MOOC on The Art of Grasping and Manipulation in Robotics: Design Choices and Lessons Learned

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Abstract. This paper presents guidelines for designing a MOOC on Advanced Robotics topics based on the authors' experience in creating an on-line course on *The Art of Grasping and Manipulation in Robotics*. After a revision of the main MOOCs and video lectures about Robotics that are available on-line, we present our course and describe the preliminary feedback we gathered from a group of Master students.

Keywords: MOOC, Robotic Grasping, Teaching Robotics

1 Introduction

Starting from 2012, MOOCs (Massive Open Online Courses) became fundamental resources in higher education and are now opening new entrepreneurial possibilities [27]. They boost the self learning of students, with easily retrievable and well structured information, and create international educational networks. A relevant advantage of MOOCs is that they make available also very specific courses, that a student couldn't get with traditional learning means. These aspects make MOOCs particularly suitable also for teaching Robotics related topics [5]. The absence of a direct contact between the teacher and the learner in MOOCs may lead to uncertainties on what is actually learnt, so this type of resources needs to be carefully designed and organised [19].

In this paper, we present a MOOC on *The Art of Grasping and Manipulation in Robotics*, that explains the mathematical foundations of grasping and the features of SynGrasp, a MATLAB® Toolbox for the simulation of human and robotic hands.

Providing a robotic system with the ability of reaching, grasping and manipulating objects is one of the main challenges in robotics research. However, to the best of our knowledge, there exist few freely available educational resources regarding this topic, especially for autonomous learners. Robotic grasping and manipulation deserve a special attention also in higher education, so that students and engineers can approach the new challenges in this field with a solid theoretical background and also the knowledge of the latest results. A MOOC containing the mathematical bases and some of the latest results in the field of robotic grasping could interest students and researchers with various backgrounds, from mechanical and mechatronic engineering, to computer science, neuroscience, and medicine. Indeed, the mathematical models underlying robotic hands can be applied also to human hands and prostheses.

The rest of the paper is organized as follows. In Sec. 2 we analyse available educational resources on robotic grasping and manipulation, and list some of the most important online courses on Advanced Robotics. Sec. 3 presents our course and describes how our design choices were evaluated by 26 students. The results of the questionnaire were encouraging and provided us with several insights on how advanced robotics topics can be tackled with a MOOC.

2 Previous Work

2.1 Educational Resources on Robotic Grasping and Manipulation

Classical theory and applications of robotic grasping have been summarized by Prattichizzo and Trinkle in the chapter entitled *Grasping* included in the Springer Handbook of Robotics [18], but also in books [13, 17], and reviews [2]. In the MOOC that we describe in this paper, we explain the theory of grasping with the help of simulations performed using the SynGrasp MATLAB Toolbox [16], similarly to what was done by Peter Corke in his book [4] and in the MOOCs *Introduction to Robotics* and *Robotic Vision*, where the explained theoretical concepts were associated to MATLAB examples using the Robotics Toolbox [5].

SynGrasp has been developed by the Siena Robotics and Systems Laboratory since 2012, and contains more than 300 functions and scripts for grasp analysis. It has been downloaded more than 4000 times, and it is currently used in 3 European Projects and continuously updated. Thanks to its simplicity and intuitiveness, the toolbox is well suited for education and is already used in the courses of Robotics, Human Centered Robotics, and Mechanical Systems of the University of Siena.

2.2 On-line Courses on Advanced Robotics

Robotics is starting to face more human-centered problems [24] and is opening many new challenges [1]. This explains why on-line courses on advanced robotics continuously increase in number, and involve some of the best Universities in the world.

One of the most popular robotics courses on YouTube is *Introduction to Robotics* by Professor Oussama Khatib [14]. It was recorded in 2008 during the CS223A course of the Stanford Computer Science Department. The 16 lectures cover all basic topic of robotics and last between 58 and 77 minutes. The first three lectures had $504,829$, $176,534$, and $81,804$ views, respectively. The average number of views of the other videos is around $35,000$. Another playlist that is on-line since 2008 is the *Lecture Series on Robotics* by Prof. C. Amarnath [1], whereas *Underactuated Robotics* by Russell Tedrake is on YouTube since 2010 [26].

More recent resources include *Robotics 1* by professor Alessandro De Luca (2014) [9], *Evolutionary Robotics* by Josh Bongard (2016) [3], *Fundamentals of Neuromechanics* by Valero Cuevas (2016) [7], and *Programming for Robotics (ROS)* by Péter Fankhauser *et al.* (2017) [12]. In 2017, Frank Park and Kevin Lynch published their book *Modern Robotics: Mechanics, Planning, and Control* [15], that is enriched with more than 90 videos covering all the chapters of the book[2].

[1] www.therobotreport.com/10-biggest-challenges-in-robotics/
[2] hades.mech.northwestern.edu/index.php/Modern_Robotics_Videos

The MOOC entitled *Control of Mobile Robots*, delivered by Magnus Egerstedt in Coursera since 2013 [11] was one of the first MOOCs on robotics and was used in a flipped classroom experiment to demonstrate its efficacy [8]. In February 2016, Coursera presented its first Robotics Specialization, consisting of a series of six courses from University of Pennsylvania [6]. Recently, also edX launched several robotics micromasters and courses[3], created by top universities, including Columbia University, University of Pennsylvania, MIT, and ETH Zurich. At the beginning of 2017, Bruno Siciliano launched his MOOC on *Robotics Foundations I - Robot Modelling*, that covered some chapters of his textbook [23] and was delivered through the Federica.EU portal.

3 MOOC on *The Art of Grasping and Manipulation in Robotics*

3.1 Design

The act of grasping and manipulating tools is the ultimate interface of a robotic system with the environment and it is one of the most complex tasks in industrial, service and humanoid robotics. This is why it has attracted the interest of the robotics community in recent years, as shown by the increasing number of articles, workshops [20, 21, 25], and projects on this topic. The development of robotic hands, in particular, is a cutting-edge research field, and the new trend is building soft and underactuated devices that can easily interact with the environment and with humans [10, 22]. This new manipulation paradigm is posing stimulating problems from the control, actuation and sensing points of view. Undergraduate students as well as researchers in robotics must have the tools to address these and other challenges that are arising in the field of grasping and manipulation, and for this reason we decided to create a MOOC containing the basic notions about these subjects.

The main challenge for an educator that creates a MOOC is to avoid that students get “lost in information”. The learning flow must be clearly stated from the beginning, and video lectures must explain one, or maximum two, important concepts at a time.

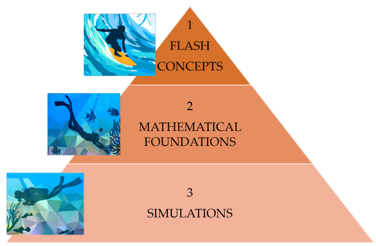
The book written by Murray et al. [17] in 1994 is a complete and fundamental reference textbook for the study of robotic manipulation. However, it can be very complex for students without a background in robotics or mechanical engineering. To encourage self-learning and create educational resources suitable for a diverse public, we adopted a pyramidal course structure with three main levels of learning (Fig. 1). We called them “Surfing”, “Snorkeling”, and “Scuba Diving” to transmit the idea that level by level, students will get a deeper and deeper understanding of the subject. People who have never studied robotic grasping will start by scratching the surface of the topic through very concise lectures explaining basic concepts (Level 1: “Surfing”). These concepts will be then examined in depth by looking at the underlying math, with equations and rigorous proofs in Level 2: “Snorkeling”. Level 3: “Scuba Diving” will allow students to apply the knowledge acquired in previous levels to code simulations with the SynGrasp MATLAB Toolbox [16].

The MOOC on *The Art of Grasping and Manipulation in Robotics* was recorded during real lectures and is structured in 4 units: the first belongs to Level 1, the second and the third to Level 2, and the last to Level 3 (see Fig. 1). Unit 1 explains basic

[3] https://www.edx.org/course?search_query=robotics

notions for understanding robotic grasping, including the difference between power and precision grasps, the friction cone, and the Grasp Matrix. Units 2 and 3 explain the mathematical model of a grasp and how it can be used to design proper control strategies for grasping tasks. Unit 4 introduces the features of SynGrasp Toolbox, and proposes some simulation exercises to the students.

Instead of relying on a specific MOOC platform, we published the MOOC in YouTube Playlists that can be retrieved from the website of the course[4]. This choice has the main drawback that student's can't get a certificate after the course, but guarantees a wider spread of it.



Level	Contents
Level 1 (“Surfing”)	Unit 1: Basic concepts
Level 2 (“Snorkeling”)	Unit 2: Grasp modelling
	Unit 3: Grasp control
Level 3 (“Scuba Diving”)	Unit 4: SynGrasp

Fig. 1: Levels of learning (left) and how they are implemented in our MOOC (right).

3.2 Students' Feedback and Lessons Learned

Between November and December 2017, the MOOC on *The Art of Grasping and Manipulation in Robotics* was used as a support for the first part of the course on *Human Centered Robotics* held by Prof. Domenico Prattichizzo at the Master of Science in Computer and Automation Engineering at the University of Siena. We asked 26 students, of which 18 declared that *Human Centered Robotics* was their first course in robotics, to fill in a questionnaire about the MOOC. The form was divided into 5 sections and contained a total of 28 questions. Most of them were five-level Likert items, others required a short answer. We report in this section the relevant results, as well as the lessons learned from them.

When asked to rate their satisfaction about the course with a score from 1 (“Not very”) to 5 (“Very much”), the majority of students answered with 4 (9 students, *i.e.* 34.6% of the answers) or 5 (8 (30.8%)). Nobody answered 1. Only one student answered 2, and the main concern that he underlined was a lack of exercises in the video lectures. This weakness was underlined also by other 5 students when answering to the question “What is the thing you liked least about the course?”, and by the answers to questions C3 and C6 (Fig. 2).

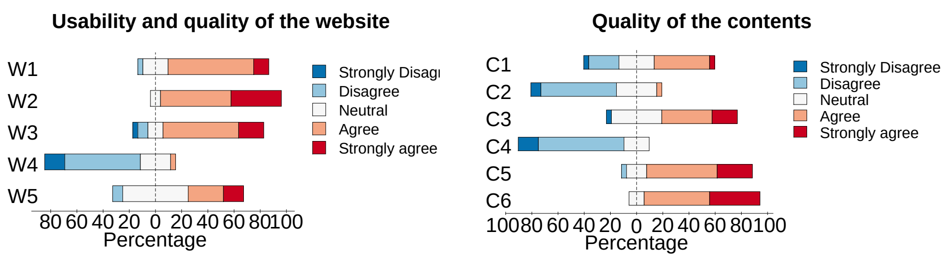
Results summarized in Fig. 2, show that in general students appreciated the MOOC website and contents. Videos were found interesting and were not perceived as too long. One of the questions requiring a short answer was: “What is the thing you liked most about the course?”. Students' answers indicate that they especially liked the fact that video lectures can be watched also by student-workers. Most of the students agreed that

[4] sirslab.dii.unisi.it/MOOC/index.html

having video lectures also for other courses would be very useful, and that watching the videos gave them a strong help while studying for the exam.

Interviewed students had different backgrounds, ranging from information engineering and computer science (21) to management engineering (3), physics (1), and mechanical engineering (1). We asked them if their previous knowledge was sufficient for understanding the course: 7 ($\sim 27\%$) disagreed and expressed the need for additional material on robot kinematics and dynamics and linear algebra.

The results of the questionnaire underlined that enriching university courses with a MOOC can be useful for students, above all when they have to learn specific topics for which educational material is not always easy to consult. We also gathered important suggestions on how to improve our course before promoting it in the robotics community. We will enrich it with more exercises and practical examples, and with material or references explaining the background required to follow the course.



W1:	The website of the course is easy to navigate
W2:	Having the videos on YouTube is an advantage
W3:	The audio of the videos is clear
W4:	The video quality is too low
W5:	A discussion forum in the website would help students a lot
C1:	My previous knowledge was enough to understand the videos
C2:	Having different video formats is confusing
C3:	The additional material available in the website should be enriched
C4:	The videos are too long
C5:	The lecturers stimulate students' interest
C6:	There should be more exercises and practical examples

Fig. 2: Students' answers to the question "Express how much you agree to the following statements on the course *The art of grasping and manipulation in robotics*".

4 Conclusions and Future Work

In this work we presented a new MOOC on *The art of grasping and manipulation in robotics*, that is on-line since November 2017. Thanks to the preliminary feedback of 26 students, the course will be improved, and will be promoted within the robotics community starting from April 2018. The content will be continuously updated with new resources and cutting edge research topics.

5 Acknowledgement

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