

International Robot High School 2017

Theme3 Most advanced technologies of robots – Bipedal robot –

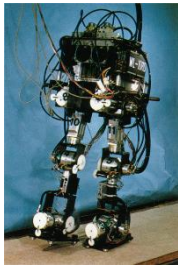
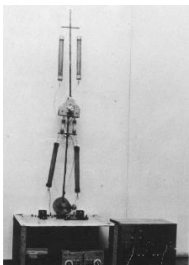
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1. Introduction

Who knows the robot ASIMO? Thank you for your cooperation. As we can know from this result bipedal robots are now a famous research topic in the field of robotics. Another question. Who can explain the newest research of bipedal robots? Thank you. These days the research of bipedal robots is accelerating, but not many people know about it. So, I want every one of you in this room to know about the newest research.

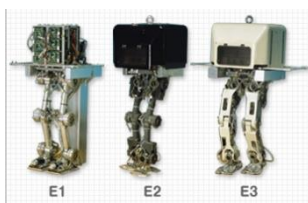
Knowing how bipedal robots evolved will make everyone understand the newest research much easier. So, I'll explain about the history of bipedal robots first.

2. Bipedal robots – The history



The idea of bipedal robots is an idea which expanded from the concept of the inverted pendulum. At the end of 20th century people established the way to make double and triple inverted pendulums. Researchers thought of the human leg as a quad inverted pendulum. But at the time, they didn't have computers that could calculate in real time, so the control method was feed forward control. Of course, with this slow method the project ended.

In the 70s researchers came up with the ZMP theory. ZMP is the method of controlling bipedal robots. Before this theory only the centroid was in the calculation but in this method researchers added inertial force. Since this theory came out, almost all bipedal robots use this method. Also, ASIMO uses it too. By the way Waseda University was the first to research about these fundamental studies of bipedal robots.



1987-1991



1991-1993



1993



1996



1997

What do you imagine when you hear the word bipedal robot. Did you imagine a humanoid? In the 80s to the 90s robot developers normally imagined a robot that has legs only. However, there were many problems moving machines with only legs. One of the big problems, is that it is hard to control the

centroid of the robot, because when the robot lifts its leg half of the weight will be out of control. Another big problem is that the leg on the floor will slip. Slipping is usually an unpredictable action, so it is hard to write it to the program. To solve these problems researchers made the robot's upper part. By making the upper part of the body the robot has a dynamic guarantee of its balance.

I think the history of bipedal robots can be divided into pre-ASIMO and post-ASIMO. As you can see ASIMO has not changed its shape since P-3. But this robot is supported by the research that HONDA has done.

- Technology of i-WALK, which makes it smoother to walk.
- Update of the walking ability, update of human interface.
- Evolution of communication skill supported by recognition ability.
 - Combination between networks
- More speedy moves
 - Autonomous continuous action
 - Mimic of human action
 - Closer running motion to human
 - Update of recognition ability during the action
 - Manipulating wagons
 - Carrying tray
 - Update of the running motion
 - Cooperative full body action
- Update of communication ability
 - Update of recognition ability during the action
 - Manipulating wagons
 - Carrying tray
 - Update of the running motion
 - Cooperative full body action
- Cooperation between few machines
 - Continuous services
 - Update of moving and working
- Stopping the presentation to the customer and tell the drink is coming
 - Hearing three people in the same time
 - Predicting the next move of the human moving and moving by the results
 - 9km per hour running
 - Both legs jumping, one leg jumping
 - Able to walk at a bumpy road
 - Grab a water bottle and pouring the water to a cup
 - Showing hand sign

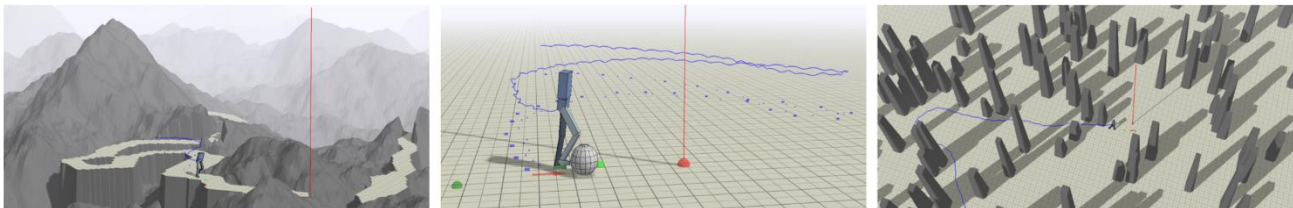
3. Bipedal robots – Newest research

As you can see the history of bipedal robots has been evolving at a tremendous speed. But in fact, it slowed down for a while. After the great ASIMO came out the research of bipedal robots seemed to be over. But there were two big new breakthroughs in the field of bipedal robots. The first breakthrough is **the innovation of material**. The second breakthrough is **the innovation of the computer**.



There is one robot that represents the innovation of materials: Cassie. Cassie is a robot that Agility Robotics invented. Cassie is a robot without an upper body. Remember what I said before, to add an upper body has been common sense since the 90s. The innovation of materials such as motor and metals means that Cassie can do more things even without an upper body. concept of this robot is to be able to go everywhere humans can go. One researcher says, "Cassie is an exciting robot that is agile and efficient and able to be controlled in a

very dynamic way.” Cassie itself is very tough and can react to stairs, floors that have a different hardness, and a variety of terrains. It is very quiet, and it only makes the sound of footsteps and the sound of electric motor.



The second breakthrough in computing is also very important. Deep Reinforcement Learning currently uses computer simulations for programs to learn the most efficient way to complete a task. Rather than focus on process, the programs learn to effectively reach the end goal. This means that the program can accumulate more information about different situations in a way that was unthinkable only a few years ago. I think you might all have thought “What does this have to do with robots?” In the future, robots’ hardware can use programs which are based on Deep Reinforcement Learning.

I am very interested in this topic and I’m also studying about this too.



Have you ever seen the robot Atlas on television? If so I think you still have the astonishing image of Atlas in your minds. Atlas is a robot developed by Boston Dynamics. It is capable of all kinds of complex movements that other robots can’t do – for example it can jump from one place to a higher place and do flips. Also, it can deliver boxes, it can walk on snowy terrain, and many other things that other robots can do – only much better. What Atlas can do is

not its most impressive aspect. Rather, the fact that Atlas is supported by newly developed materials and information technologies is what is more important.

A single flip of Atlas means a robot is recognizing the world in real time. A single landing of Atlas is supported by stronger robot parts and the development of a structure that reduces stress on the robot. Atlas unites the two innovations I mentioned above.

Another robot also unites them but in a unique way.

On the computing side, the usage of sensors and computer control is unique. By using a human as the master movement controller, it overcomes issues of movement efficiency. A humanoid is in general hard to move, but by using humans, who are already bipedal, the robot follows actual human moves and thus the programming process is easier. Also, since the human controller doesn’t have a problem walking, the robot takes no risk when walking.



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Toyota’s T-HR3 has a motor that moves smoothly when information is transferred from human to robot.

4. Interview – International Robot exhibition 2017

At last, I want to share the result of the questionnaire which I did at the exhibition.

Q.1 Do you think the bipedal robots have matured for some extent?

Yes(0) • No(9)

- The bipedal robots still can't adapt to the dangerous places like mountains.
- There is no universal method for controlling the balance.
- Humans physical performance is far better than those robots.
- It can walk, but doesn't directly help people.
- The price is too high.

Yes 5 and no 5 was my prediction, because I was thinking that bipedal robots have already reached the ultimate form when it is walking. But researcher was seeing farther, and they were thinking to make the bipedal robot adapt to dangerous places like mountains.

Q2. What is the main condition that can lead bipedal robots to new epoch?

Innovation of material (2)

- Making the material lighter
- Innovation of the actuator

Innovation of computers (1)

- The establishment of new theory

Innovation of Artificial Intelligence (3)

- Image recognition
- Circumference recognition
- Prompt decision

Other new approaches (3)

- Knowhow of human clearing their difficulties to different terrain.
- Making the device, which can easily access to artificial intelligences order.

There were many interesting response for this question, but development of AI and making the device, which can easily access to AI's order seemed to be the next challenges.

Q3. In what place can these robots play an active role?

Home/Recreation(2)

- Because our goal is to make the robots, which we can live along with.

Rescuing(3)

- Grounding spaces are small that they can act more widely.

Nursing care(0)

Other (4)

- When we build big things, which entail danger.

I was imagining the bipedal robot playing a active role at nursing care, but the result implies that researchers is not very positive about bipedal robot taking place at nursing care.

Q4. In the future, what do you think about the relationship between human and robots?

Live together(7)

- They can work on behalf of human beings.
- The measures for the Japanese aging society and birthrate problem.
- It is necessary to live along with robots.

Terror(0)

I don't know(2)

Even so there is many negative thoughts in the world that the bipedal robot will completely take over the world, but the researcher was looking at the brighter side.

Q5. Do you think these robots are required?

Yes(5)

- Working for the replacement of the human beings.
(space, polar regions, and etc.)
- Only effective when the user interface is human.

No(1)

- It doesn't have to be in human shape.

I don't know(3)

- Depends on time and space.
- It doesn't have to be bipedal.

In the future the robot will be working as the replacement of human beings so there were opinion that it doesn't always have to be in a humanoid form. The development of bipedal robot following the historical backgrounds will be needed.

From now on the bipedal robot with a light and tough materials, which can easily access to artificial intelligences order will coexist with us in the real life by sharing what they are good at and what we are good at.

5. Conclusion

There is a robot contest called RoboCup that I have been competing in since I was 11 years old, this competition started with a dream: "By the middle of 21st century (2050), a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup" When it started in 1997 it was just a dream, and by 2002 the robot was only able to kick a small ball lifting its leg on a small carpet, but at this year's world competition I was able to see the robot kicking the official ball on an artificial lawn. From now on it is easy to predict that the research of bipedal robots will be one of the big topics in the field of robotics, and that a humanoid winning against a human team is not just a dream. In the year 2050, the moment the robot team wins against the human team I wish to be included in the developer team of the robots. To make my dream become real I will continue my studies and research.