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LINEAR ALGEBRA WITH SAGE-MATH AND THE SMARTPHONE

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Over the last 20 years, our learning environment for linear algebra has been dramatically changed. Recently the Korean government initiated "e-Campus Vision 2007" and after that we designed it and actively adopted those changes for teaching of linear algebra in various ways. We found Sage-Math has features that can be used for most of the mathematical problems, including linear algebra, algebra, combinatorics, numerical mathematics and calculus. Nowadays there are more mobile/smartphones than the number of personal computers in the world. Furthermore, the most sophisticated smartphones have almost the same processing power as PC and it can be connected to the internet. For example, we can create a connection from mobile phone to Sage-Math server through the internet.

In this article we will show the technology we have developed over the years on Mobile mathematics with Smartphone in teaching of Linear Algebra. We will also discuss how those changes have affected the quality of student learning.

Key words: Linear Algebra, Sage, Mobile math, Matrix calculator, Smartphone, Technology

1. Introduction

IT has been the leading source of innovation in education. Korea is no exception to this tendency(http://www.elearningkorea.or.kr). Due in part to government investments, Korea is generally considered to be competitive in terms of internet connectivity, and most Koreans have easy access to internet services. South Korean tertiary institutions are in process in change. Five local universities ranked among the top 200 in the world in 2010, according to the London-based Quacquarelli Symonds education consultancy. This was up from just two in 2007

Korean Minister of Education announced "Strategies for Advancement of Mathematics Education' in January, 2012. Ministry of Education and Korea Science Foundation in Korea had a Declaration ceremony of 'The Year of Mathematics Education: 2012' in April 17th, 2012. According to that, CAS tool use for mathematics education in Korea will be more visible.

   For over 20 years, the issue of using an adequate CAS tool in teaching and learning of linear algebra has been raised constantly (Shiskowski & Frinkle, 2010; Butt, 2011). And a variety of CAS tools were introduced in several linear algebra textbooks. However, due to some realistic problems in Korea, it has not been introduced in the class and the theoretical aspect of linear algebra has been focused in teaching and learning of it. We have tried to find or make a simple and comprehensive method for using IT in our classes.

   We found that Sage-Math and it can be used for our linear algebra class. We did choose Sage as an alternative for CAS tool overcoming the problems mentioned above. It will be introduce, what we have developed over the years on Web and Mobile mathematics with Smartphone in teaching of Linear Algebra.

2. Learning Environment in 21st century

Due to the dramatic changes in educational environment, we are aware that CAS tool and internet resources can be incorporated into classes sooner or later. In particular, Korean students have a strong interest in such a tool. Korean students are not well trained with hand calculators or graphing tools, but they are now prepared for internet-based computational tools. Linear Algebra is the first abstract mathematics subject for most of new college students. Hence, most of the students face some difficulties to deal with various novel mathematical concepts at the level. Now most of instructors can demonstrate their work to students in the classroom through the internet, without the high-performance computer being present in the classroom. Students can therefore experience visualized results, which help enormously in understanding complicated new mathematical concepts.

3. Sage

   Korea has a decent internet infrastructure, but there are virtually no reasonable CAS tools for our mathematics classroom in general. Sage-Math (http://sagemath.org, Free open source software to do mathematical computations) should be considered a leading candidate for mathematical requirements. It was developed by William Stein at the University of Washington. It has a familiar grammar system, like the commercial software, and it follows the GPL (GNU Product License) and is therefore free. Furthermore, Sage-Math has a client-server model (illustrated in Figure 2 below) which is well-adapted to the internet. We found that Sage-Math could be an excellent solution for our needs, so a large effort has been made at our BK21 Mathematical Modeling HRD Division. We found Sage can be used for students' better understanding in college mathematics education.

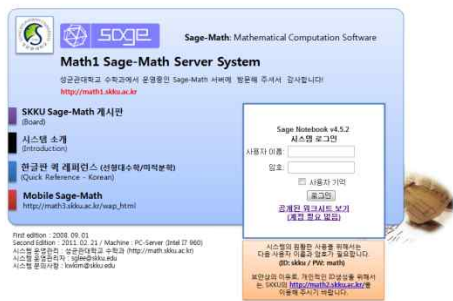## 4. Development of Korean version of Sage and Mobile Sage server.

   Sage is programmed in the Python programming language, which has many functions related to mathematical computation. Furthermore, Sage is open source software, so it can be modified freely.

We were able to understand the structure and customize it for our needs. The following <Table 1> shows the address of our Sage servers.

Table 1: Address of Sage servers

Location	Nature	Address for open sources
Korea	Sage Server 1	http://math1.skku.ac.kr/pub/
Suwon	Sage Server 2	http://math2.skku.ac.kr/pub/
SKKU	Mobile Sage	http://math3.skku.ac.kr/pub/
BK21 Lab	Single Cell	http://matrix.skku.ac.kr/2012-sage/

Students may install Sage on their PC if they have a limited access to Internet. A snapshot of the website is provided in Figure 1. In order to use full feature of Sage, Google Chrome and Firefox are recommend. The primary hosting site is the following:

http://math1.skku.ac.kr(ID: skku, Password: math)

Figure 1 Front page of one Korean Sage server

5. Linear Algebra with Sage Contents

We have developed most of Sage commands for teaching of elementary linear algebra class as a following web contents. A snapshot of the website http://matrix.skku.ac.kr/2012-Sage/sage-la/is provided in Figure 2.

Figure 2 Web: Sage commands for Linear Algebra class

Linear Algebra with Sage

Students can save times to learn or memorize most of Sage commands and programming languages. http://matrix.skku.ac.kr/2012-Sage.They only have to find in the organized web page or published pages, copy and paste their commands, they may revise when it is necessary.

6. Mobile Sage

Sage can be applied on various other platforms which have a connection with the internet, such as MP3 players, cellular phones, Sage was written in the Python language, and Python supports the XML-RPC functions. Thus, we can use this function to revise Sage source code. Proceeding in this manner enables all clients which are able to connect to the internet to get the output of mathematical computation (including graphic visualizations) from the Sage server.

XML-RPC can be used on cellular phones, so mathematical results using Sage can be freely displayed in any location. Students do not need to spend their time to install specific software on their cellular phones; simple internet connectivity is required. The computation load will be entirely borne by the server. We have made a mobile service module which fits on cellular phones.

Furthermore, we have developed the mobile module of Sage for use in smartphone environment. Some mobile contents and smartphone App was developed. It has all lecture notes, video lectures, solutions of problems, computational tools and social networking features. Now students can have a whole process of learning linear algebra in their hand.
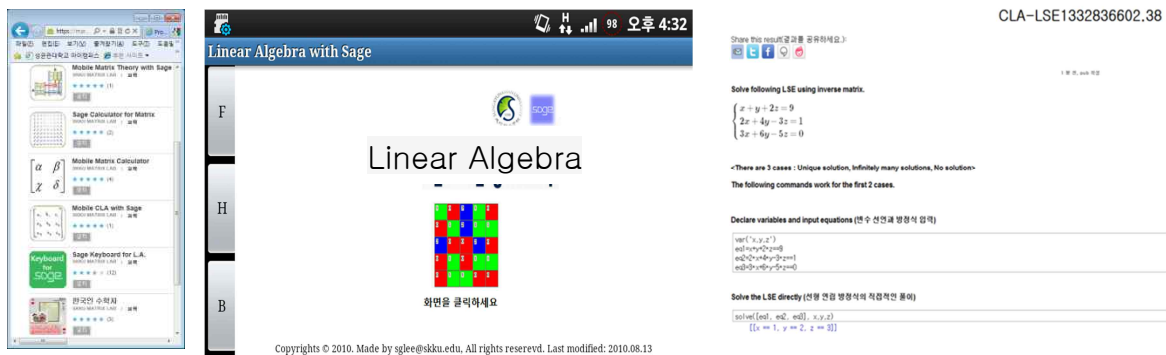

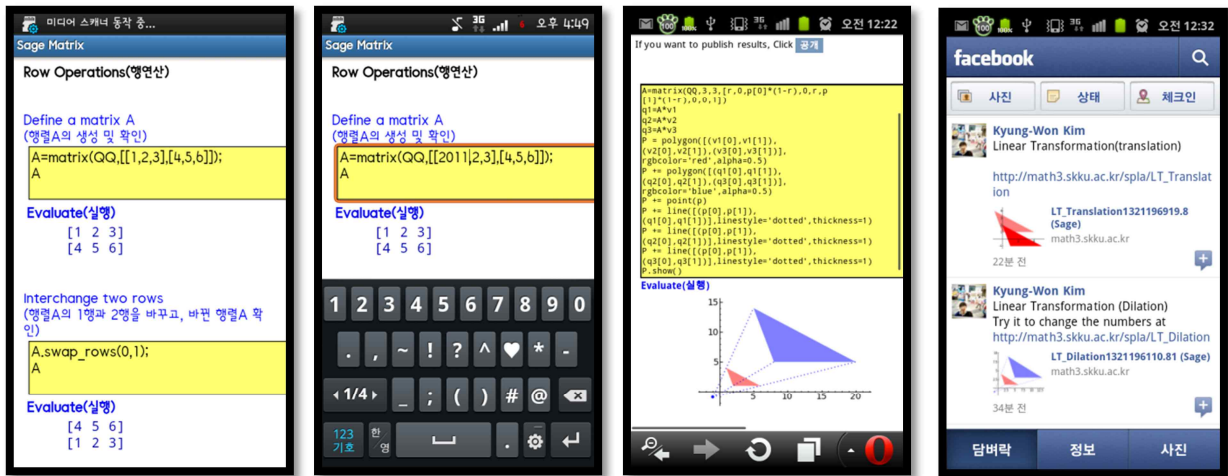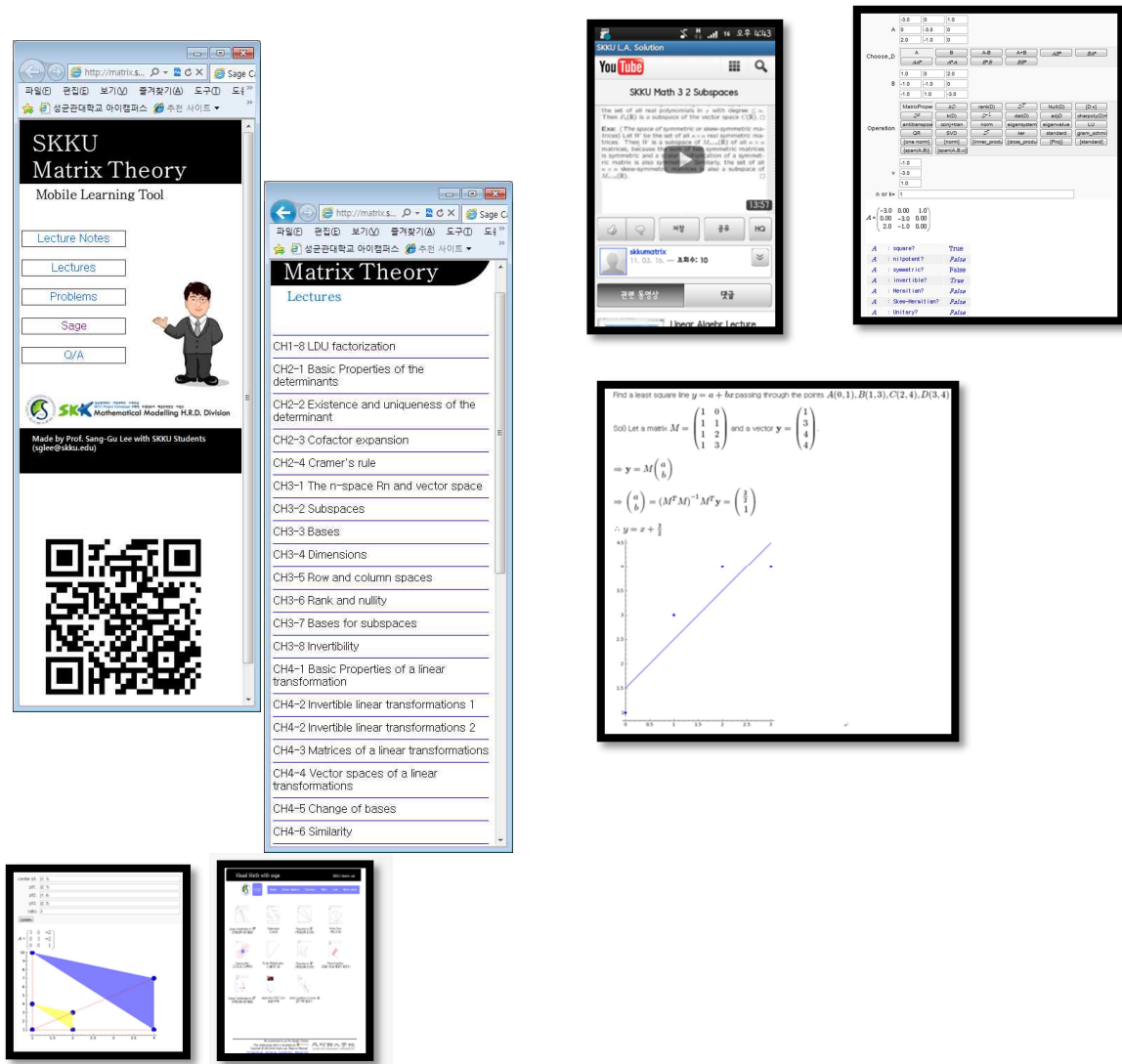**Figure 3 Free Android Smartphone App's for Linear Algebra**

Figure 4 What to do with Android Smartphone App's for Linear Algebra

Recently, we found single cell server http://matrix.skku.ac.kr/2012-Sage for computation and simulation which is prefered by the students.

7. Conclusion

In 2005, Bill Gates of Microsoft mentioned the 2nd IT Boom and Mobile revolution. We were trying to find, what we can do for a better teaching of Linear Algebra in this changing educational environment. We found Sage-Math and Mobile Sage can be well used for our linear algebra class in 21st century.

In this article, we introduced web contents for most of Sage commands for linear algebras, and a model of smartphone App that contains Lecture PPT, Lecture movies, Solutions on Problems, and Computational tools with most of Sage commands. It provided all possible resources for students not only to study the contents but also to deal with large size computations such as LU, SVD, QR algorithms and visualizations that can be used for their own research problems with no cost and time to learn programing language. We tried to provide affordable and inspiring solutions and model on effective teaching and learning of Linear Algebra.

References

Bahns, D., &Schweigert, C. (2007).Softwarepraktikum - Analysis und Lineare Algebra: Ein MAPLE-ArbeitsbuchmitvielenBeispielen und Lösungen, Vieweg+Teubner.

Butt, R. (2011).Applied Linear Algebra and Optimization Using MATLAB, Mercury Learning & Information.

Gray, M.A. (2008). Sage: A New Mathematics Software System, *Computing in Science & Engineering*, 10(6), 77-75.

Kim,D.-S., Bak, J.Y.& Lee,S.-G. (2008). The educational models using enhanced mathematics ICT in the Korean IT environments, *J. Korea Soc. Math. Ed. Ser. E: Communications of Mathematical Education,* 21(2), 533-543.

Kim, D. -S., Lee,S.-G. & Jung, K. -H. (2007). Linear Algebra Class Model using Teachnology(Matlab)-LINEAR SUBSPACES OF R^n, *J. Korean Soc. Math. Ed. Ser. E; Communications of Mathematical Education*, 21(4), 621-64.

Kim, D. -S., Markowsky, G. & Lee, S. -G. (2010). Mobile Sage-Math for linear algebra and its application, *Electronic Journal of Mathematics and Technology,*4(3), 1-13.

Ko, R. -Y.,Kim, D.-S.,Bak, J. -Y.&Lee, S. -G. (2009).Development of Mobile Sage-math and its use in Linear Algebra, *J. Korea Soc. Math. Ed. Ser. E: Communications of Mathematical Education*, 23(4), 483-506.

Lee, S. -G. (2009). Contemporary Linear Algebra, Kyungmoon Publish Ltd.

Lee,S.-G. & Kim,D.-S. (2009).MathML and JAVA Implementation in Linear Algebra, *The Electronic Journal of Mathematics and Technology,*3(1), 1-11.

Lee, S. -G. &Ham, Y.-M. (2005).New Learning Environment of Linear Algebra in Korea, *Journal of Korean Soc. Math. Ed. Ser. D: Research in Mathematical Education*, 9(1), 57-66.

Lee,S.-G.,Yang, J. –M. &Wellman, R. (2001). Use of CAS tools the 7th Math. Educational curriculum*, J. Korean Soc. Math. Ed. Ser. E; Communications of Mathematical Education*. 11, 355-365.

Neil, P. (1991). Visualization in linear algebra, *International Journal of Mathematical Education in Since and Technology*, 22(3), 387-394.

Torrence, B. F.&Torrence, E. A. (2009). The Student's Introduction to Mathematica: A Handbook for Precalculus, Calculus, and Linear Algebra, 2nd ed., Cambridge University Press.

William, S.& David, J. (2005). SAGE: System for Algebra and Geometry Experimentation. *ACM SIGSAM Bulletin*, 39(2),61-64. http://www.sagemath.org/library-publications.html