotors), searching and continually tracking function of the reflected prism Lock-Mode and automated pointing function into the middle of the reflected prism (ATR – Automated Target Recognition). Stepping motors (eventually servomotors) enable instrument rotation round its vertical and horizontal axis.

Automated target searching means identification of the reflected prism in a working area of the searching target function that is represented with the range of the telescope- viewing field (Hennes, 1999). Is concerned RS with the passive reflected prism. Searching of the reflected prism carries out by the sequential scanning of the telescope-viewing field in a whole working area. At another principle of the target searching work the robot stations with the active reflected prism. The active reflected prism is equipped with a communication unit with a radio station that ensures a communication between a prism and a robot station.

RS differ also with a principle of the pointing to the reflected prism. Generally it is about determination of the reflection that is sensing with built-in CCD sensor, eventually about a pointing on a principle of the maximal intensity of the reflected prism. Automated pointing gives out in a moment of the measurement running.

3. PROBLEM OF THE ANGULAR AND LENGTH MEASUREMENT IN THE CINEMATIC MODE

Robot stations with automatic searching and tracking of the reflected system in the cinematic mode enable to observe and navigate cinematic processes. It is necessary for the angular and length system to work together. But RS are not constructed like this way, angles and lengths are measured with time slide that size is not known. By the static mode this very short time slide is not a handicap. In a cinematic mode it essentially influences a quality of the measured values because the measured angle and length are associated to the one point by the registration but in fact these are two points. Short time slides between angular and length measurement of the cinematic object effects that measured angle belongs generally to the other point as measured length.

4. DYNAMIC TEST OF ROBOT STATION

Efficiency of RS enables their utilisation in the tasks of the engineering surveying by that it is used continually record of the measured values. It is also suitable for the continuous monitoring of the water works (dams, tail bays) as well as the other building structures.

Producers of RS present the accuracy characteristics of the angular and length measurement upon which it appreciates their availability eventually inadvisability for the particular type of the task. Problem is that the producers present of the RS that can be unbroken only in a static mode. For measurements in a cinematic mode they present only accuracy of the length measurement. For the utilisation of the instrument for the measurements in a cinematic mode it is necessary to have more information as for example precision of the angular measurement or a general capability of the instrument to represent a geometric figure of a measured object (eventually trajectory of the object) and its position (eventually trajectory position) in a space. For this purpose was made an experiment, the aim of this experiment is to verify and supplement the producer information about the accuracy of RS with the automatic searching and tracking of the reflected system. This experiment was aimed to their possible utilisation in the near-spatial applications.

For the solution of this task were used the Leica TCA 1800, Leica TCRA 1101 plus and Zeiss Elta S10 (tab. 1). From the measurement of the cinematic reflected system on the trajectory with the known geometry (the circle and the straight-line) were obtained the parameters that characterise internal precision of the tested RS.

Tab.1 Accuracy characteristic of measured values given by producers

	Leica TCRA 1101 plus	**Leica TCA1800**	**Zeiss Elta S10**
Static mode	2mm + 2ppm	2mm + 2ppm	1mm + 2ppm
	$0,5^{cc}$	$0,3^{cc}$	$0,3^{cc}$
Tracking (measuring time)	5mm + 2ppm (0,3 sec)	5mm + 2ppm (0,3 sec)	Undefined
Fast tracking (measuring time)	10mm + 2ppm (<0,15 sec)	10mm + 2ppm (0,15sec)	Undefined

4.1 Movement of the Prism on the Circle

The experiment was made at the Slovak University of Technology at the Faculty of Civil Engineering in a laboratory of the Department of Surveying. For the realization of the experiment we used a simulator for testing sensors of the inertial measurement systems (Fig.1). Its construction and attributes is suitable for such experiment. Its main part is an arm that rounds in a horizontal plane. At the end of this arm there is fixated measurement board that rounds opposite the spinning arm (Kopáčik, 1998). It ensures that the measurement board (and also the reflected prism which is fixated on the board) is always in the same swing out towards the observer. Arbitrary point of the platform is moving at the circle with 500 mm radius. This equipment enables a rotation in various stages of the speed.

The reflected system was fixated on the measurement board and the tested RS that were fully managed by the program observed its motion. Measured values were registered in a PC by the program.

Motion of the prism was measured step by step with each RS. Measurements were realized from the two various stations that were in various distances (from the spatial reasons it was not able to have more stations) and in various degrees of speed.

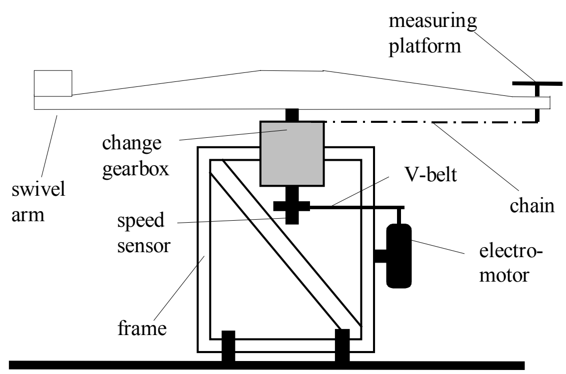

Fig.1 Simulator for sensor testing used by Kopáčik (1998)

4.2 Motion of the Reflected System on the Straight-Line

The experiment was made at the Slovak University of Technology at the Faculty of Civil Engineering in a laboratory of the Department of Concrete Structures and Bridges on the four meters long metal block. In the middle of the block is very exactly incised line (with accuracy of 0,1 mm) and which present ideal straight-line. The special constructed carriage with the fixed reflected prism we could move in the incised line. We used all types of mentioned instruments and measured values were registered in a PC. We measured from the three stations that were located in a various relations to the straight-line (vertically, along the straight-line and in a general position).

This paper analyses only partial results from the measurements of the moving reflected prism on a circle.

5. DATA PROCESSING

From the registration of the motion of the prism on the trajectory with the known geometric shape and parameters we obtained measured parameters of the trajectory it means the co-ordinates x, y, z and horizontal angle, vertical angle and slope distance of individual points of the trajectory.

Using the methods of the mathematical statistics (for example regression analysis) it is possible to estimate a trajectory of the prism in a space, its parameters and their a posterior accuracy characteristic. With the comparison of the both trajectories (the measured and the defined beforehand) it is possible to obtained parameters that characterised a accuracy of the robot stations.

The Figure 2 present one of the realised motion measurement of the prism on a circle trajectory. Elliptical shape of the measured trajectory is visibly differs from the shape of the real trajectory. As all measurements show similar result we can say that measurement of the cinematic target is influenced by the certain systematic influence which is probably subjected (besides the other factors) with time slide between angular and length measurement.

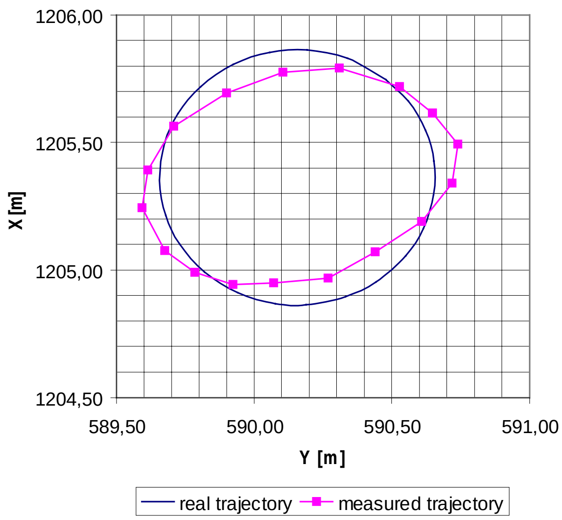

Fig. 2 Trajectory of the prism determined by Zeiss Elta S10 (11 meters distance of the RS from the middle of the circle, 18 seconds one round time)

In the table 2 there are presented the maximum deviations of the measured points from the real circle (that are vertically defined to the circle) for the individual instruments and the speeds of rotation. From the table is clear that the divergence of the point increasing of the rotation speed. It is probably because of the time slides between the angular and length measurement. There are also another factors there like increasing of the mean error in an automated pointing by the higher speed rotations.

The smallest deviations from the circle are by the Leica TCRA 1101 plus instrument. The maximum deviations are by the Zeiss Elta S10 instrument that by the defined speed registers very small quantity of the points in a comparison with the others (see table 2)

This problem of the time slides between angular and length measurement in cinematic mode is solved also at the Munich University of Technology. W. Stempfhuber et al. mathematically suggested a positioning correction of the monitoring object by the cinematic measurement

(Stempfhuber et al., 2000). The suggested modification of the measured data is one of the possible solutions of this problem.

Tab. 2 Maximum deviations of the measured points from the real circle

Distance of the instrument from the middle of the circle [m]	Instrument	One swing out lasting [s]	Number of the points for one swing out	Maximum deviation of the point from the circle [mm]
11,2	Leica TCRA 1101 plus	5	23	44,3
		7	24	15,0
		18	59	18,0
		48	135	9,9
	Leica TCA 1800	5	16	109,8
		7	21	95,1
		10	30	66,1
		47	144	16,7
	Zeiss Elta S10	10	9	180,9
		18	8	111,6
		53	15	71,9
2,5	Leica TCRA 1101 plus	6	24	50,2
		7	28	39,7
		9	35	34,7
		10	39	27,3
		16	58	19,0
	Leica TCA 1800	6	14	81,0
		7	20	95,5
		9	28	70,5
		10	30	67,0
4	Zeiss Elta S10	30	10	74,7
		32	9	79,6
		3	14	42,6

6. CONCLUSION

Realized experiments could indicate a utilization of the automated total stations also in such areas in which they haven't been applied yet. The aim of our experiment measurements is also to verify the correction suggested in Stempfhuber et al. (2000) and to suggest an optimal promotion of elimination of systematic influences by the cinematic measurement. From the obtained results it can be possible to verify availability of its utilization for example in an area of the industrial robot controls, in the car industry, in the aircraft etc.

In an abroad there are several specialists who devote only to RS. To this problem of the effectiveness and accuracy of RS with automatic searching and tracking of the reflected system is written several articles (Stempfhuber *et al.*, 2000, Stempfhuber *et al.*, 2001, Kuhlmann, 1999). Authors are searching for optimal measurement promotions, they solve the problem of time slides between angular and length measurement, they suggest corrections that regulate measurement values, for example Stempfhuber *et al.* (2000). In the present time there are some discussions about correctness of the suggested mathematical promotions of the modifications of the measured values in a cinematic mode and about availability of the utilisation of the cinematic way of measurement.

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