Lecture 17 : Current Trends in Robotics Research

We welcome you to the last module of this NPTEL course on Experimental Robotics. So, in this module, that is module 8, we are going to discuss the current trends in robotics research. So, in this course, we have carried out various experiments using five different robots and we have seen how to use the different robots to carry out different types of tasks. Now, in today's presentation, I am just going to show you a few recent trends of this robotics research. Now, this is the structure of my talk. I will give a brief introduction to artificial intelligence, that is, AI and we will be discussing how to use the principle of AI in different areas of robotics.

Now, we have already discussed that in robotics, we have got four distinct modules. For example, we have got the kinematics, dynamics, control schemes and intelligent issues. Now, out of these four modules, the principle of AI cannot be used in kinematics and in dynamics, we can use only in the areas like multi-body dynamics. However, in the modules like control schemes and intelligent issues, there could be different types of application of the principle of AI.

Now, here in this particular lecture, what I am going to discuss? What do you mean by intelligence? How to define the word artificial intelligence, that is AI? How does it differ from the human intelligence, that is HI? Now, many people compare AI with HI and they try to find out, which one is superior out of these AI and HI. So, we will be discussing that particular issue, whether AI can defeat HI and vice-versa. We will be discussing the concept of the computational intelligence, that is CI and how to use AI in different areas, so that we can design and develop intelligent and autonomous robots. Now, let me start with the very definition of this particular term: intelligence. Like, what do you mean by intelligence? And, to define this particular term intelligence, let me start with the way the concept of intelligence that was introduced in ancient times.

Now, if you see this particular term intelligence that was initiated in Greek civilization, Egyptian civilization, the term intelligence was used by Aristotle, then comes your Rene Descartes. So, this concept is very old and how to define this particular term: intelligence? Now, a person is called intelligent, if that particular person can take the decision in varying situations, as situation demands in a very adaptive way. So, if the person is having that particular intelligence, that intelligent person will be able to solve a variety of problems. So, this is what we mean by the term intelligence. Now, if you see the history, the first project on artificial intelligence that was actually submitted in the year 1956 and this particular project was on Bayesian logic.

Now, then comes your the DARPA project, very famous. So, US DARPA project was sanctioned and the purpose of this particular project is how to design and develop intelligent robots. Now, these particular two terms, that is the intelligent system and the autonomous system, we use very frequently and we always say we want to design and

develop an intelligent and autonomous robot. But, truly speaking, there is a difference between an intelligent robot and an autonomous robot. Now, we have already defined that particular term intelligence and a robot is called intelligent, if it can take the decision in a very adaptive way as the situation demands.

And, a robot is called an autonomous, if it has got the permission to act as an intelligent way. So, there is a difference between an intelligent robot and autonomous robot. Now, all intelligent robot may not be autonomous, but all autonomous robot must be intelligent. So, this is the difference between an intelligent system and an autonomous system and this is the difference between an intelligent robot and autonomous robot. Now, our aim is to design and develop an intelligent and autonomous robot.

Now, with this little bit of discussion on the concept of intelligence, now let me now define what do you mean by the artificial intelligence. Now, this artificial intelligence, that is AI, that is incorporated to the head of an agent. Agent means this is an intelligent robot through training or learning carried out by human intelligence. So, that this particular agent can perform its assigned task more efficiently using his inbuilt sensor. So, let me try to explain in more detail.

Now, supposing that a robot has got a few sensors and the robot has collected some information using different types of sensors. So, with the help of sensors, the robot has collected different types of data. Now, how to use it? How to use this particular data to train or learn this particular robot with the help of this human intelligence, so that some artificial intelligence is developed and incorporated into the head of a robot. Now, this concept of AI and your human intelligence, that is AI. So, I am just going to find out their difference in a more detailed way with the help of some examples.

Now, supposing that I am just going to take one hypothetical example. Now, the example is something like this. Supposing that an undesired incident has occurred at a particular place and there had been one murder case. Now, if there is a murder case, then the police will try to find out who could be the possible murderer. So, the investigation will start, the policemen will start investigating to find out the possible murderer.

Now, if the policemen can find out who could be the possible murderer, the problem is solved. But, supposing that the policemen could not find the possible murderer, in that case, what will happen? The policeman is going to take the help of one sniffer dog. Now, the policemen could not find out the possible murderer, but there is a possibility that the sniffer dog will be able to find out, who could be the possible murderer. And, supposing that the sniffer dog has solved the particular problem and the murderer has been caught. Now, this particular problem of finding the murderer could be solved by a sniffer dog, which could not be solved by the policemen.

So, the sniffer dog has got some sort of artificial intelligence that is incorporated by the

human intelligence, that is the same human police. Now, this human police could not solve the problem and sniffer dog could do it. Now, here AI could defeat the human intelligence, that is HI. So, this is the way we can find out the difference between the concept of artificial intelligence and human intelligence. Now, I am just going to take another example.

Take a small mathematical example, it is very simple mathematics like 2 plus 3 equals to how much? Now, if I ask the policeman 2 plus 3 equals to how much? The policeman will be able to give the solution very quickly that 2 plus 3 equals to 5, but the same question if you ask to the sniffer dog, there will be no answer. The sniffer dog will not be able to give that particular answer that 2 plus 3 equals to 5. Now, here in this particular example, the human intelligence could defeat the artificial intelligence because the sniffer dog was not trained to solve that particular simple mathematics. Now, here in the second example, the human intelligence could defeat artificial intelligence, just the reverse. So, in one problem, AI could defeat HI, in another problem, HI could defeat AI.

Now, to conclude, we should not compare the performance of this AI and HI, it depends on the task. Now, what we want to do is, we want to use the principle of AI, that of HI or a combination depending on the task, so that we can solve the real-world complex problem more efficiently. So, I hope you got the idea that the difference between the AI and HI, artificial intelligence and human intelligence. So, we should not compare which one is superior, instead we always try to find out to solve the real-world problem, sometimes AI is going to solve the problem, sometimes we will have to take the help of human intelligence, sometimes a combination of AI and HI and these two are to be used as a complement of one another, depending on this particular task. Now, this is actually the difference between your AI and HI.

Now, if you see the literature, we have got a concept of the computational intelligence. Now, this computational intelligence is actually what? That is nothing, but the artificial intelligence using soft computing and the soft computing are nothing, but the nature inspired optimization tool, nature inspired modeling and learning tools and their combined techniques. So, today's AI or the modern AI, which are generally used very frequently to solve the different types of real-world problems are nothing, but the computational intelligence tools and those are nothing, but the modern AI tools using soft computing to solve different types of the real-world problems. Now, if you see the principle of the biological adaptation, we use the concept of learning and evaluation. Now, we know, so long as we live in this particular world, we go on learning and if we can learn some good things, some good ideas, good rules, we pass it to the next generation and the evaluation of the next generation is going to be accelerated, if there is a proper learning.

Now, this particular learning is going to accelerate the rate of evaluation and another fact that during the learning knowingly or unknowingly, we use the principle of optimization and this learning is nothing, but an iterative method and in this optimization method, that is the iterative optimization tool, we use the principle of evaluation. So, learning is going to

help evolution, evolution is going to help learning and consequently, we get accelerated biological adaptation. Now, this biological adaptation will be copied in the artificial way, that is nothing, but the artificial adaptation using the principle of the computational intelligence tools or the modern AI tools. Now, if you see the literature, we have got a few evaluation tools like biologically-inspired optimization tool like genetic algorithm, genetic programming, evolution strategies, evolutionary programming, differential evaluation, cultural algorithm, particle swarm optimization, ant colony optimization, then comes your bat algorithm, bonobo optimization and others. So, we have got a large number of evaluation tools.

Similarly, we have got a few learning tools in the form of your neural networks, in the form of fuzzy reasoning tool and you will be astonished, our brain has got the neural network, the fuzzy reasoning tool and our neural network is very strong and we have got a very large number of neurons working in series and parallel. In soft computing, we have got a few combined tools like genetic fuzzy system, that is a combination of genetic algorithm and fuzzy reasoning tool. Then, genetic neural system is a combination of genetic algorithm and neural networks, then comes your the neuro fuzzy system is a combination of neural network and fuzzy reasoning tool and genetic neuro fuzzy system, all three things taken together. So, here basically, we are combining the evaluation tools along with the learning tools to develop some CI tools or modern AI tools to solve some complex real-world problems. So, this is the way actually, we will have to solve the complex real-world problem.

Now, if you see the literature on AI, a huge literature is available and there exists a large number of AI tools. For example, say we have got the heuristic techniques. Now, these heuristic techniques may solve a problem, may not solve also and there is no guarantee that every time you will be getting some solution. Then, we have got some hill climbing approach and this hill climbing approach are going to use the gradient-based technique. We also have got a few search algorithms like depth first search or the breadth first search and so on.

We have got some logic like symbolic logic, we have got the conditional probability concept of conditional probability using the Bayes rule and this particular Bayes rule is used to solve or to tackle uncertainty. So, for uncertainty modeling, we can use the Bayes rule. We have got a few nature-inspired optimization tools, these are also known as the metaheuristics. We have got the input-output modeling tool like fuzzy logic neural networks. We have got the clustering tools based on similarity, so that the similar things will be put in the same cluster and two dissimilar things should be put in two different clusters.

We have got some sort of classification tools, which is supervised. So, we can do the classification. We have got a few dimensionality reduction technique, so that from higher dimension, we can map it to the lower dimension for the purpose of visualization, so that

the higher dimensional data can be mapped to either three dimensions or two dimensions or one dimension for the purpose of visualization. Now, all these AI tools are not applicable to the problem of robotics. Now, I am just going to concentrate on a few problems in robotics, where we can use the principle of AI or the principle of the computational intelligence.

Now, let me start with the very first problem. I have got a few tasks or a particular task and this particular task has to be tackled, to be solved, to be performed and for that, I am just going to design one robot. Now, supposing that I have designed that particular robot, I have carried out some sort of kinematic and dynamic analysis. Now, I want to find out, what could be the optimal design of that particular robot, so that the robot can perform that particular task by consuming the minimum energy by maintaining its dynamic balance. So, if I want to find out or if I want to evolve that particular design of the robot, we can take the help of some sort of AI tools, that is the nature-inspired optimization tool.

At this nature-inspired optimization tool, like genetic algorithm and others, we will be able to evolve that particular optimal design of the robot. The next is that we collect information, the robot collects information of the environment with the help of camera. So, at regular interval, the camera is going to collect a few pictures, the drawings and these pictures, the images are to be analyzed to extract the useful information. Now, this particular image analysis or digital image analysis, we can carry out using the principle of AI, so that we can collect more accurate information of the dynamic environment. So, there, we can use the principle of AI.

Now, besides the camera, the robots will be equipped with a few sensors. For example, we collect sensor, we collect information of the environment with the help of our eyes, with the help of skin, ears, nose and all such sensors, we have. Now, we have got a few sensors, different types of sensors. Similarly, in the robot, we use different types of sensors and we collect information, the data, the necessary data with the help of the different sensors. Now, these collected information are actually applicable in different ranges and those are to be normalized before we go for the multi-sensor data fusion.

Now, to collect information with the help of sensor of the environment, we generally go for the multi-sensor data fusion and to solve that particular problem, there is no way out, but you will have to go for the principle of CI or the principle of AI. And, supposing that we have got the information of the environment and now, the robot is going to make some plan, some course of action and while making that motion planning or adaptive motion planning in varying environment, the robot once again is going to use the principle of AI. That means, the robot should be equipped with different adaptive motion planner and depending on the scenario, depending on the environment, the robot should be able to make the plan in a very adaptive way. The next is the robot should be equipped with adaptive gait planner, if it is a multi-legged robot or a two-legged robot like humanoid robot. Now, this based on the motion planning, the robot should be able to make a plan of the sequence of leg movement,

so that it can perform the task by consuming the minimum energy and by maintaining your dynamic balance.

Now, if you just concentrate on the two-legged robot or the humanoid robot, so the robot is going to operate in a dynamic environment and the robot has already made a few plans and those plans are to be executed with the help of this leg movement. That means, it should have the adaptive gait planner and of course, for the real implementation, the robot should have the adaptive controller. Generally, at each of the robotic joints, we use the DC motor and DC motor is controlled with the help of one PID controller, Proportional Integral Derivative Controller and this controller has got some gain values like your say Kp, Ki and Kd, that is the proportional gain, integral gain and the derivative gain. Now, if you can use the fixed gain values, you can solve it, but for a varying situation. So, the PID controller with the fixed values may not perform well.

So, we will have to go for the adaptive controller and this adaptive controller should be able to supply the values, the gain values like Kp, Ki and Kd in a very adaptive way depending on the requirement. And this is the way actually, we can get the adaptive controller and we human beings, we are intelligent, we are emotional too and any decision taken by us might be a combination of intelligence and emotion. So, if you want to copy that particular human being in the artificial way in the form of a robot, the robot should be capable of making some prediction related to the emotion. So, this particular robot should be equipped with an adaptive emotion planner. So, the robot should be intelligent, it should be autonomous, it should have the adaptive emotion planner and the robot should be able to walk or perform just like a human being.

So, these are all requirements and a lot of work is going on like in these areas like your how to use the principle of AI artificial intelligence, the principle of computational intelligence to design intelligent autonomous and emotional robots. Now, here in this particular discussion or the lecture, I give a brief introduction to the concept of AI, then comes your human intelligence, that is, HI, I try to find out the difference between the AI and HI, I introduced the concept of computational intelligence, that is, CI, and then we discussed in short how to use the principle of AI in different areas of robotics, so that we can design and develop an intelligent autonomous and emotional robot, so that it can perform just like a human being in the artificial way to solve different real-world problems. Thank you.