Journal of the Korea Academia-Industrial cooperation Society
Vol. 15, No. 12 pp. 7424-7429, 2014

http://dx.doi.org/10.5762/KAIS.2014.15.12.7424
ISSN 1975-4701 / eISSN 2288-4688

Monitoring of the Crustal Movement by the Earthquake Effect using Web-based GPS Data Processing Solution

Joon-Kyu Park[1], Kap-Yong Jung[2*]
[1]Department of Civil Engineering, Seoil University
[2]Department of Civil Engineering, Chungnam National University

웹기반 GPS 데이터 처리 솔루션에 의한 지진영향에 따른 지각변동 모니터링

박준규[1], 정갑용[2*]
[1]서일대학교 토목과, [2]충남대학교 대학원 토목공학과

Abstract GPS (Global Positioning System) is currently used widely in the ground section, such as surveying, mapping, geodesy, geophysics, the aviation section, such as aerial navigation and aerial photography, the sea section, including ship navigation and bathymetry, and space section, such as the satellite orbit and Earth's orbit. On the other hand, its use is limited due to the professional knowledge and expense to process the data for precise analysis. As a result, a web-based data processing solution for precise point positioning using GPS data was developed by c# for non-specialized people to process easily. In addition, the crustal movement speed of Korea after an earthquake was calculated to be an average of 30mm/year for each CORS, suggesting that it is possible to monitor crustal movement.

요 약 현재 GPS는 측량 및 지도제작, 측지, 지구물리와 같은 지상부문, 항공기 항법, 항공사진 촬영과 같은 공중부문, 선박의 항법, 수심측량과 같은 해상부문, 위성 궤도, 지구궤도와 같은 우주부문 등 다양한 분야에서 폭넓게 활용되고 있다. 그러나 넓은 활용분야에 비해 정밀 해석의 자료처리를 위해서는 전문지식뿐만 아니라 비용적인 문제로 인해 활용에 제약이 있다. 이에 본 연구에서는 전문지식이 없는 사용자도 GPS 데이터를 이용하여 손쉽게 정밀절대측위 성과를 얻을 수 있도록 C#을 이용하여 웹기반의 GPS 자료처리 솔루션을 개발하였다. 또한, 개발된 솔루션을 이용하여 우리나라가 일본 지진 이후 상시관측소 별로 평균 30mm/year의 지각변동이 나타남을 산출하고, 기존 지각변동 속도와 비교함으로써 지각변위속도 모니터링의 활용가능성을 제시하였다.

Key Words : GPS, Web-based Data Processing Solution, Precise Point Positioning

1. Introduction

Large-scale earthquakes have become more frequent recently including the great earthquakes in east Japan in March 2011 and April 2014, raising the significance for crustal movement monitoring and earthquake disaster detection [1]. In line with this GPS has become essential in high precision areas such as worldwide crustal movement monitoring and earthquake and crustal movement monitoring by interpreting the precision point positioning of observatory data is a very effective method [2]. Scientific data processing

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning(NRF-2012R1A1A1004414).
*Corresponding Author : Kap-Yong Jung(Chungnam National Univ.)
Tel: +82-11-9819-9369 email: jungjusa@hanmail.net
Received October 31, 2014 Revised November 17, 2014 Accepted December 11, 2014

software for GPS data processing used various models to remove GPS positioning errors. The method has been utilized for precision position determination including earthquake slip or crustal movement calculation [3]. However, this academic software-based precision point positioning requires various kinds of specialized knowledge and accompanied time and cost for data interpretation thus, users need an easier method of data interpretation [4,5]. In this study, data processing mechanism of GPS post processing was analyzed. And to develop a web-based GPS data processing solution capable of effective precise point positioning and processes GPS data of NGII's CORS to calculate crustal movement speed and compare it with previous research results to assess the developed solution's applicability.

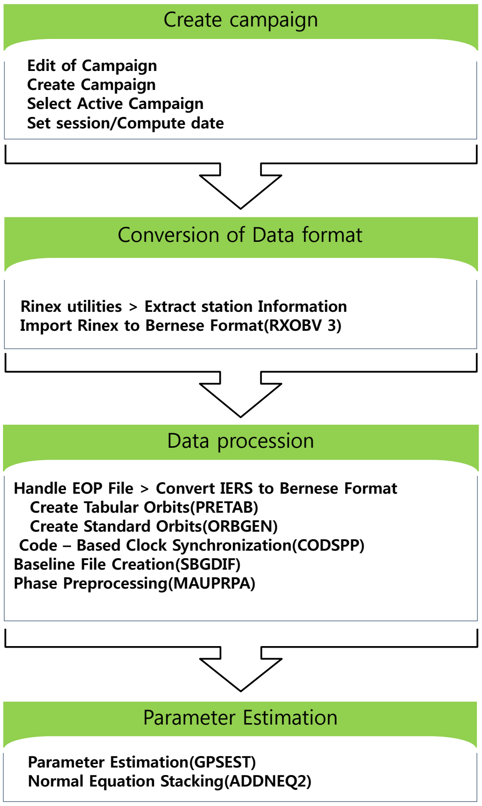
2. Development of Web-based GPS Data Processing Solution

In this study, data processing flow of Bernese 5.0, a scientific software was analyzed and applies MCV model based on C# to successfully develop an web-based data processing solution. Fig. 1 shows data processing flow of Bernese [6].

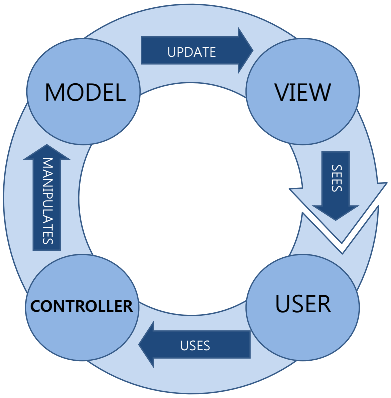
MCV model is the architectural pattern used in software engineering. It divides a given software application into three interconnected parts, so as to separate internal representations of information from the ways that information is presented to or accepted from the user [7]. Fig. 2 shows Typical collaboration of the MVC components [8].

The model directly manages the application's data, logic and rules. A view can be any output representation of information, such as a chart or a diagram; multiple views of the same information are possible, such as a bar chart for management and a tabular view for accountants. The third part, the controller, accepts input and converts it to commands for the model or view [8].

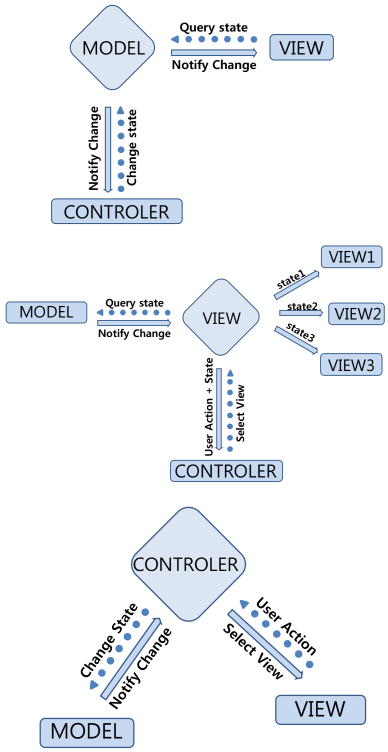
By using MCV model, Developers can make an application easier to fix the business logic that is running on a visual element or of the application without affecting each other to group the business logic from the user interface. Fig. 3 shows concept of each component.



[Fig. 1] Data processing flow of bernese

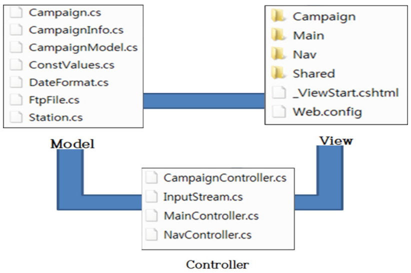


[Fig. 2] Typical Collaboration of the MVC components



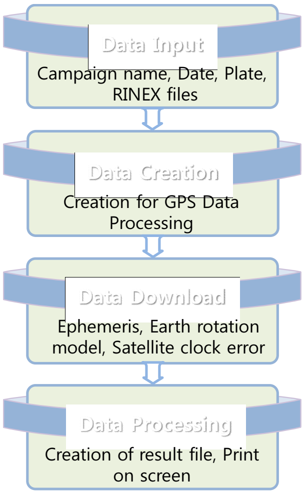
[Fig. 3] Concept of Each Component

The solution is comprised of data input, data generation, data download, data processing and result output while minimizing necessary information input for data processing other than GPS observation data for the convenience of users. Fig. 4 represents the Structure of web-based data processing Solution.



[Fig. 4] Structure of web-based data Processing Solution

The model is comprised of data on campaign, campaign information, observatory, and observation date (GPS date, day of year). Main Controller among the controller treats index page, introduction page, about page and contact page and Campaign Controller analyzes observatory files [6]. Fig. 5 shows Data processing flow of Solution [9].



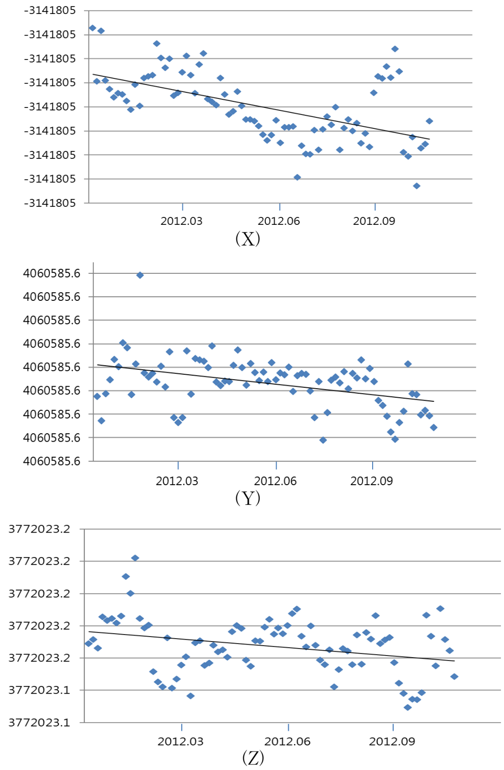
[Fig. 5] Data processing flow of Solution

3. Monitoring of Crustal Movement

In this study, to evaluate the applicability of the web-based GPS data processing solution for crustal movement monitoring, NGII(National Geographic Information Institute)'s CORS data were processed for precision point positioning and crustal movement speed was calculated. A total of 44 stations were examined for their monitoring data and crustal movement speed was calculated in comparison with extant study outcomes. Fig. 6 shows location of CORS [10].

[Fig. 5] Location of CORS

Observation data from January 1 to December 31, 2012 were processed by unit of a week. Fig. 6 shows part of the time series of data processing results. Table 1 shows comparison of the crustal movement speed with extant study [11].

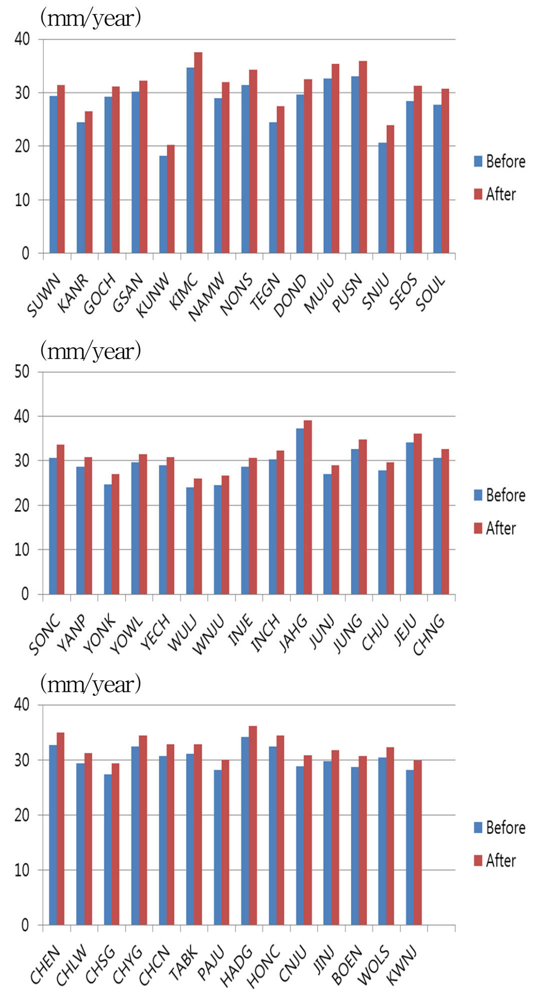


[Fig. 6] Time Series of Data Processing Result

[Table 1] Comparison of Crustal Movement Velocity

ID	Crustal Movement Velocity(mm/year)					
	X		Y		Z	
	Before	After	Before	After	Before	After
SUWN	-24.2	-25.4	-11.6	-11.82	-12	-14.1
KANR	-21.5	-22.7	-6.6	-6.81	-9.7	-11.8
GOCH	-23.7	-24.9	-12	-12.22	-12.1	-14.2
GSAN	-22.1	-23.3	-14.7	-14.93	-14.4	-16.5
KUNW	-14.4	-15.6	-7.6	-7.85	-8.1	-10.2
KIMC	-29.9	-32.3	-13.6	-13.84	-11.3	-13.4
NAMW	-25.3	-27.7	-8.9	-9.12	-11	-13.1
NONS	-25.4	-27.8	-12.6	-12.81	-13.5	-15.6
TEGN	-18.8	-21.2	-9.1	-9.31	-12.8	-14.9
DOND	-25.5	-27.9	-10.4	-10.61	-10.9	-13
MUJU	-23.5	-25.9	-16.6	-16.81	-15.3	-17.4
PUSN	-27.4	-29.8	-12.3	-12.51	-13.7	-15.8
SNJU	-16.1	-18.5	-4.9	-5.11	-12.1	-14.2
SEOS	-22.8	-25.2	-13	-13.21	-10.8	-12.9
SOUL	-24.5	-26.9	-6.1	-6.31	-11.5	-13.6
SONC	-26.3	-28.7	-11.4	-11.61	-11	-13.1
YANP	-21.3	-22.5	-10.7	-10.91	-15.8	-17.9
YONK	-18.4	-19.6	-2.7	-2.91	-16.2	-18.3
YOWL	-25.1	-26.3	-10.8	-11.01	-11.3	-13.4
YECH	-25.8	-27	-9.2	-9.41	-9.5	-11.6
WULJ	-20.6	-21.8	-8.7	-8.91	-8.9	-11
WNJU	-19.7	-20.9	-8.8	-9.01	-11.7	-13.8
INJE	-24	-25.2	-9.7	-9.91	-12.3	-14.4
INCH	-24.6	-25.8	-11.8	-12.01	-13.1	-15.2
JAHG	-30.8	-32	-15.4	-15.61	-14.2	-16.3
JUNJ	-23.7	-24.9	-8.4	-8.61	-9.9	-12
JUNG	-26	-27.2	-12.8	-13.01	-15.1	-17.2
CHJU	-23.3	-24.5	-10.7	-10.91	-10.7	-12.8
JEJU	-26.8	-28	-13.5	-13.71	-16.2	-18.3
CHNG	-22.4	-23.6	-13.7	-13.91	-15.7	-17.8
CHEN	-16.8	-18	-15.7	-15.91	-23.2	-25.3
CHLW	-25.6	-26.8	-9.7	-9.91	-10.6	-12.7
CHSG	-19.9	-21.1	-12.4	-12.61	-14	-16.1
CHYG	-27	-28.2	-12.4	-12.61	-13.1	-15.2
CHCN	-23.5	-24.7	-11.9	-12.11	-15.7	-17.8
TABK	-24.5	-25.7	-17.1	-17.31	-8.8	-10.9
PAJU	-21	-22.2	-15.1	-15.31	-11	-13.1
HADG	-28	-29.2	-12.3	-12.51	-15.2	-17.3
HONC	-23.6	-24.8	-14.6	-14.81	-16.7	-18.8
CNJU	-23.9	-25.1	-10.4	-10.61	-12.4	-14.5
JINJ	-25.5	-26.7	-9	-9.21	-12.4	-14.5
BOEN	-24	-25.2	-10.5	-10.71	-11.8	-13.9
WOLS	-26.7	-27.9	-10	-10.21	-10.5	-12.6
KWNJ	-27.3	-28.5	-1	-1.21	-6.7	-8.8

The web-based GPS data processing solution successfully gave precision point positioning results just by entering GPS observation data. And time series data processing gave crustal movement speed. The previous crustal movement speed was 30mm/year on average as calculated based on GPS data from 2006 to 2007. However, the average crustal movement speed of 2012 calculated in this research was 33mm/year. Such a result seems because of the 2011 great east Japan earthquake which changed crustal movement speed. Fig. 7 shows comparison of average crustal movement velocity.



[Fig. 7] Comparison of Average Crustal Movement Velocity

By continuing data processing in the future as well, the web-based GPS data processing solution is expected to fully contribute to crustal movement monitoring.

4. Conclusion

This research developed a web-based data processing solution capable of GPS data processing and assesses its applicability about crustal movement. These research findings are as follows:

1. The scientific software was analyzed and web-based GPS data processing solution was able to be developed based on MCV model and C# which is minimized the necessary information input.
2. The web-based GPS data processing solution successfully gave the precise point positioning results and crustal movement speed without any additional data than observation data.
3. The applicability of the developed solution was evaluated by comparing with extant diastrophism studies. By continuing data processing in the future as well, the web-based GPS data processing solution is expected to fully contribute to crustal movement monitoring.

References

[1] E. Crystal, Crystallinks, Available From: http://www.crystalinks.com/, (accessed Oct., 30, 2014)

[2] D. S. Song and H. S. Yun, “Crustal Deformation Velocities Estimated from GPS and Comparison of Plate Motion Models”, *Journal of Korean Society of Civil Engineers*, Vol.26, No.5D, pp.877-884, 2006.

[3] Wanninger, L. and Heßelbarth, A. “GNSS Precise Point Positioning und seine Anwendung in der Hydrographie”, Hamburg, DVW-Schriftenreihe Band 58/2009, pp.3-18, 2009.

[4] J. Kouba, “A Possible Detection of the 26 December 2004 Great Sumatra-Andaman Island Earthquake with Solution Products of the International GNSS Service”, *Studia Geophysica et Geodaetica*, Vol.49, pp.463-483, 2005.
DOI: http://dx.doi.org/10.1007/s11200-005-0022-4

[5] R. Dietrich, A. Rülke, J. Ihde, K. Lindner, H. Miller, W. Niemeier, H. W. Schenke, and G. Seeber, “Plate kinematics and deformation status of the Antarctic Peninsula based on GPS”, *Global and Planetary Change*, Vol.42, pp.313-321, 2004.
DOI: http://dx.doi.org/10.1016/j.gloplacha.2003.12.003

[6] K. Y. Jung and J. K. Park, “Development of Web-based Expert System for Convenient Precise Positioning”, *International Journal of Control and Automation*, Vol.7, No.5, pp.101-110, 2014.
DOI: http://dx.doi.org/10.14257/ijca.2014.7.5.12

[7] T. Reenskaug and J. O. Coplien, The DCI Architecture: A New Vision of Object Programming, 2009, http://www.artima.com/articles/dci_vision.html, (accessed Oct., 30, 2014)
[8] Code Project, Simple Example of MVC (Model View Controller) Design Pattern for Abstraction, 2008, http://www.codeproject.com/Articles/25057/Simple-Example-of-MVC-Model-View-Controller-Design, (accessed Oct., 30, 2014)
[9] J. K. Park, M. G. Kim and J. S. Lee, "Construction of Expert Service for GPS Relative Positioning Data Processing", *Journal of the Korea Academia-Industrial cooperation Society*, Vol.14, No.5, pp.2481-2486, 2013. DOI: http://dx.doi.org/10.5762/KAIS.2013.14.5.2481
[10] NGII, GNSS Data Service, 2013, http://gnss.ngii.go.kr, (accessed Oct., 30, 2014)
[11] K. S. Kim, "Crustal Deformation Monitoring by the Precise Positioning of Permanent GPS Site", Department of Civil Engineering, Graduate School Chungnam National University, pp.112-113, 2009.

Joon-Kyu Park [Regular member]

- Feb. 2003 : Chungnam National Univ., Civil Engineering, MS
- Aug. 2008 : Chungnam National Univ., Civil Engineering,, PhD
- Mar. 2011 ~ current : Seoil Univ., Dept. of Civil Engineering, Professor

<Research Interests>
Geodetic Science, Surveying, Geospatial Information

Kap-Yong Jung [Regular member]

- Feb. 2009 : Chungnam National Univ., Civil Engineering, MS
- Feb. 2013 : Chungnam National Univ., Civil Engineering,, PhD
- Feb. 2013 ~ current : Chungnam National Univ., Dept. of Civil Engineering, Researcher

<Research Interests>
Geodetic Science, Surveying, Geospatial Information