RYERSON UNIVERSITY

Precise Orbit Prediction for PPP

Hamad Yousif

Ahmed El-Rabbany

Presentation topics :

- **Introduction**
- **What is Artificial Neural Networks (ANN)?**
- **Prediction Strategy**
- **Comparison between ANN-based and IGS ultra-rapid prediction**
- **Conclusion and Future Recommendations**

Introduction :

- **PPP requires highly accurate real-time GPS satellite ephemeris**
- **Currently seven IGS analysis centres produce high quality ultra-rapid products, namely, NRCan, CODE, ESA and others**
- **The accuracy of the predicted part of the IGS ultra-rapid product is around 10 cm which is not sufficient for PPP**
- **To overcome this problem, a neural network model is developed in this research to produce an improved GPS satellite ephemeris using NeuralWorks Predict® software**

What is Artificial Neural Networks (ANN)?

- **Artificial neural networks (ANN) are computational models that imitate the human brain in performing a particular task**
- **Capable of solving complex problems through learning, or training, and then generalizing the output model for other inputs**
- **ANN stores knowledge that can be used for future purposes of modeling and reproduction**
- **ANN acquires this knowledge through a combination of complex procedures referred to as the training process**

Prediction strategy:

Part one: Data processing using Bernese

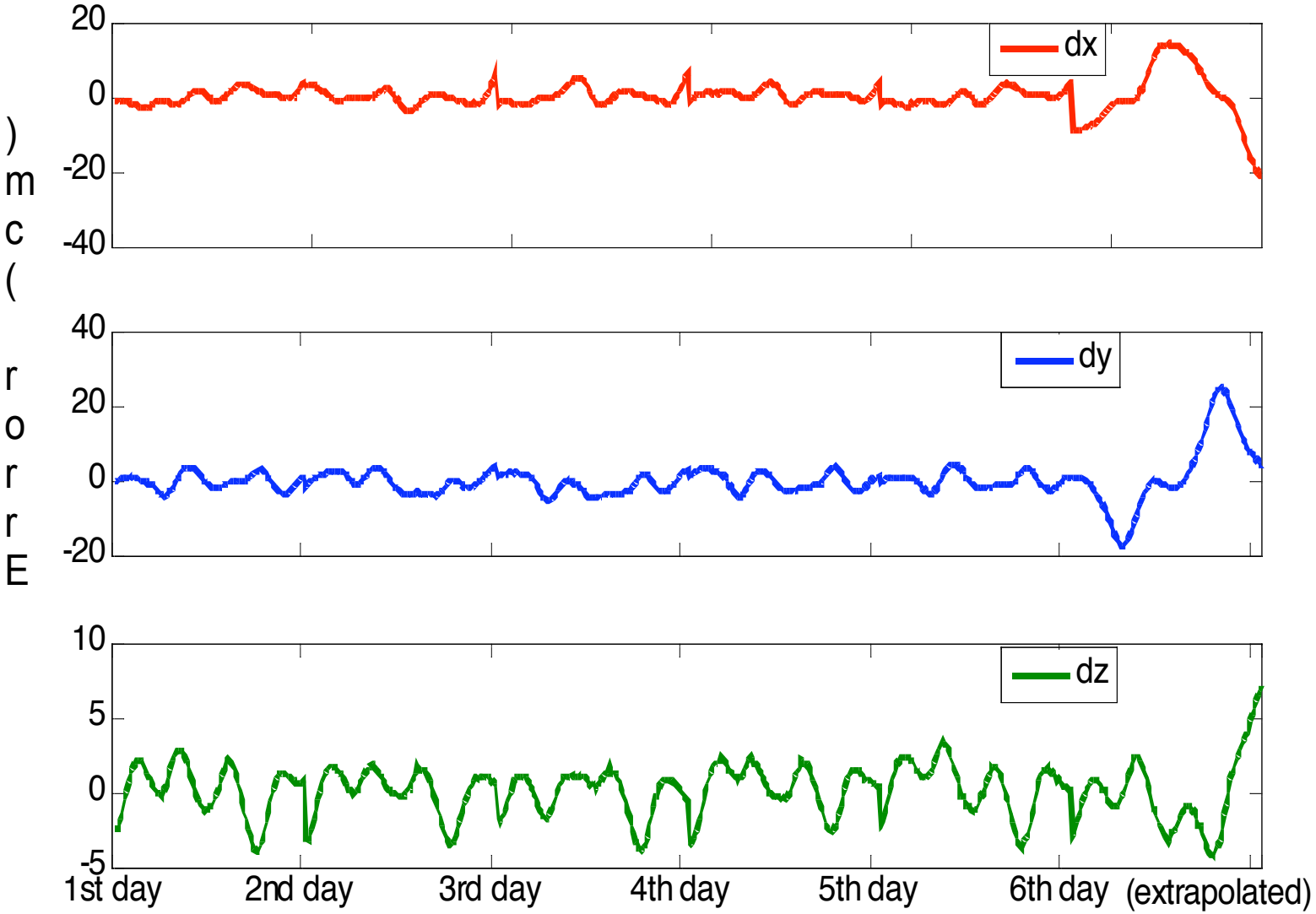
- The procedure starts with importing IGS rapid precise ephemeris for ten days preceding the predicted part were used in this research
- Using Bernese, the ten ephemeris files were concatenated, fitted to a 10^{th} degree polynomial and extrapolated to obtain a 6-hour orbital arc
- The satellites clock correction coefficients were then extracted from the precise ephemeris files and saved to a separate file, which was used later for receiver clock synchronization
- RINEX observations from a well-distributed 35 IGS stations for one day preceding the predicted part were used in this research

Distribution of IGS stations used in this research

Prediction strategy (cont'd):

- The previously extracted satellite clock corrections were used to synchronize the receiver clock
- Station baselines were then created and the double difference linear combination is performed. Bernese automatically selects a set of baselines with the maximum number of observations. In our case, the number of baselines was 34.
- Cycle slips were detected and repaired. In addition bad observations are excluded. Then a float solution is carried out, followed by ambiguity fixing for each baseline individually
- The results of ambiguity resolution from the previous step are used for the final solution
- The most important output of the final solution is the improved orbital parameters file

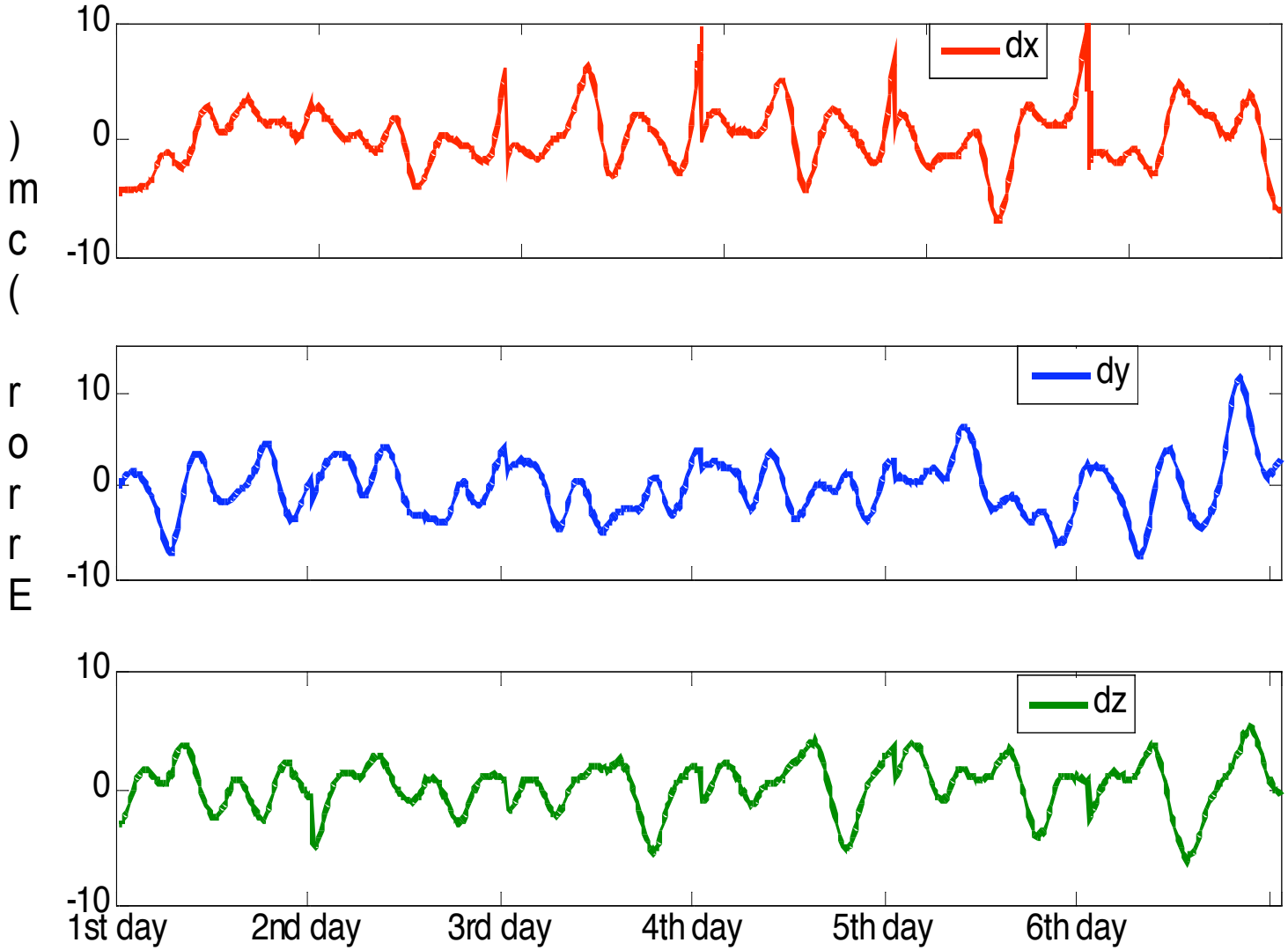
Residuals of polynomial fitting before orbit improvement



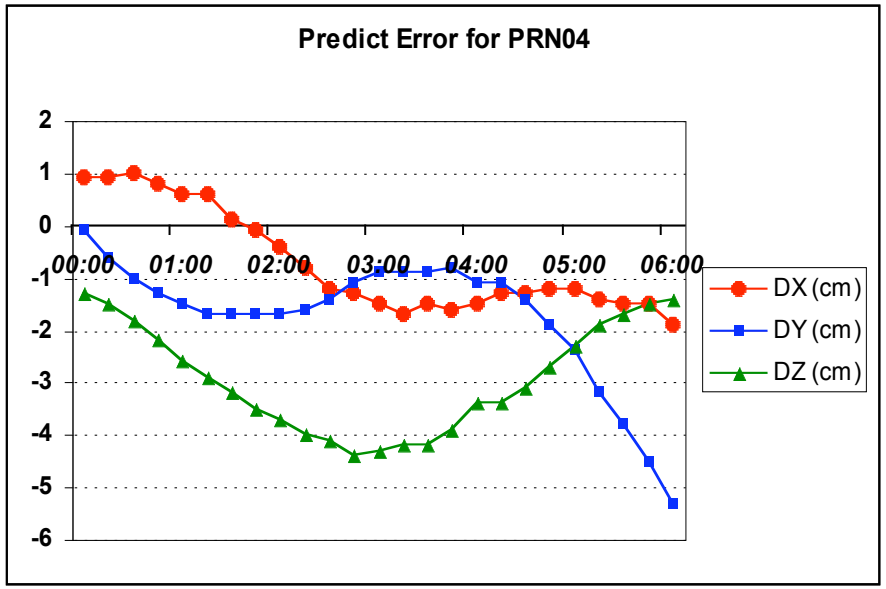
Part two: Prediction enhancement using ANN:

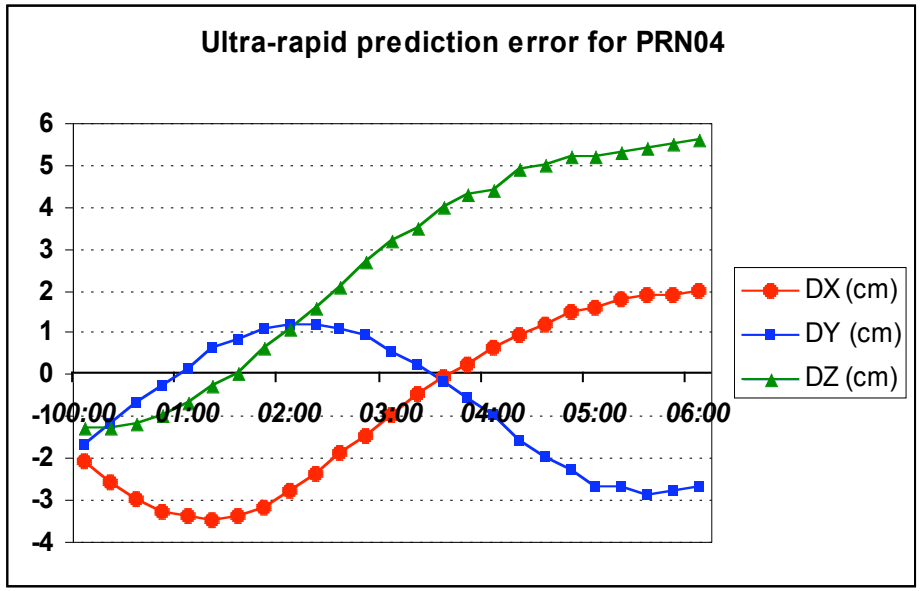
- **The residuals between the ten precise and fitted ephemeris were calculated and used to train a NeuralWare Predict network**
- **For generality, three GPS satellites from different generations were used to test the prediction in this paper; namely PRN 04 (Block IIA), PRN 13 (Block IIR) and PRN 17 (Block IIR-M)**

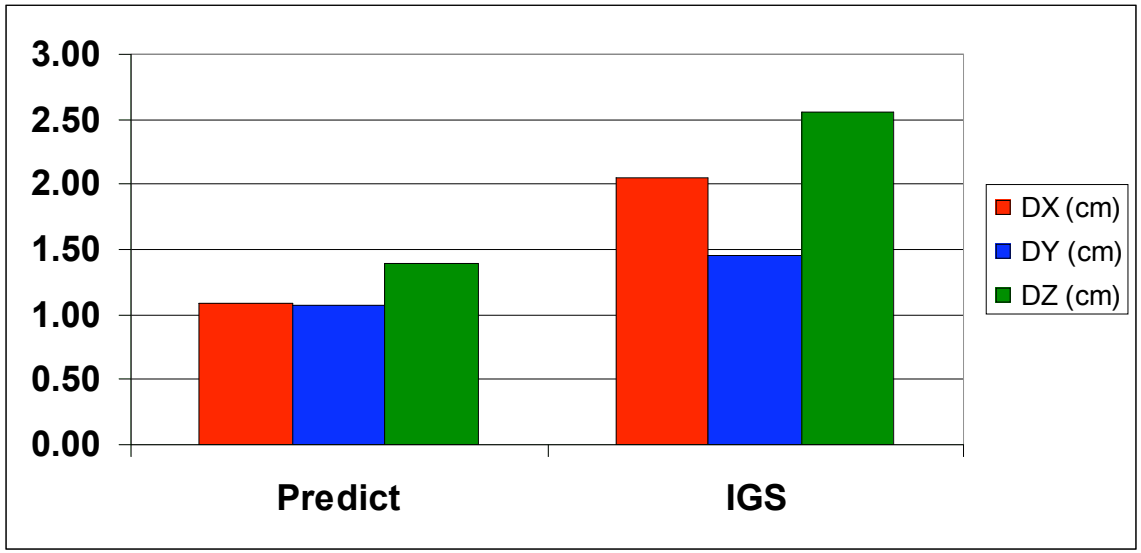
Residuals of polynomial fitting after orbit improvement



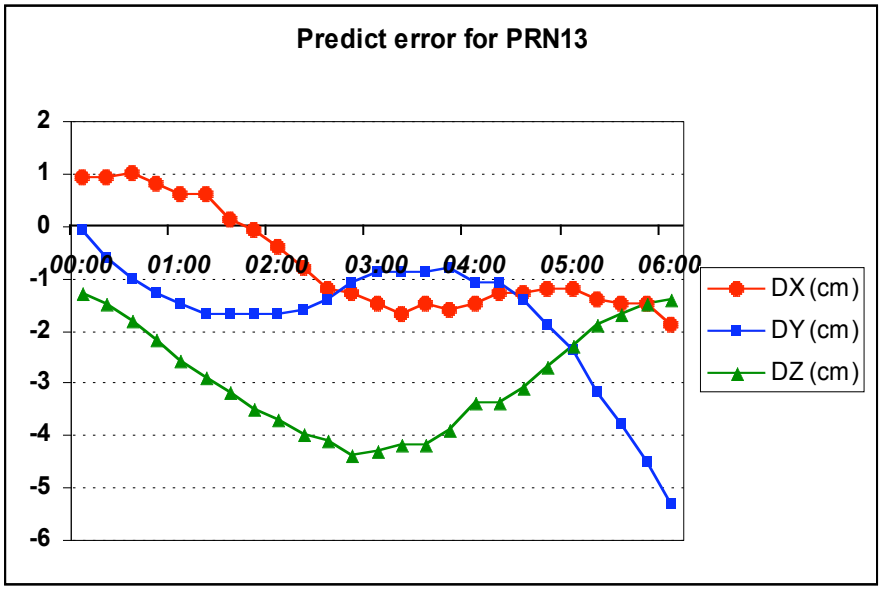
NeuralWare Predict Error for PRN 04 (Block IIA)

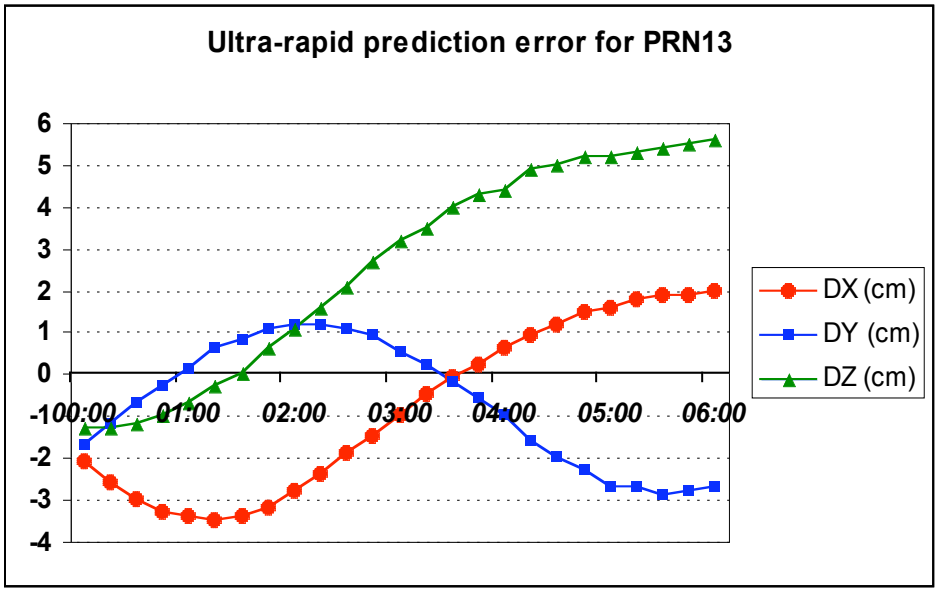


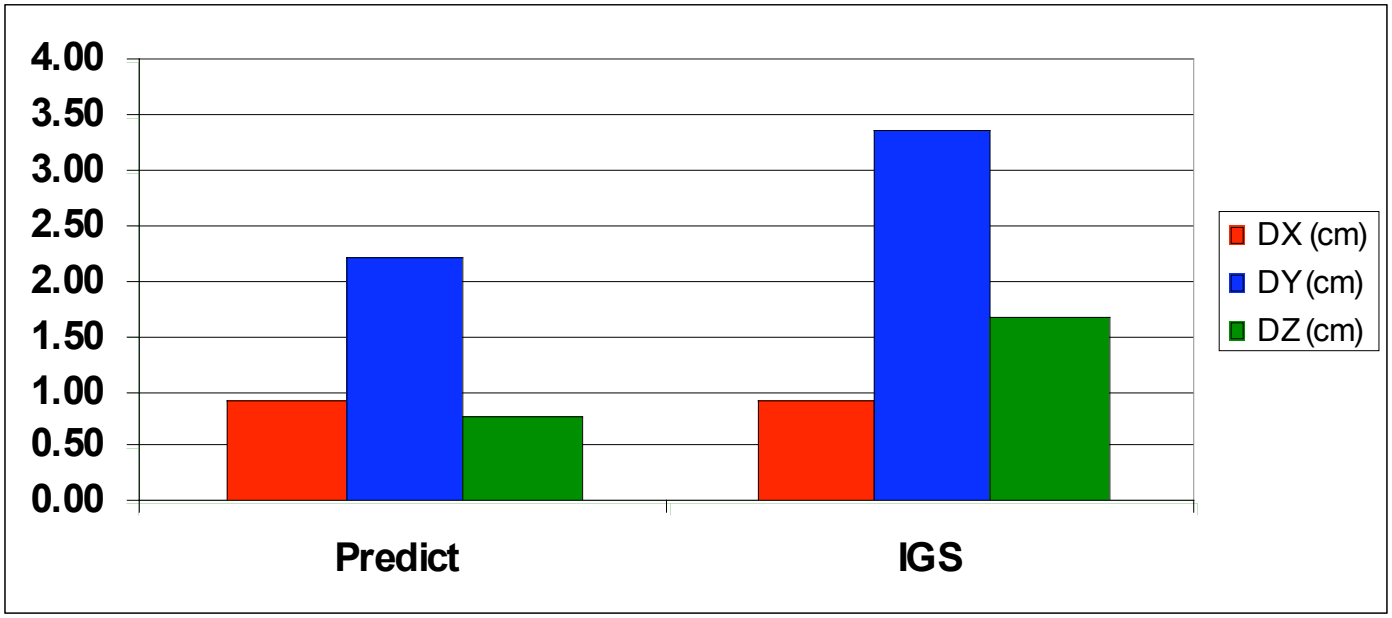




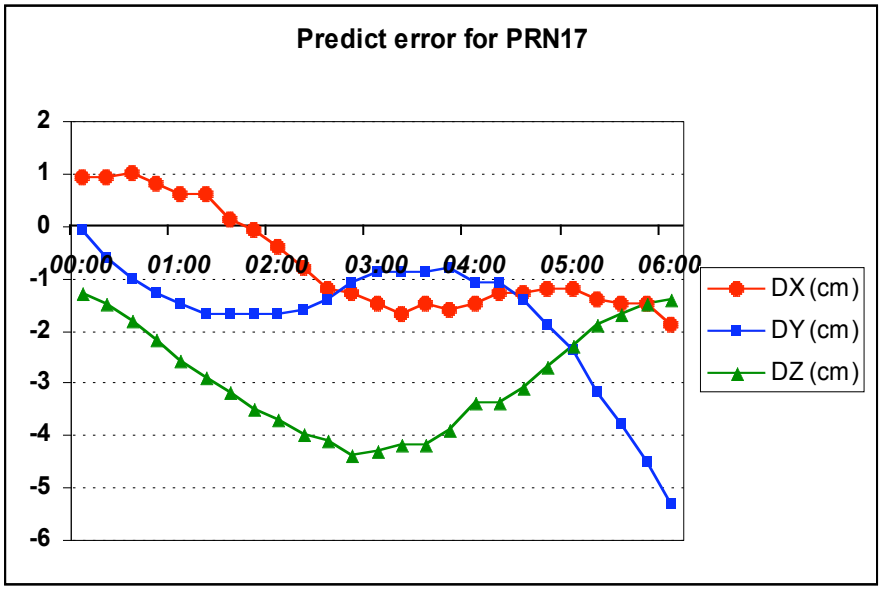
NeuralWare Predict Error for PRN 13 (Block IIR)

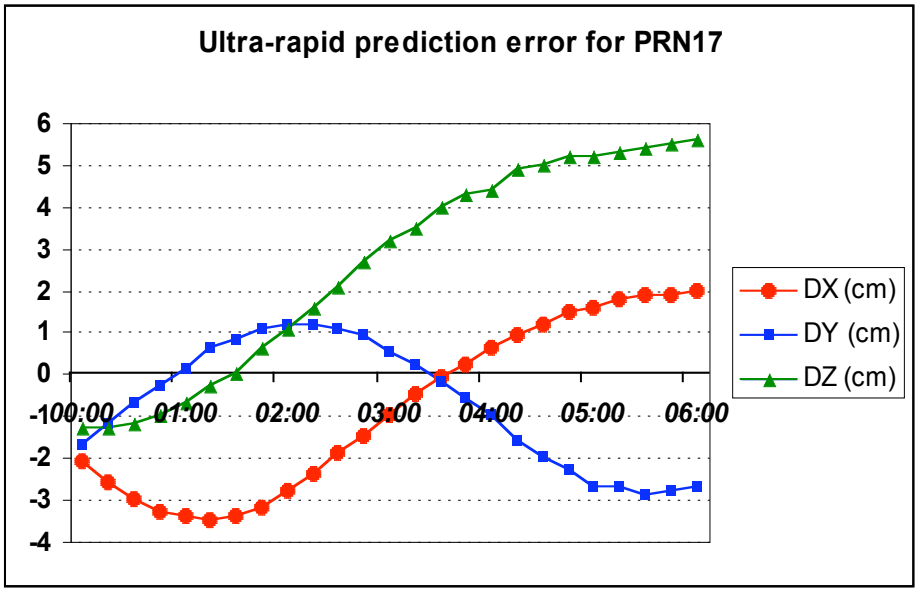


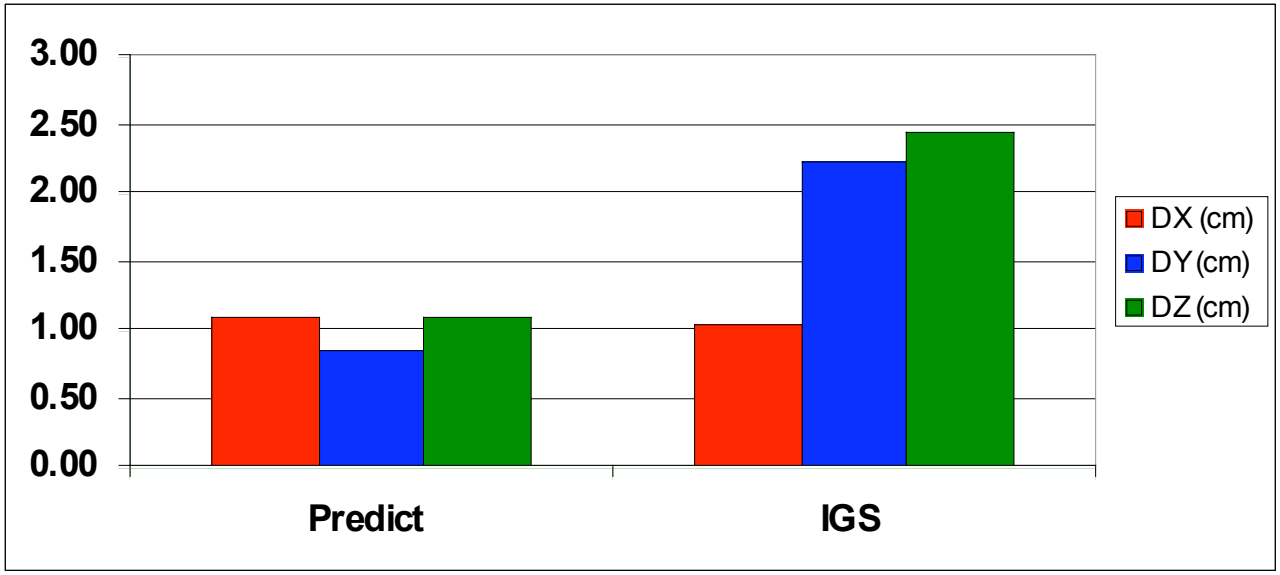




NeuralWare Predict Error for PRN 17 (Block IIR-M)







NeuralWare Predict Error (cm) and ANN percentage improvement

Satellite ID	PRN 04		PRN 13		PRN 17	
Prediction method	IGS-U	ANN	IGS-U	ANN	IGS-U	ANN
x	2.1	1.1	0.9	0.9	1.1	1.1
y	1.5	1.1	3.4	2.2	2.2	0.86
z	2.6	1.4	1.7	0.8	2.5	1.1
total	3.6	2.0	3.9	2.5	3.5	1.8
Percentage improvement	42%		35%		49%	

Conclusion and Future Recommendations:

- **An initial 6-hour predicted orbit is first obtained by extrapolating a 5-day IGS rapid orbit**
- **The initial orbit is then improved by using GPS observations from a network of 35 globally-distributed IGS reference stations**
- **Lastly, a modular, three-layer feed-forward back-propagation neural network is used to enhance the predicted orbit**
- **In comparison with the IGS ultra-rapid orbit, the newly developed neural network-based model improved the orbit prediction by 42%, 35%, and 49% for Predict ANN for PRN 04, PRN 13 and PRN 17 respectively**
- **In future, rapid ephemeris of the day preceding the predicted has to be produced to avoid the 17-hour latency**

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Thanks