Teaching Mechanical Engineering and Humanoid Robotics with respect to Gender and Diversity Aspects

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INTRODUCTION

The basic principles in engineering mechanics and robotic courses such as kinematics have the reputation of being difficult and primarily of academic interest. Previous experiences show that many students have problems retaining their knowledge, mastering fundamental methods, and applying them in a new context even after multiple exposures to a certain topic. For example, even though basics of kinematics is usually dealt with extensively at school and in introductory physics courses at universities, many students encounter serious difficulties in trying to solve even simple problems of kinematics posed in engineering mechanics courses. But instead of repeating the same topic over and over, a student-centred learning unit is presented in which prior knowledge and empirical learning interact in order to construct a new understanding of, to a certain extent, presumably familiar physical relations.

1 BASIC CONSIDERATIONS

Simple human activities, such as „the throwing of a ball“, include complex issues when they are regarded under technical, mathematical, gender or diversity criteria. The following concept, based on these considerations and constraints can only show aspects and are not intended to be a complete analysis. First the humanoid NAO robot is presented with its technical features, then the task is discussed taking different perspectives, and after reviewing experimental results, the concept of a study course as well as the requirements of an interactive learning tool with respect to gender and diversity aspects is outlined.

1.1 Gender an Diversity Aspects in Teaching and Learning

Statistics and gender research show that women are still underrepresented in technical fields [1], so the female perspective is missing in technical developments. Implementing the gender perspective will not only guarantee the participation of women and men but may also help to overcome gender stereotype so that technology can be useful for "everyone". In order to fulfill this vision of equal rights and opportunities in technology, women and men have to be qualified for engineering profession.

The development of technical competencies is not only a question of studying but a lifelong learning process which depends on both, the individual abilities and the available resources. There still exist barriers to higher education and knowledge in the sense that gender, age, educational qualification of the parents, and income level of the family may significantly impede the path to academic degree.

A key to overcome such barriers may be in integrating different perspectives into teaching and learning of technical subjects and sharing complex knowledge in order to improve vocational prospects. This may require more effort in teaching and learning, because the visual representation, language usage, examples and subject-related explanation have to be analyzed and, if necessary, revised in order to ensure that they are not excluding or discriminating the learning person.

For example the term "degree of freedom" that plays an important role in both mechanical engineering and robotics implements a conceptual understanding and it takes time until it is well understood. The term can be described through textual explanation or visual representation. It can perhaps easier be understood if the possible degrees of freedom are shown through experiments, e.g. through the robot's movement.

Difficulties in understanding are best eliminated through direct and open personal discussion and a variety of presentation and demonstration. In daily-life this time-consuming method is not possible to be realized. So giving a maximum of information without overwhelming the learning person should lead to an interactive learning tool with feedback functions to supplement the regular teaching and learning unit.

If the basic principles are understood, complex technical application can be created. In this field there is also a difference in interests that men and women are developing. Especially in robotic research Cynthia Breazeal can be seen as a pioneer in developing robots by implementing a new different view on robots [2]. She developed the social robot "Kismet" that is able to interact with people. The human-robot interaction is designed in a human-centered way attempting "…to define a vision of sociable robots of the future". By modeling the basic emotions and interactions of human beings, Breazeal designed the robot head that is able to recognize the emotions through the vision and auditory system and is able to express basic emotions such as sadness, happiness or surprise using over 20 degrees of freedom that are driven by motors that move ears, mouth, eyes and even eye brows.

So considering these aspects the teaching process was revised by using the methods of gender analysis "Rethinking Concepts and Theories" and "Rethinking Language and Visual Representation" as it is shown in [1].

1.2 The humanoid NAO Robot

The NAO robot manufactured by the French company Aldebaran [3] has been developed for education and research purposes, especially in the field of autonomous behavior and human-machine interaction. It has a friendly appearance reflecting the vision of its inventor Bruno Maisonnier, who intended to integrate the robot and its successor models into every-day life as an assisting tool, e.g. for elder or handicapped people. Therefore the hard- and software not only provides the technology to functional purposes but it also features an innovative human-robot interaction concept making the robot appear alive and interact with human beings in a human-centered way (Figure 1).

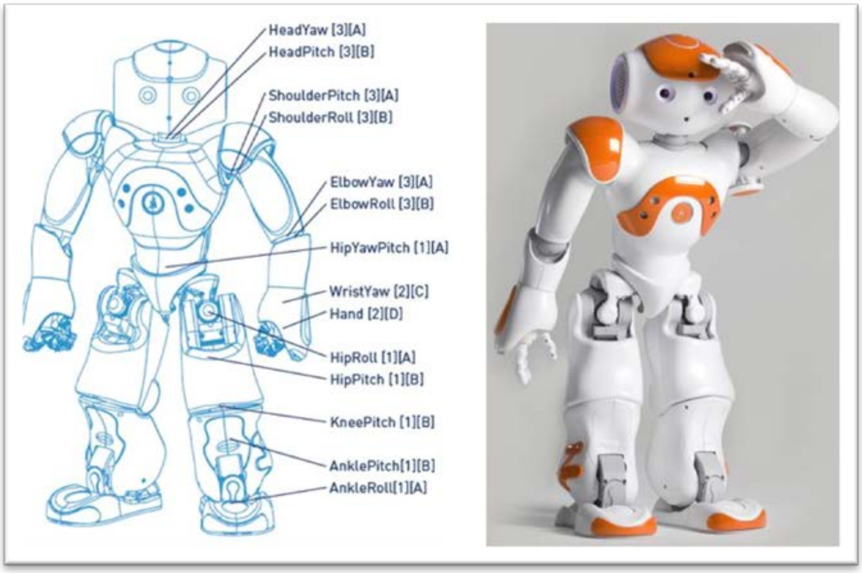

Fig. 1. The humanoid NAO Robot from Aldebaran Robotics [4]

The robot's size is roughly 58 cm, it has 25 degrees of freedom (2 in the head, 5 in each arm, 1 in each hand, 5 in each leg and 1 in the pelvis), and it is equipped with a variety of sensors (vision, tactile, auditory, sonar, etc.). The functions provided by NAOqi, the robot's middleware, can be accessed by using the Choreographe software released by the manufacturer but NAO is also compatible with Microsoft Robotics Studio, Cyberbotics Webots, and Gostai Urbi Studio. NAOqi supplies also bindings for high-level languages, such as Python, C++ and Urbi, to communicate with the various motorboards, which control the joint servos, and read sensor data.

In Choreographe movements and interactive behaviors can be implemented by using the graphical user interface. This way, continuous sequences of movements can be recorded to operate the joints over time. Choreographe can also be used to create and simulate sequences of movements without connection to the real robot.

Although the robot is a humanoid one it has no sex and can be used to analyze gender attitudes of the person who is working with it. Through giving the robot a name it can be defined as female or male and gender stereotypes can be analyzed and even overcome through trying to create feminine or masculine behaviors. The kind of human-robot-interaction the programming person tries to realize leads to the reflection of his or her own way of interaction. Using this kind of robot has a great gender influence on the learning process without fostering abstract concepts. So implementing the robot in the study course helps to find out the way how students learn with the help of the robot and depict structural and cultural mechanism across classes, educational background and stereotypical assumptions can be avoided.

2 TEACHING AND LEARNING UNIT “THROWING A BALL”

The trajectory of a thrown object is a classical example in kinematics to introduce basic concepts of motion and their mathematical description in terms of vector quantities. Gender and diversity aspects are integrated through additional considerations. In physic books and introductory lectures the throwing of a ball often is frequently discussed in the context of an example taken from sports, such as basketball, baseball, or (mini-)golf. This is intended to make the subject more interesting and motivating to the learner. But this may not have the desired effect, when the learning person is not interested in or has negative experiences with sports. In addition using only one example may not be sufficient to understand the mathematical background. But for this topic a detailed description with multi-perspective explanation and a variety of examples already exists, which may serve as basis for connecting theory with experimental robotics [5], [6].

The influence of gender and diversity aspects will be important when the robot’s behavior and the human-robot interaction and the context of the task is designed. The robot has to take or to get the ball in order to throw it. Taking the ball means autonomous motion of the robot while the human is in the role of an observer. Giving the ball to the robot and the throwing movement can be triggered through different ways. The robot can be controlled through tactile sensors. Speech controlling can be realized through key words or in dialogue. The choice of interaction may be an individual matter of taste but it also may hint at cultural background. Here further investigations should be conducted. However it is assumed that the difference between male and female engineers may not differ that much than it is supposed between female and male as it is seen from the cultural gender point of view.

These considerations lead to a reflection of gender and diversity aspects by analyzing the robots behavior if different human-robot interaction were implemented. It is necessary to include these different perspectives in order to prevent discrimination in study courses. Concluding to the considerations the learning objectives of the new study course are not only to program the movement but also to describe the movement mathematically and realize what parameters influence the width of the thrown ball and vary them. In order to control the robot the kinematics of the robot’s arm, the joints have also to be described mathematically and the function of motors and sensors have to be understood.

2.1 Basic Principles in Mechanical Engineering “Throwing of a Ball”

Although the throwing of a ball belongs to everyone’s personal experience, the calculation of the throwing parabola needs some theoretical background and basic mathematical skills in differentiation. In order to motivate the learning person the benefit of the effort and the steps of modeling have to be outlined. The learner needs to identify the parameters that describe the movement of the ball, that are the starting velocity v_0, the angle α and the height h in which the ball leaves the hand. The basic constraints are that it is a planar movement, the air resistance is negligible and the gravity force is in negative y-axis direction (Figure 2, left side). The governing equation of motion reads as

$$\vec{F} = m\vec{a} \Rightarrow \begin{bmatrix} 0 \\ -mg \end{bmatrix} = m \begin{bmatrix} a_x \\ a_y \end{bmatrix} \quad (1).$$

$$x = v_0 \, t \cos\alpha \quad (2).$$

$$y = -\frac{1}{2} g t^2 + v_0 t \sin\alpha + h \quad (3).$$

Eliminating the time from the expressions (2) and (3) yields

$$y = -\frac{1}{2} g \frac{x^2}{v_0^{\,2} \cos^2 \alpha} + x \tan \alpha + h \qquad (4).$$

It is essential to note that the motion along the horizontal direction does not affect the motion along the vertical direction and vice versa. In Figure 2, the trajectories obtained for v_0=1,25 m/s and α=0° and α=45°, respectively, are shown.

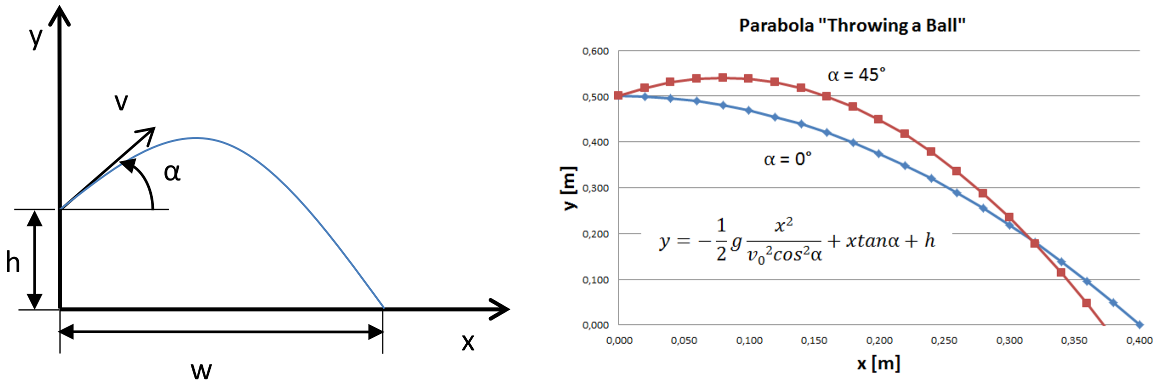

Fig. 2. Theoretical and experimental results

2.2 Mechanical Engineering and Robotics

Above, the parameters of the model of a thrown ball have been introduced. Next, these parameters are varied through programming the humanoid robot. Here the kinematics of the robot plays an important role and makes the task rather complex. The velocity of the ball is included by the movement of the robot's arm. In a first approach, the students should program the movement by using the graphical user interface of the software program Choreographe. The poses of the robot can be detected through the rotation sensor in the joint of the robot's arm. Figure 3 shows one result of the experimental work.

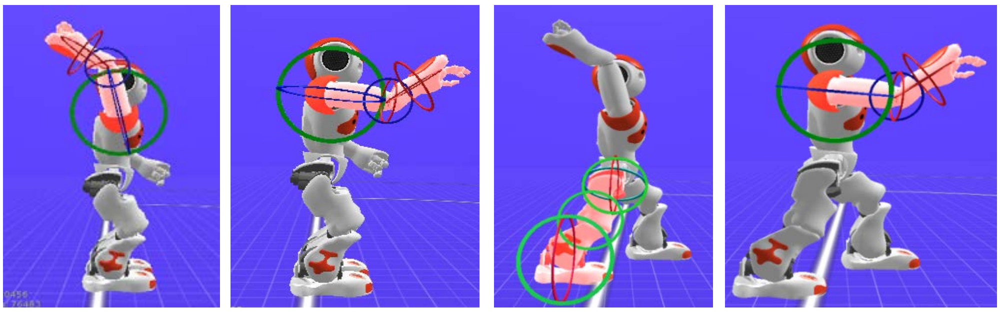

Fig. 3. Different poses of the NAO Robot

In order to describe the throwing situation, the problem is considered as a planar movement by controlling the corresponding motor. Figure 4 shows the construction of the robot's arm.

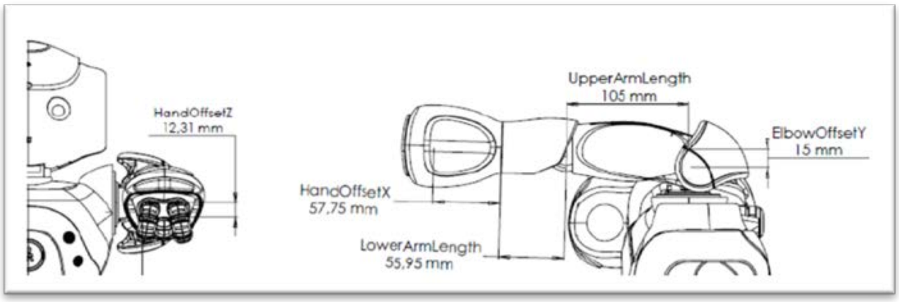

Fig. 4. Arm construction of the NAO robot [4]

Varying the robot's behaviour in order to get a human-like movement leads to a complexity in the calculation that cannot be solved in a simple manner. The maximum velocity could not be reached because of the dynamic instability of the robot. Increasing the velocity means increasing the reaction forces and the robot would fall. Here further examination employing methods of multibody dynamics should be taken into account.

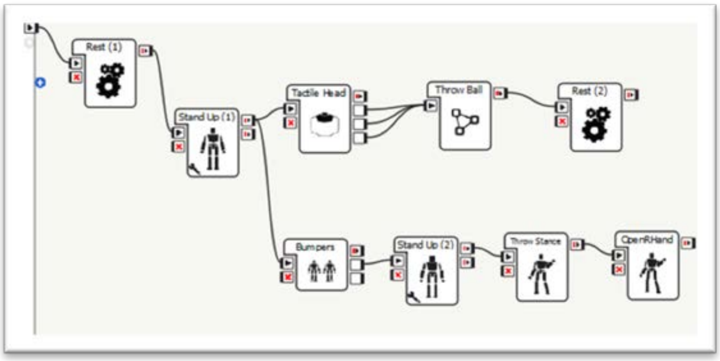

Fig. 5. Realized program "Throwing a ball" with sensor interaction

The control of the robot is mainly realized through sensor interaction, i.e., the extensive dialogue tool is not used. A detailed discussion is provided in the next chapter.

2.3 Human-Robot Interaction

Gender and diversity aspects and their influence to the program are not considered in "normal" learning structure or culture. Not only the students but also the teaching person are involved in unconscious processes and have his or her own perception and understanding of solving technical tasks. In order to reach the learning objectives, the students must be involved and motivated to learn the complex task in their own way. Using the robot as a learning media is tempting to the practical oriented engineering students. The program structure shown in Figure 5 fulfills the technical task of throwing the ball. If the human-robot interaction is deepened, the program has more dialogue components and the interaction becomes more individual. One example of a more complex human-robot interaction is shown in Figure 6.

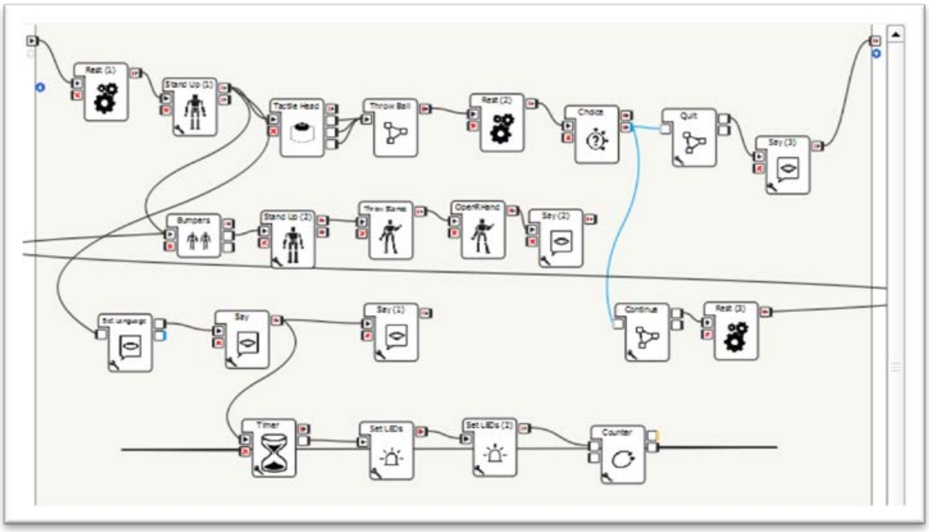

Fig. 6. Realized program “Throwing a ball” with HRI-focus

Here, gender and diversity aspects in contrast to the simple functional realization plays an important role. The variety of solutions increases with the individual requirements for the robot’s behaviour.

2.4 Interactive Learning tool NAO KINnematics (IL-NAO-KIN)

Analog to the discussion of gender and diversity aspects the requirements on an interactive learning tool are enormous and represent a great challenge to realize. Figure 7 shows the approach in a new interactive learning tool (IL-NAO-KIN).

According to the presented learning unit the interactive learning tool shows the different aspects of the given task in a problem-based manner in order to activate and motivate the students to solve the problem in their own way in a student-centered learning process. The learning unit is divided into the different steps, e.g. mathematical description, that are necessary to solve the given task. This transparency gives orientation and a kind of feedback to the learning person in order to get used to structured solving procedures as it is used in the engineering profession.

The theory is implemented in a multiperspective view with gendered language and visual representation so that learning persons with different educational background have the chance to understand and solve the given problem. The learning person can retrieve the knowledge base for his or her own purpose. The possibility to combine the different learning steps facilitates to individualize the learning process to the needs of the students and makes it possible to reflect their own way of learning in order to ameliorate their competencies. Through the calculation with variation of the parameters and the experimental verification of the developed model the students are able to apply the learned theory and can directly see whether their calculations were correct.

And the last but not least aspect of the learning tool is the implementation of the experimental verification with the chosen user-friendly and motivating humanoid NAO robot construction in a virtual or real way.

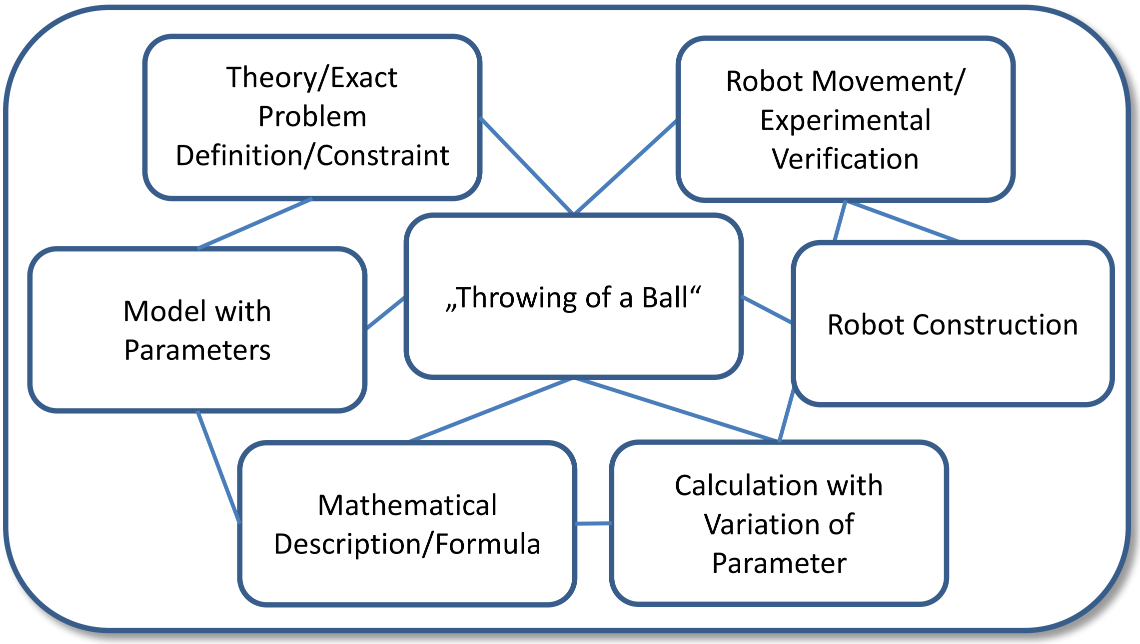

Fig. 7. Structure of the Interactive Learning Tool NAO KINematics (IL-NAO-KIN)

3 SUMMARY

The presented learning unit with the seemingly simple example of the “throwing of a ball” provides not only an introduction to basic principles of kinematics as well as to programming, but also to the variety and complexity in teaching mechanical engineering and robotics with respect to gender and diversity aspects. It depicts a first approach combining learning, theoretical and experimental work with technical features in order to improve qualification and vocational prospects. In this regard the humanoid NAO robot may serve as an innovative learning media. In combination with an interactive learning tool, it represents a promising enhancement to regular courses. The depicted learning strategy must be further examined, especially with respect to gender and diversity aspects as outlined in this contribution.

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