



2014 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
SCIENCE, TECHNOLOGY, ENGINEERING, MATH & EDUCATION
JUNE 16, 17, & 18 2014
ALA MOANA HOTEL, HONOLULU, HAWAII

DEVELOPMENT OF AN INTERACTIVE TEXTBOOK FOR COMMAND-SHAPING CONTROL METHODS

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Development of an Interactive Textbook for Command-Shaping Control Methods

Synopsis

The paper presents an interactive textbook for teaching command-shaping control methods to engineering students.

DEVELOPMENT OF AN INTERACTIVE TEXTBOOK FOR COMMAND-SHAPING CONTROL METHODS

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ABSTRACT

Many universities, high schools, and elementary schools are attempting to capitalize on the success of the iPad by generating curricula that exploit portable touchscreen computers. One important element of these efforts is the development of interactive textbooks that go beyond the static display of printed words, equations, and figures. Features of interactive textbooks include: embedded videos that can be viewed with the tap of a finger, picture slideshows, user-controlled simulations, and interactive charts that accept user input and provide immediate feedback. Unfortunately, the skill sets required to generate such books usually do not reside in one person. Some professors may have the knowledge to produce traditional textbooks, but they usually lack the skill and time to produce interactive elements. However, undergraduate students, graduate students, and web designers can be trained to develop the drawing and programming skills required to develop the interactive elements. This paper describes how an interactive textbook was developed for courses that teach command-shaping control methods. The features of the book are illustrated and ideas for future work that can improve interactive textbooks are discussed.

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1 INTRODUCTION

The success of the iPad has led to a revolution in portable computing. Many universities, high schools, and elementary schools are capitalizing on this revolution by generating curricula to exploit portable touchscreen devices. While these tablet devices have been available for only a short time, results are already showing that the devices offer interactive functions that can improve learning.

Two important goals can be achieved by integrating tablet computers into classrooms: improved student motivation and improved learning. Liu et al. developed an iPad-based signal-processing project to enhance an electrical engineering course at Arizona State University, and found that the activity improved student enthusiasm, as well as learning outcomes [1]. Perez et al. found that student grades and student satisfaction improved when students were provided with iPads, even if those iPads had no particular software for the courses in which they were issued [2]. Oostveen studied the work of non-science students and obtained mixed results. This suggests that the way students interact with tablet devices is an important factor in their overall outcomes [3]. Weisberg reported a project in which undergraduate business students were given a variety of digital readers in order to compare their different experiences and outcomes with those of students using a traditional hard copy textbook [4]. Here again, results were mixed, as students who used the different com-

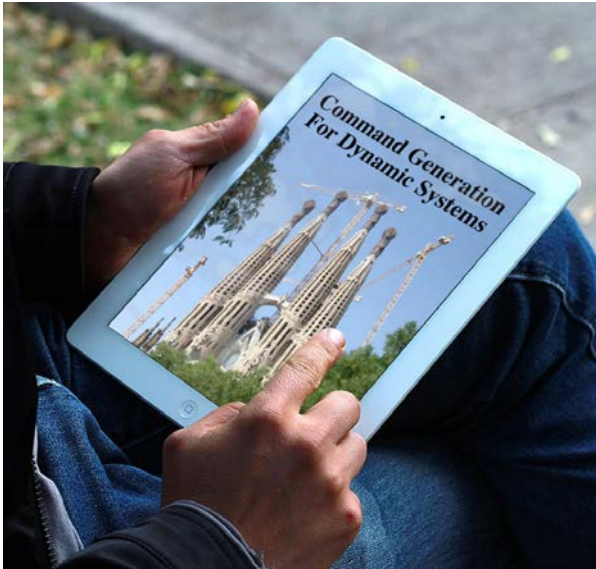


Figure 1: Cover of iBook.

puter devices had outcomes that were similar to those using traditional textbooks.

These findings indicate that students respond well to tablet computers when they offer some type of interactive capacity that addresses course goals. At the time these studies were conducted, interactive projects were difficult to develop and interactive textbooks were not widely available. The problem that is revealed in these curriculum development efforts is that interactive textbooks must move beyond the static display of printed words, equations, and figures that are typically seen when traditional textbooks are converted for display on computer screens.

Features that extend interactive textbooks beyond traditional books include: embedded videos that can be viewed with the tap of a finger, picture slideshows, rotating 3D drawings, user-controlled simulations, and interactive charts that accept user input and provide immediate feedback. To be effective, interactive elements must illuminate the course material in seamless and interesting ways.

Unfortunately, the skill sets required to generate interactive books usually do not generally reside in one person. Some professors have the knowledge and experience to produce traditional textbooks, but they often lack the skill and time required to make the interactive elements. However, undergraduate students, graduate students, or web designers can be trained to develop the interactive elements.

An interactive textbook offers many capabilities, and it requires both authors and students to reconsider how a book looks and works. Figure 1 shows an iPad opening up the interactive textbook described in this paper. *Command*



Figure 2: Chapter Format.

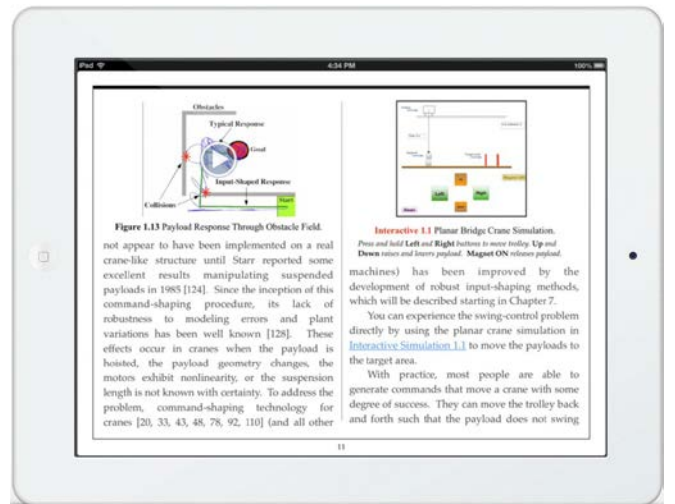


Figure 3: Interactive Crane Page.

Generation for Dynamic Systems [5] is a textbook that focuses on non-feedback control methods. Figure 2 shows the format when the book is opened to the start of Chapter 1. Near the bottom of the page are small figures that preview the next several pages of the chapter. The user is able to jump ahead several pages by simply touching one of the small icons. At the very bottom of the screen is a row of dots that allow the user to jump to other chapters.

Figure 3 shows the format of a single page with two columns. At the top of the left column is an embedded video. When the reader touches the arrow in the center of the figure, a video demonstrates the difficulty of moving a crane with a suspended payload. The video shows the oscillation problem in a meaningful way that cannot be captured by a two-dimensional plot of the time response. At the top of the right column is an interactive simulation of a crane. When then reader clicks on this object, a simulation window appears with buttons that allow the user to drive

a real-time simulation of a bridge crane. The user presses the Right, Left, Up, and Down buttons to transfer a payload from the left side of the simulation window to a target location on the right side of the window.

The next section of this paper describes how a team was formed to produce a textbook that would take advantage of the interactive capabilities provided by the iBooks environment. Section 3 documents and illustrates the features and advantages of the command-shaping iBook. Section 4 discusses future work that can improve interactive textbooks.

2 DEVELOPMENT TEAM

The interactive book discussed in this paper started as a traditional textbook that was written by authors Singhose and Seering [5]. Drs. Singhose and Seering are mechanical engineering professors at Georgia Tech and MIT, respectively. They teach courses in mechanical design, system dynamics, and controls. While these two authors were able to create a traditional textbook, they lacked the skill set and time to develop and integrate interactive elements.

To produce the interactive elements, funding was obtained from the Pappalardo Textbook Fund and industrial sponsors to hire and train undergraduate and graduate students. The undergraduates created three-dimensional drawings that can be rotated with a swipe of a finger. The graduate student was tasked with creating several advanced interactive elements that complemented and extended the material that was in the traditional textbook. To this end he created embedded videos, real-time simulations, and interactive charts that were designed to augment the traditional textbook material. These interactive elements are described in the following section.

3 INTERACTIVE FEATURES

The program **iBooks Author**, distributed at no cost by Apple, allows authors to easily insert interactive elements, generally described as “widgets,” into their books. However, creating the interactive elements is a programming challenge. For example, if an interactive dynamic simulation is to be inserted, then there is no shortcut for creating the simulation. The dynamic mathematical model must first be generated. Then, the simulation interface must be developed, the real-time commands that are received through the interface must be transferred to the model, and the output of the simulation must be visually displayed on the screen. The widgets discussed in this section were programmed in Apple’s Dashcode environment; however, they are essentially embedded webpages, so any webpage de-

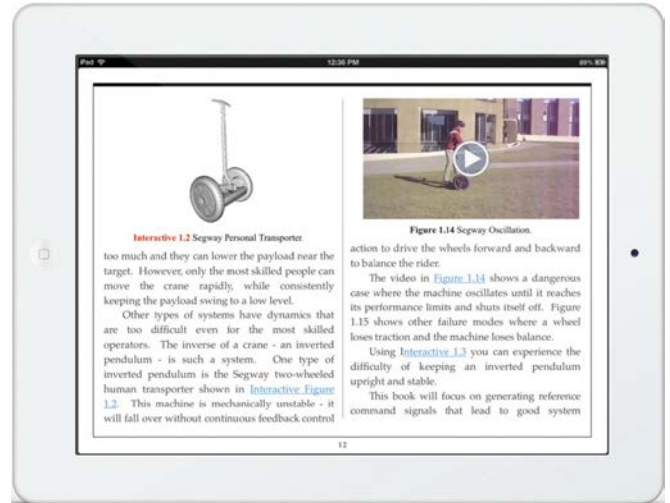


Figure 4: Interactive Inverted Pendulum Page.

velopment software could be utilized. The **iBooks Author** program provides some built-in interactive features. Three of these elements are discussed on the following subsections.

3.1 Picture Galleries

Among of the simpler interactive elements are picture galleries. Such galleries provide two main functions, i) they save space by decreasing the need to advance pages, and ii) they allow the user to compare multiple pictures quickly and in a single place. This is an improvement over conventional textbook layouts, where related images may not be close enough together for the reader to view them at the same time.

3.2 Three-Dimensional Drawings

Figure 4 shows a page in the book that contains two interactive elements related to inverted pendulums. The image on the left is a detailed solid model drawing of a Segway Personal Transporter. The user can examine this drawing in detail by tapping on the figure to expand it. In addition to expanding the figure, the user can, with a finger swipe, rotate the figure and examine the drawing from all angles. A progression of such rotations is shown in Figure 5. This display of 3-Dimensional images is a significant advance over the flat displays of traditional textbooks. This is particularly true in engineering courses, where detailed objects must be presented and examined.

3.3 Embedded Videos

Another useful feature of an interactive textbook is the ability to embed video within the book. By simply touching a figure, the book will start to play a video that can

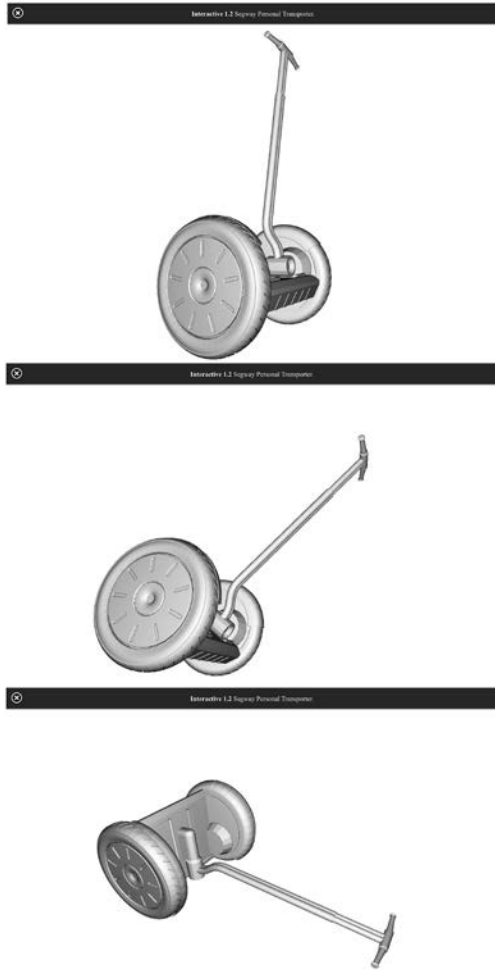


Figure 5: Progression of 3D Drawing Rotations.

visually illustrate a concept that might be very difficult to convey with words, equations, and static figures. The image on the right side of the page shown in Figure 4 is an embedded video that shows the oscillation and instability problem of the Segway. Figure 6 shows a few frames from the video. The ability to show a video that explains a concept that is hard to describe with text and 2D static figures is an invaluable feature of interactive textbooks.

3.4 Real-Time Interactive Simulations

The right side of Figure 3 showed an interactive real-time simulation of a bridge crane. Figure 7 shows the expanded view of the simulation. Near the bottom of the screen are buttons that allow the user to move the overhead trolley of the crane. They can move it left or right. They can also raise and lower the payload by pushing the

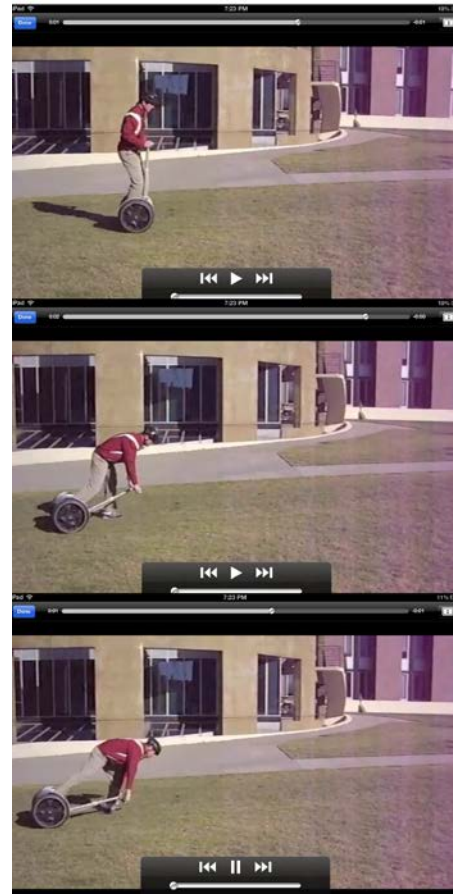


Figure 6: Frames from a Segway Accident Video.

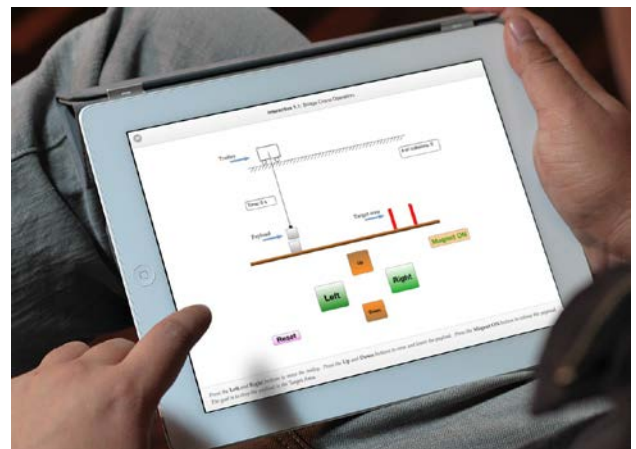


Figure 7: Interactive Bridge Crane Simulation.

Up and **Down** buttons. The goal of the simulation is to give the user a “hands-on” experience of driving a crane. They quickly learn that it is difficult to control the payload because it swings every time a **Left** or **Right** control button is pushed. The instructions that go along with the simula-

tion challenge the user to pick up the payloads and safely deposit them in the area between the two red walls shown on the right side of the simulation screen. A progression of one such trial is shown in Figure 8. With a little practice, the user can usually develop the skill to control the payload swing and safely lower the payloads into position.

The book also contains an interactive simulation of the inverse of a crane - an inverted pendulum. This simulation is used to illustrate the difficulty of controlling such systems over and beyond the difficulty of controlling a crane. The simulation is used in connection with the 3D drawings and videos of the Segway shown in Figures 5 and 6. The instructions that explain the inverted pendulum simulation challenge the user to move the inverted pendulum to the middle of the screen and maintain it balanced within a target area delineated by red walls. A progression of such a simulation is shown in Figure 9. This hands-on experience is virtually impossible to master - the pendulum usually falls over in a short period of time. This provides a nice complementary experience to the crane simulation.

These simulations are critical for interactive textbooks because they realistically represent engineering concepts, while providing entertaining interactions for the student users of the textbook. The development of such interactive simulations should be a top priority for authors of engineering textbooks.

3.5 Interactive Charts

The same programming structures that are used to create real-time interactive simulations can also be used to create interactive charts. These widgets can be used to prompt the user for input to questions and then provide immediate feedback to the user. Or, they can be used to step the user through an engineering process. Users only get to proceed to the next step once they have correctly mastered the current step in the process. Another interesting use is to allow the reader to assemble individual functional blocks into complete and connected block diagrams.

4 FUTURE WORK

The current version of the textbook has a variety of interactive components that make it more valuable than the traditional words-and-figures version of the book. However, the interactive elements can clearly be improved using feedback from the users - just as any book can be improved with feedback.

The area that needs the most improvement are the interactive charts. Because these are mostly static displays, they are fundamentally less compelling than the real-time

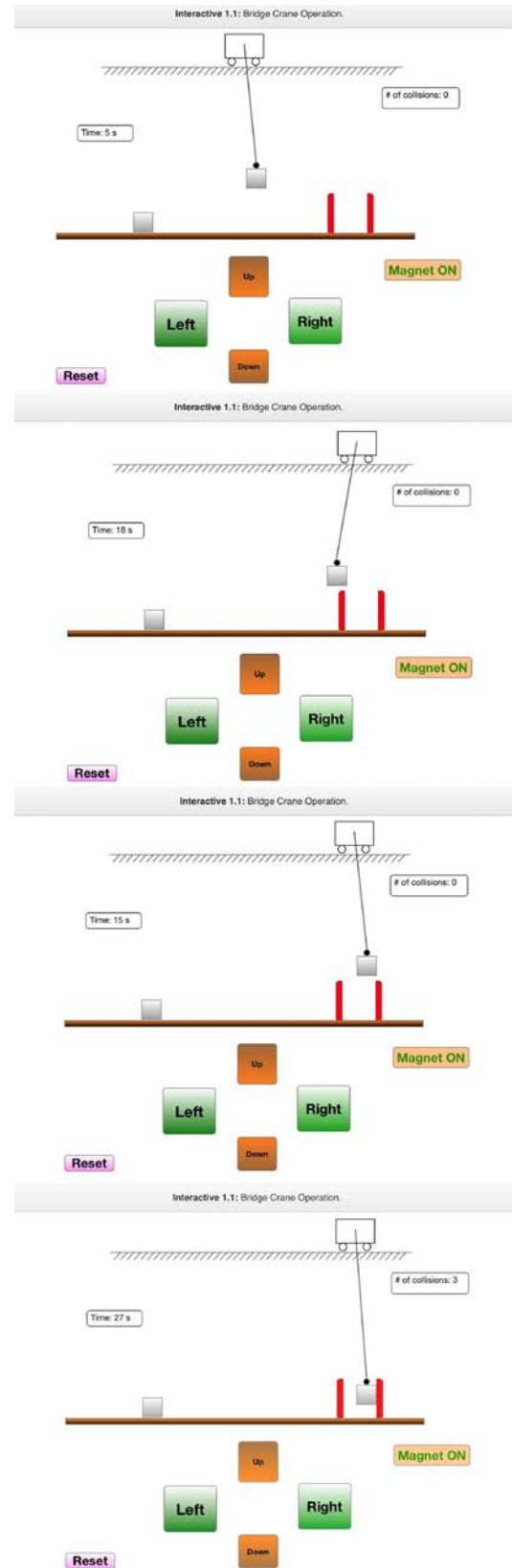


Figure 8: Progression of Crane Simulation.

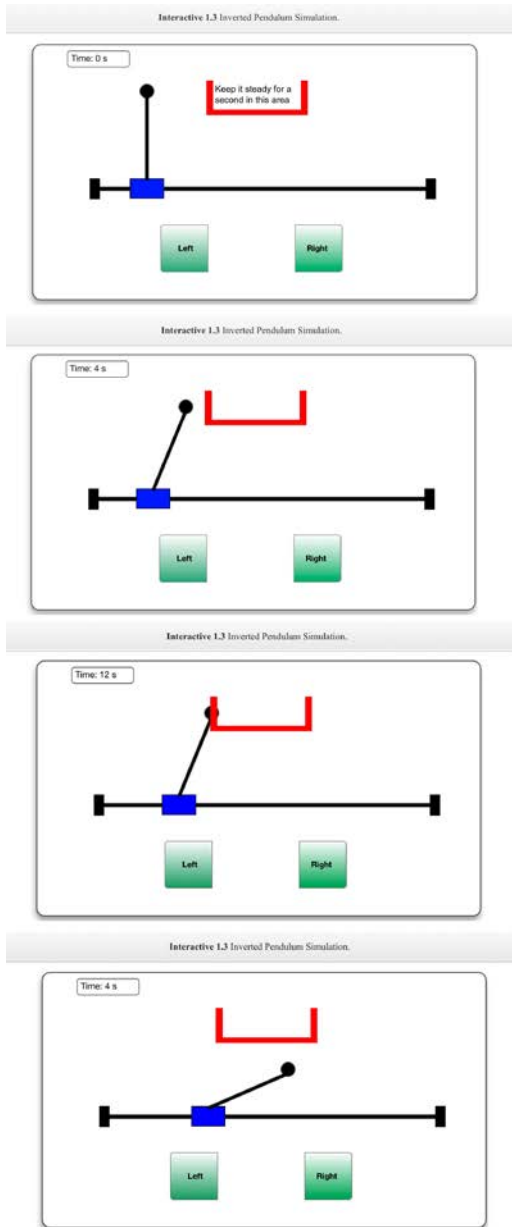


Figure 9: Progression of Inverted Pendulum Simulation.

simulations, embedded videos, and rotating 3D drawings. Such innovations will require authors to use imagination, as well as programming skill. New methods must be sought for students to interact with course materials that have been presented in static form, for some of us, through our whole careers. Therefore, methods for improving the ease of use, increasing the motivation for completing the charts, and providing improved feedback from the chart to the user would be very useful.

5 CONCLUSIONS

Interactive textbooks can provide significant features that traditional textbooks cannot. Some of the more important interactive features include: picture galleries, rotating 3D drawings, embedded videos, real-time simulations controlled by the user, and interactive charts. Unfortunately, the skills needed to create a textbook with such diverse features usually do not reside in one person; rather a team is needed to develop interactive textbooks. Such a team was used to develop a textbook on command-shaping control methods. This paper demonstrated the features and utility of many of the interactive elements contained within the book.

6 ACKNOWLEDGEMENTS

Our controls courses have been supported by donations from Siemens, CAMotion Cranes, and Boeing. Without their support, the interactive textbook could not have been developed. Furthermore, we would also like to thank the Pappalardo Textbook Fund for sponsoring the initial development of our iBook. Finally, we would like to thank Kevin Miron for his development of the three-dimensional drawing of the Segway.

REFERENCES

- [1] Liu, J., Thiagarajan, J., and Spanias, A., 2011. "Iphone / ipad based interactive laboratory for signal processing in mobile devices". In American Society of Engineering Education Annual Conference, pp. AC 2011–456.
- [2] Perez, A., Gonzalez, V., Pitcher, M., and Golding, P., 2011. "Work in progress: Analysis of mobile technology impact on stem based courses; specifically introduction to engineering in the era of the ipad". In American Society of Engineering Education Annual Conference, pp. AC 2011–1126.
- [3] van Oostveen, R., and W. Muirhead, W. G., 2011. "Tablet pcs and reconceptualizing learning with technology: a case study in higher education". *Interactive Technology and Smart Education*, **8**(2), pp. 78–93.
- [4] Weisberg, M., 2011. "Student attitudes and behaviors towards digital textbooks". *Publishing Research Quarterly*, **27**, pp. 188–196.
- [5] Singhose, W., and Seering, W., 2009. *Command Generation for Dynamic Systems*. No. 978-0-9842210-0-4. www.lulu.com/content/621219.