

The Exploring of Teaching New Navigation Technology Based on Case Teaching Method

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ABSTRACT

Learning new navigation technologies is very important for the master students, who major in navigation technology or autonomous systems. However, new navigation technologies are very different from traditional navigation methods; they involve a wide range of theories including computer vision, linear algebra, numerical computation and so on, moreover, new navigation technologies are not very close to fundamental courses; this causes difficulty to the course teaching. Case teaching is one of the most effective teaching methods in law and business education; it has the advantage to instantiate abstract theories by using practical cases and deepen the understanding of the knowledge. As an engineering field, the teaching of new navigation technologies is very different from the teaching of law and business courses, therefore teachers have to adapt the case teaching method to fit in the teaching of new navigation technologies. We have explored teaching new navigation technologies with case teaching method. The experience and case teaching method are summarized and presented in this work.

Keywords: Case teaching, master education, new navigation technology

1. INTRODUCTION

Master education is a key part to train talent engineers, and a key part to improve the innovation level of the whole county. To focus on master education, the Ministry of Education held the National Master Education Conference held in August, 2020, which is regarded as a manifesto to improve the quality of master education.

Courses of navigation technologies are mostly for the master students major in *Navigation Guidance and Control*, or *Autonomous Systems*. The goal of the courses is to train engineers and autonomous systems for the fields of aerospace, robotics computer science. As the fourth industrial revolution is sweeping around the world, autonomous systems have shown promising future in a wide range; this puts a sharp rising demand for excellent navigation engineers in recent years.

To improve the quality of master education, the National Defense University has opened a new course named as *New Navigation Technologies*, which consists a series of sessions; each session introduces one kind of new navigation technology, and each session has three class hours. The goal of the sessions is to help the master students to understand the fundamental principle the new technologies, to have the basic skills to start related research, and to be informed of the current trend in industry. Most of the student chosen the course are the first year PhD students and first year master students.

The new course also faces some challenges. Firstly, the new navigation technologies introduced in the sessions are

very different from the traditional navigation methods both in fundamental principles and navigation algorithms. Moreover, the new navigation technologies are not very close to the courses in the bachelor education; this causes challenges to teachers to conduct the teaching process. How to achieve the goal of the courses in limited class hours is one of the main difficulties.

Case teaching was first introduced at Harvard university, and it is initially used to teach law courses [1,2]. The method uses cases to train the students to apply their learned knowledge at the chosen cases. The case teaching method has shown impressive effects and greatly improved the students' practical skills. Later, case teaching method has also been used to other discipline, such as business and social sciences.

Excellent case teaching simplifies the teaching of difficult theoretical knowledge points. Though the teaching of new navigation technology is very different from teaching law courses and business courses, but the core idea of case teaching method is still applicable. However, copy the case teaching method from law teaching and business teaching may not suitable for the teaching of new navigation technology, teachers have the use their skills to adapt the course teaching method to fit in the teaching of new navigation technology [3,4]. This publication use teaching visual navigation as an example, to illustrate how to perform case teaching in the class of *New Navigation Technology*. The experiences could also be applied to the teaching of other courses in engineering field.



2. TEACHING NEW NAVIGATION TECHNOLOGY WITH CASE-BASED METHOD

Using case-based method to teach the master students at the class of new navigation technology, teachers should firstly sort out a clear framework of the class content, and analyse every knowledge point. Secondly, teachers should carefully consider which point is suitable for case-based teaching method and which is not, and then chosen suitable cases. Lastly, the teachers have to deliberately design the case teaching process. The teaching process of *New Navigation Technology* with case-based method is conducted as shown in Figure 1.



Figure 1 The design flow chat of case teaching for the course of New Navigation Technology

2.1. Analysing the Characteristics of The Course

Navigation is a technology with long history, it estimates the attitude, velocity and position of the moving agents from the measured geophysical, inertial and other information. It is a technology focusing on guiding the agent to a goal with the estimated motion parameters.

At the basic principle level, navigation technology involves geophysics, electromagnetics, computer science and other sciences; at the engineering level, navigation technology is related to signal processing, algorithm design and so on; at the application level, it is almost applicable to all the mobile agent, including aircrafts, ships, cars and human.

Teaching navigation technology usually start with the fundamental principle, and then process to the navigation algorithms and end with navigation applications. Take the class of satellite navigation technology for instance. The class firstly starts with doppler effect, and then processes to pseudorange-based positioning, and then ends in application examples. At each teaching process, the related mathematical and physical knowledges are presented.

The new navigation technologies have similarities to traditional navigation methods, but they also have some new characteristics. Take visual navigation technology as an example. Same as other navigation method, visual navigation also estimates the agent's attitude, velocity and position. While inertial navigation sensors and satellite navigation sensors directly output motion information,

visual sensors only capture the appearance of the surroundings. Engineers have to develop algorithms deliberately to extraction motion information from image streams, and the algorithms are closely related to multi view geometry, linear algebra, and nonlinear optimization. Unlike inertial navigation and other navigation technologies where the input information is not frequently used in daily life, visual navigation is used in every day life and it is a main navigation method for human. This helps the students to have an understanding of the method. Furthermore, as more and more intelligent mobile robots are deployed in a wide range of applications, the students have great interests to learn visual navigation method. In summarize, visual navigation is different from other navigation methods in the basic principle level, but it is more related to our daily life at the application level.

2.2 How to Choose the Case

The goal of using case-based teaching method is to better bring in the topic, to better organize the knowledge points and to make the abstract theories more concrete. The interaction between the theories and the cases helps the students to have a better understanding of the knowledge. Excellent case not only helps teaching at a single process, but also helps the whole class teaching process.

Here, we take teaching the visual navigation technology as an example to illustrate how to choose a case. The chosen cases should help the students to have a good glimpse of the technology's background: Visual navigation technology stems from NASA's Mars rover project, which started at 1980s. At that time, engineers were get stuck at seeking a high precision and lightweight technique. After a long period, they finally turned to visual navigation method. It is after the 2000s that the visual navigation method became widely recognized as the computational power improved. At the application level, the visual navigation method is still under development, and face series of challenges.

The chosen case should reflect the history of visual navigation and helps the student know what problems have been solved and what problem is still under research.

The chosen case should support the whole process of the class teaching. Visual navigation consists of series of knowledge points, including camera model, two view geometry, 3D reconstruction and so on. Good case is not only useful for teaching a single knowledge point, it can also help organize all the knowledge points and ensemble separated knowledge points into a whole knowledge system.

The chosen case should also enlighten the students to consider the current challenges and future trends of the technology. In summary, excellent case helps the teaching process in bringing in the topic, in teaching the knowledge points and in enlightening considerations for future works.



2.3 Case Teaching Practice

This section, we use the teaching of visual navigation technology, which is a session in the course of *New Navigation Technology*, as an example to illustrate the practice of case teaching.

2.3.1. Bring in the topic

At the beginning, we employed the case "how robots navigate indoor" as a case to bring in the teaching topic. Students were then picked to give their own thoughts.

After that, the teacher systematically analysed the advantage of visual navigation: visual navigation is widely used in nature animals. At indoor environment, global navigation satellite signal is not available, meanwhile small indoor robots is not capable to use high precision inertia navigation systems, which are extreme expensive and heavy. Visual navigation provides a novel solution for the indoor robot navigation scenario; it is a self-navigation method, that doesn't need to receive electromagnetic signal; it is an accurate, cheap and lightweight. These characteristics make it suitable for indoor navigation.



Figure 2 Illustration of using case to bring in the topic

2.3.2. Case-based teaching

After using the case as the bridge-in, we then processed to the teaching of knowledge points. The first knowledge point is the camera model. We firstly pointed out that the key sensor for a visual navigation system is a camera and shown pictures of robots that equipped with cameras. The teaching was performed as follows: vision is the main navigation source for human and other animals. Camera has the same effect to mobile robots as eyes to humans. Pine hole camera is one of the most widely used kind of camera, which is based on the well-known pin-hole image optical principles.

Then we presented the mathematic model equations with pictures and videos to combine the knowledge point with the case. Before processed to the next knowledge point teaching, we also highlight the contribution the Zhang's camera model calibration method[5] to show the contribution of the Chinese engineers.



Figure 3 Teaching the camera model with case. The first line shows the knowledge branch and the second line shows the case branch.

We then processed to the next knowledge point to illustrate the two-view geometry and how robots can use two-view geometry to localize themselves. Before teaching, we firstly looked back to the case, and shown that many animal and mobile robots are equipped with two cameras. Then we put a short discussion about why most nature animals have two eyes and what benefits can we have if use two cameras on our robots. After the discussion we pointed out that one of the most significant advantage of using stereo cameras is to sense the three-dimensional information from two image's disparity. Then we used mathematic equations combined with pictures to illustrate how to compute the three-dimensional position of a feature from its observations in two images.

At this point the basic knowledges to build a visual navigation algorithm was all prepared. The next teaching process is to demonstrate how to organize the knowledge points to obtain a robot's location and attitude. We again used the case of robot as an example, and gave backbone algorithm flow chat as: the robot first use two-view geometry to reconstruct the three-dimensional position of the world points; then it moves to a new location and again observed world points; by using the correspondence between the three dimensional world points and two dimensional image points, the new position and attitude can be calculated based on the camera model.



Figure 4 Open discussion bring with the case

2.3.3. Open discussion of the case

Finally, we used the case to set an open discussion. The main discussion topic is: how the mobile robots can perform visual navigation under severe visual conditions,



such as illumination changes and image blur caused by motion. The real challenges introduced by the case can inspire the students' interests and set up goals for their future research. The discussion based on the case is shown as in Figure 4.

3. CONCLUSION

This work explored using case teaching method in the course of *New Navigation Technology*, which is for the master students majoring in navigation technology and autonomous systems. We summarized the experience of adapting the case teaching method from business education and law education into engineering education. We also present a teaching practice to illustrate how to conduct the case teaching in the course.

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