The Application of the Rapid Data Observations of The Quasar VLBI Network in Order to Improve the Accuracy of the Universal Time Prediction

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Abstract The main purpose of this work is to test various ways of using "QUASAR" VLBI observation data to improve the accuracy of the UT1-UTC prediction. A brief overview of the theoretical foundations of the method used—local approximation, IAA Universal Time series description, and testing procedure—is included in the paper. Our tests' results show that the most accurate and prompt prediction for the entire length is obtained by replacement of the past few points of the reference series with values according to the R program. The study is more important from a practical point for rapid data analysis.

Keywords The Quasar VLBI Network, local approximation, prediction, Universal Time, rapid data

1 Introduction

The VLBI Stations of the "QUASAR" network (VGOS 13.2-m antennas SVERT13V, BADRT13V, and ZELRT13V, and Legacy antennas "Svetloe", "Badary", and "Zelenchukskaya") [1] perform rapid observations to determine Universal Time several times a day. This UT1-UTC series is available more quickly than the IERS finals data [2] are updated. Therefore, it is advisable to use them to solve the problem of operative analysis, in our case, for short-term prediction of Universal Time. It is important for users who perform operative processing of the space geodesy data. The first two points of the forecast are especially essential, because they are used in the Lagrange interpolation for four points in the data's reductions.

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2 The Local Approximation Technique

The Local Approximation technique (LA) [3] is used as the prediction method in this work. The method was tested and proven to be high quality in the short-term prediction of Universal Time in our previous work [4]. The main idea of the LA is to divide the area into several local subareas, build an approximating model (we chose a linear function in our case), estimate the parameters of these models separately in each area using the least squares method, and then build a forecast based on the calculated parameters. We use an iterative, few-steps-ahead method for the LA technique in this work. The example of the UT1-UTC prediction for the 2021 year is shown in Figure 1; the comparison (using the root mean square (RMS)) with the IERS prediction and the method currently used in the IAA RAS is presented in Table 1.

3 IAA RAS Universal Time Series

We used two IAA Universal Time series from 2021 for our tests. The first series "iaa-R.eopi" was obtained in the IAA RAS from two-hour observations for the R program: on a network of three 13.2-m VGOS VLBI antennas located in the "Svetloe", "Badary", and "Zelenchukskaya" observatories. Observations were held four times a day. The second series "iaa-RI.eopi" was obtained from daily one-hour sessions of VLBI

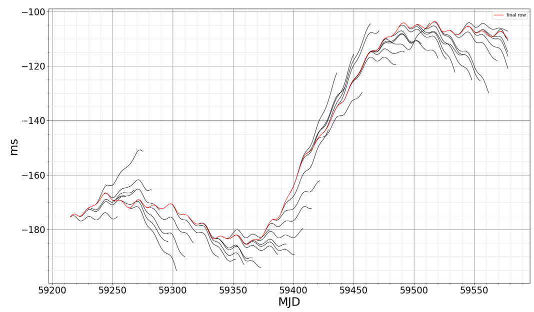

Fig. 1 "finals.data" for 2021 (red) and the LA forecast of up to 40 days with seven days step (black) for UT1-UTC.

Table 1 Example of accuracy of the UT1-UTC different predictions for several years, ms.

Years	Method	Days				
		1	5	10	20	40
2019	LA	0,08	0,45	1,25	3,49	10,09
	IAA RAS	0,41	2,35	3,52	5,60	9,12
	IERS	0,09	0,26	0,61	2,11	6,51
2018	LA	0,08	0,58	1,69	4,92	10,45
	IAA RAS	0,46	1,27	2,51	4,67	8,47
	IERS	0,08	0,20	0,54	2,34	5,10
2017	LA	0,20	0,55	1,29	3,04	6,04
	IAA RAS	0,38	1,02	1,85	3,15	6,74
	IERS	0,08	0,20	0,63	1,92	5,60
2016	LA	0,16	0,72	1,98	5,44	14,16
	IAA RAS	0,50	1,14	2,18	4,19	7,44
	IERS	0,12	0,22	0,67	1,99	4,50

observations for the RI program: on 32-m antennas of the "QUASAR" complex. The Zelenchukskaya-Badary baseline is mainly used, and if necessary, one of the stations can be replaced by the Svetloe station. E-vlbi technology is used for data transfer. The RAS-FX correlator developed at the IAA RAS ([5]) is used for the data correlation. Secondary data processing is performed with the QUASAR software package ([6]), also developed at the IAA RAS. The latency of the IAA dUT1 results is about six hours.

4 Testing Procedure

We used the rapid IERS EOP series "finals.data" as a reference series for the prediction and two IAA RAS Universal Time series "iaa-R.eopi" and "iaa-RI.eopi" for our experiments. In the first part of the tests, the last few points of the reference series "finals.data" were replaced by the points from the rapid series "iaa-R.eopi" and "iaa-RI.eopi". In the second experiment, the first one or two points of the constructed forecast were replaced by these values from the corresponding time series. We try to simulate the real situation with this way, when the "finals.data" series is still unavailable. The epochs of the IAA dUT1 time series do not correspond to the midnight epoch, so the UT1-UTC values were interpolated by splines of order 1 to midnight epochs for the comparison with the "finals.data". The comparison between each version of the LA prediction and the final series "finals.data" was performed. The RMS and the mean absolute error (MAE) of the difference prediction series and the final series were chosen as criteria for estimating the accuracy of the prediction. We used the first order iterative method with the reference interval of three years for the LA prediction. The test results are shown below. The statistics are given for 2021.01.01–2021.12.31. The number of last points replaced for the first test is four, and the number of first ones for the second experiment is one. The table shows the RMS and the MAE for each forecast version. We use the following designations: the "LA" is the ordinary version of the prediction with no IAA RAS data; "`Refer_repl`" is the prediction with the replacement of the last few points of the reference series, and "`Pred_repl`" is for the replacement of the first points of the constructed forecast. Also Figure 2 shows the concept of our tests.

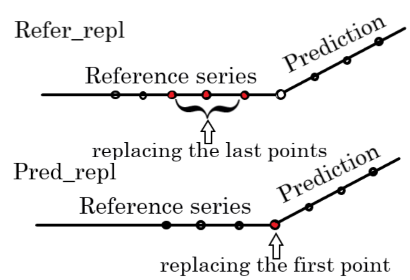

Fig. 2 Illustration of two test versions.

5 Results

As we can see from Table 2, using the IAA RAS rapid data improved the results in all kinds of the tests in

Table 2 Accuracy of the UT1-UTC prediction for 2021, ms.

Years	Method	Days								
		1	2	3	4	5	10	15	20	40
RMS										
	LA	0,12	0,20	0,32	0,48	0,66	1,84	3,34	5,01	12,56
R	`Refer_repl`	0,06	0,14	0,26	0,41	0,58	1,74	3,24	4,86	11,99
	`Pred_repl`	0,02	–	–	–	–	–	–	–	–
RI	`Refer_repl`	0,15	0,28	0,45	0,64	0,85	2,08	3,56	5,23	12,64
	`Pred_repl`	0,07	–	–	–	–	–	–	–	–
MAE										
	LA	0,09	0,17	0,28	0,40	0,56	1,60	2,85	4,38	10,62
R	`Refer_repl`	0,04	0,11	0,21	0,33	0,46	1,43	2,72	4,17	9,89
	`Pred_repl`	0,08	–	–	–	–	–	–	–	–
RI	`Refer_repl`	0,11	0,22	0,36	0,51	0,68	1,71	2,97	4,31	10,18
	`Pred_repl`	0,05	–	–	–	–	–	–	–	–

comparison with the LA method. The more precise results for the entire length of the prediction are obtained from the replacement of the last few points of the reference series with iaa-R.eopi values. Using the rapid series for the first point instead of the forecast shows obvious good results, so it's an important advantage to have constantly updated operative observations.

References

1. D. Ivanov, A. Ipatov, D. Marshalov, and G. Ilin, "Quasar" VLBI Network Stations Report, In D. Behrend, K. Armstrong, and K. Baver, editors, *International VLBI Service for Geodesy and Astrometry 2019+2020 Biennial Report*, NASA/TP-20210021389, pages 100–104, 2021.
2. International Earth Rotation and Reference Systems Service. URL: https://www.iers.org/
3. A. Loskutov, D. Zhuravlev and O. Kotlyarov, "Applications of a local approximation technique for forecasting of economic indicators", Physics Faculty, Moscow State University after M. V. Lomonosov, 2003.
4. M. Gribanova and E. Skurikhina, "Prediction of Earth rotation parameters using local approximation techniques", *Transactions of IAA RAS*, Iss. 54, pages 11—20, 2020.
5. I. Surkis, V. Ken et al., "The RASFX VGOS GPU based software correlator", *Transactions of IAA RAS*, Iss. 41, pages 123-–126, 2017.
6. S. Kurdubov. "QUASAR software in IAA EOP service: Global Solution and Daily SINEX", In J. Boehm, A. Pany and H. Schuh, editors, *Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting*, pages 79-–82, 2007.