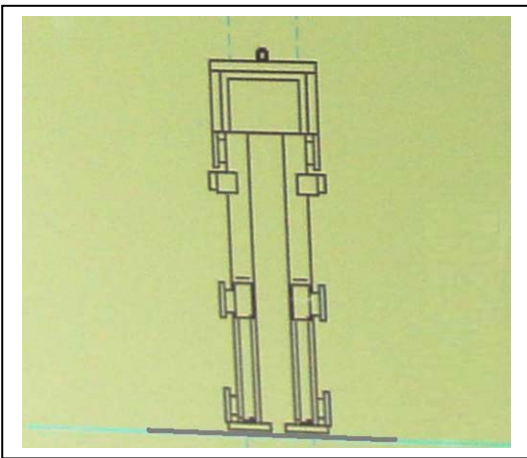


ASIMO - Advanced Stepping Innovative MObility**Ovidiu ANTONESCU, Paun ANTONESCU**University "Politehnica" of Bucharest, Mechanism and Robot Dept.,
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Abstract: The paper presents the evolution of Honda's walking robots. There are presented eleven types of stepping robots developed within 1986–2005 period. From just two stepping legs to the latest walking robot model called ASIMO, one of the best humanoid robots in the world that has an excellent balance during stair climbing.

1. Start of Research and Development on Two Leg Walking

In the beginning it was E0 robot (fig. 1). For the year 1986 he was a revolutionary walking robot [1]. Of course, like a baby learning how to walk, it was difficult to teach him the complicated task of stepping. Understanding how to walk on two legs puzzled the scientific community of robotics since the very beginning. The major problem was and still the balance.

As it can be observed in figure 1, E0 has just two simply legs linked by a small body. Each leg is consisting of three major elements similar to the human one: thigh (femur), shank (tibia and fibula) and foot (tarsus). Also, each leg has three joints between each pair of elements: haunch, knee and ankle.

Fig. 1 E0 - Honda's first walking robot (1986)

2. Achieving Faster Walking by Robots

Within this period of four years Honda looked for development of the walking process on robots (fig. 2). Beginning with the second model E1 (fig. 2 – left), Honda has introduced another rotation to the ankle joints to simulate the real human joint between shank and foot. Model E2 (fig. 2 – middle) has another rotation to the haunch joints too. These additional degrees of mobility have successfully improved the overall robot balance.

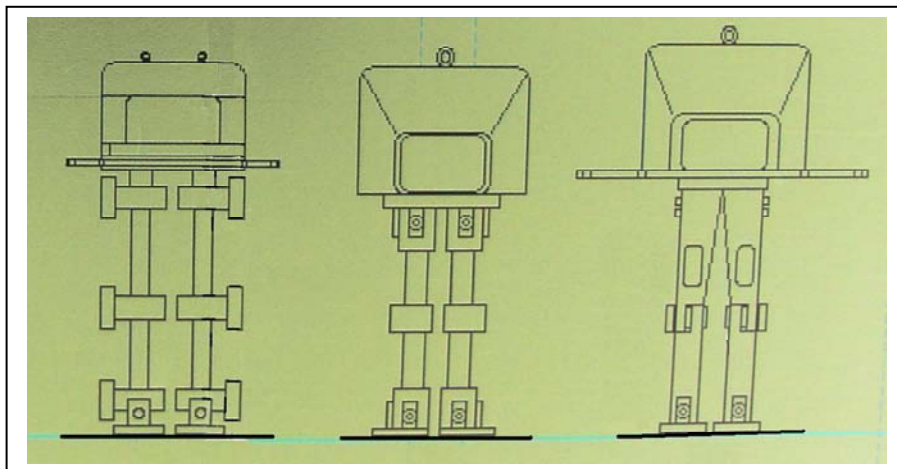


Fig. 2 E1, E2 and E3 - Honda's stepping robots within 1987-1991

Model E3, as it can be observed in figure 2 - right, has a better solution on knee rotate joint structure and he has a wider body base for improving the balance. Also, it was clear the trend to increase the high of robot to look like more human.

3. Achieving Stair Climbing by Robots

The next three robot models have improved technology to allow them to climb on stable stairs and to fast walking on uneven surfaces (fig. 3). Beginning with model E4 (fig. 3 – left), Honda has introduced the step sensors that can be observed on lateral sides of each shank, but the narrow soles and little distance between legs have a negative influence on balance. The model E5 (fig. 3 – middle) has supple distanced legs and counter weights on the body for better balance. In addition the soles, much wider than E4, offer a good stability on walking.

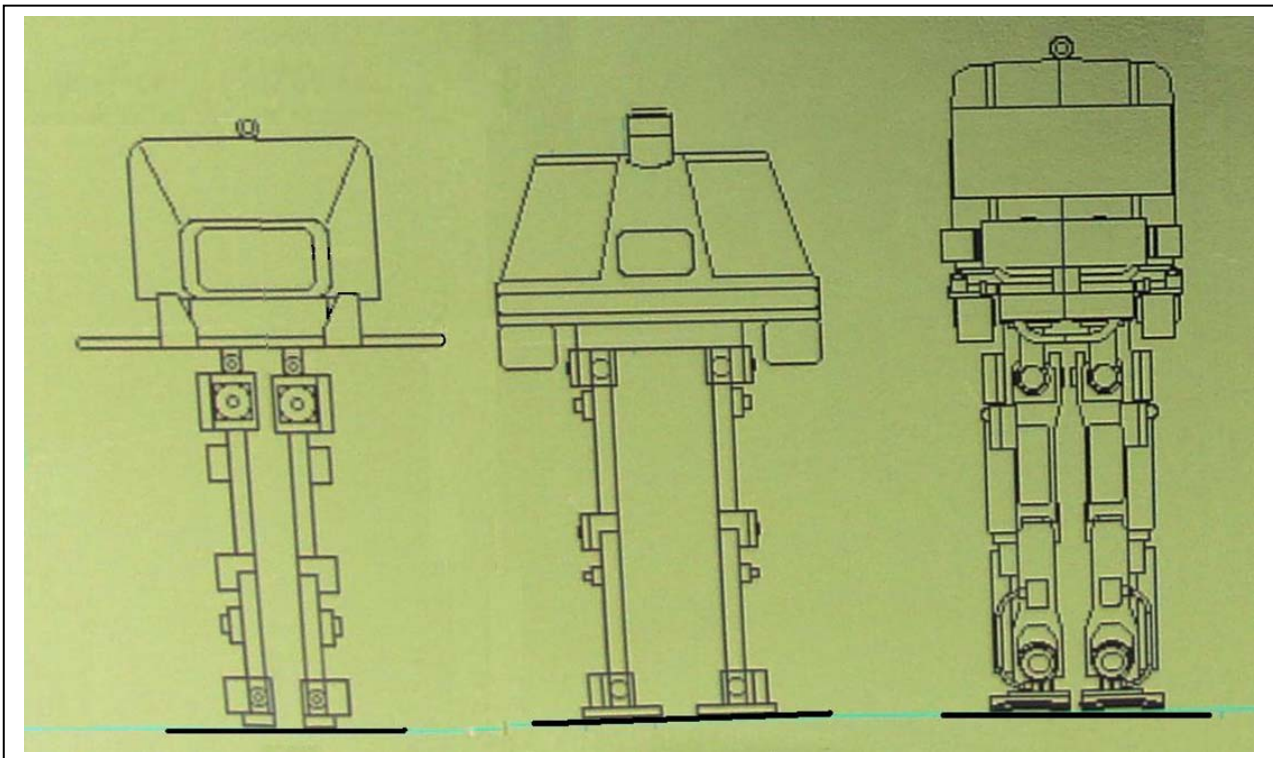


Fig. 3 E4, E5 and E6 - Honda's walking robots within 1991-1993

The robot model E6 (fig. 3 – right) has more complex leg mechanisms to control the stepping and balance. Also, the feet have improved soles for a smooth contact with soil on walking. Again, a trend to develop taller robots can be seen.

4. World's First Completely Independent Walking Humanoid Robots

The next three robot models on the evolution scale look more human because of the body with two arms that has been attached (fig. 4). Thus, like the human arm design, Honda has equipped P1 robot model (fig. 4 – left) with two arms consisting of three major parts: arm (humerus), forearm (radius and ulna) and hand. The joints between each pair of elements are shoulder, elbow and wrist as human-being has. The shoulder joint has two rotations to simulate the spherical human one. The wrist joint has also two rotations to simulate the rotate human wrist, and another rotate mobility to simulate the one given by the two forearm bones: radius and ulna. In the case of P1 model the hands are very simply, they representing in fact two grippers with just two "fingers". P1 was the first completely independent walking humanoid robot.

P2 robot model (fig. 4 – middle-left) looks more human due to the body proportions related to the legs and the round shapes that define him. But the overall appearance was still not so human.

An importing step in this direction has been made by P3 model (fig. 4 – middle-right) that has a good humanoid look or, more precise, an astronaut. In this case a major improvement regarding the hands has been achieved. As it can be observed in figure 4, the hands have a rigid thumb but at least one finger with two phalanges for a better grasping.

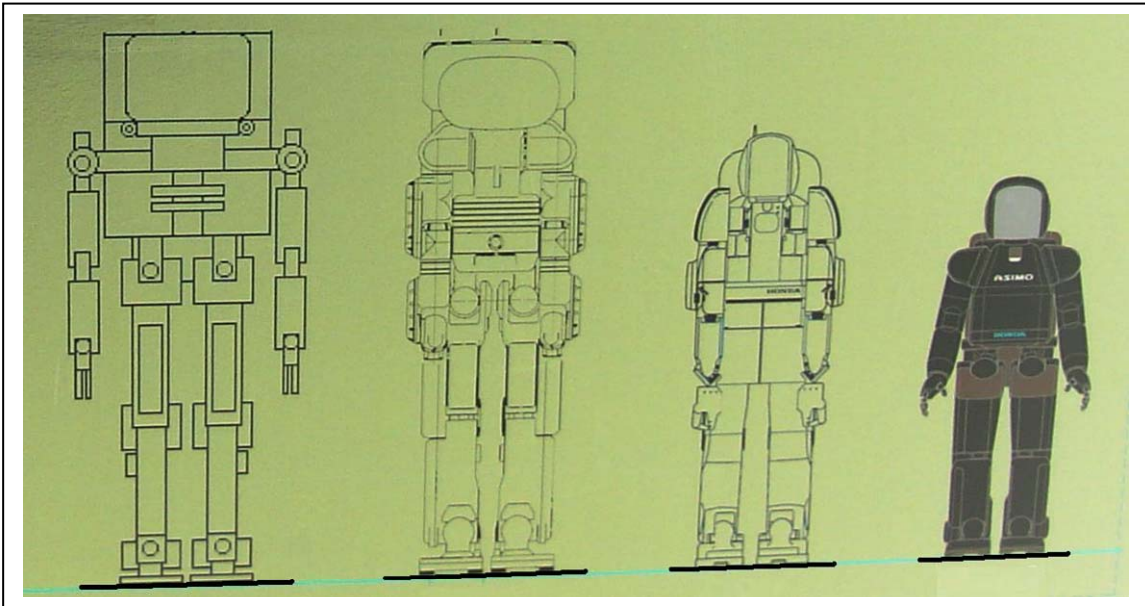


Fig. 4 P1, P2, P3 and ASIMO - Honda's humanoid robots within 1993-2005

The latest and the most humanoid robot by Honda is ASIMO (**A**dvanced **S**tepping **I**nnovative **M**Obility) – figure 4 (right). He is separately studied in the next chapter because he represents a giant leap on robot evolution scale. Thus, Honda honors one of the greatest science-fiction writers: Isaac Asimov.

Unlike the previous trends of robot height increasing, within this latest period of twelve years Honda's designers decrease the height of each new model.

5. ASIMO - The First Truly Humanoid Robot



“Meet ASIMO!” said the show animator (fig. 5). ASIMO is always ready to observe, hear and talk like a human-being. More than that, he can learn many things including human faces and voices, later recognizing them. He has two human basic senses: eyesight by two “eyes” (fig. 10) and hearing by two “ears”. His binocular vision helps him to see in 3D and to estimate correctly the distances.

ASIMO can make a lot of human gestures like the one shown in figure 6 or a hand greeting in figure 7.

He has the basic degrees of freedom of the human body. On hand design a great technological step is achieved. As it can be observed in figure 7, the hands have five fingers each, the thumb with two phalanges and the other fingers with three phalanges each, like the human hand. Unlike the human hand he has not yet the carps and meta-carps “bones”. Anyway, his hands can take the fist position (see the left hand in fig. 7).

Fig. 5 ASIMO - Honda's latest human robot (2005)



Fig. 6 ASIMO's human gesture



Fig. 7 ASIMO's hand greeting

ASIMO's performances are really incredible. Figure 8 shows a good example of how much human is ASIMO. He is able to move just like the show animator, doing the same "warming" exercises.

One of the strong features of ASIMO is walking as he can be seen in figure 9. As man does, he walks with an outstanding balance. More than that, he does not need to move his arms for a better balance like man does. Maybe in the future, when he will be able to run!



Fig. 8 ASIMO's human movements



Fig. 9 ASIMO's human walking

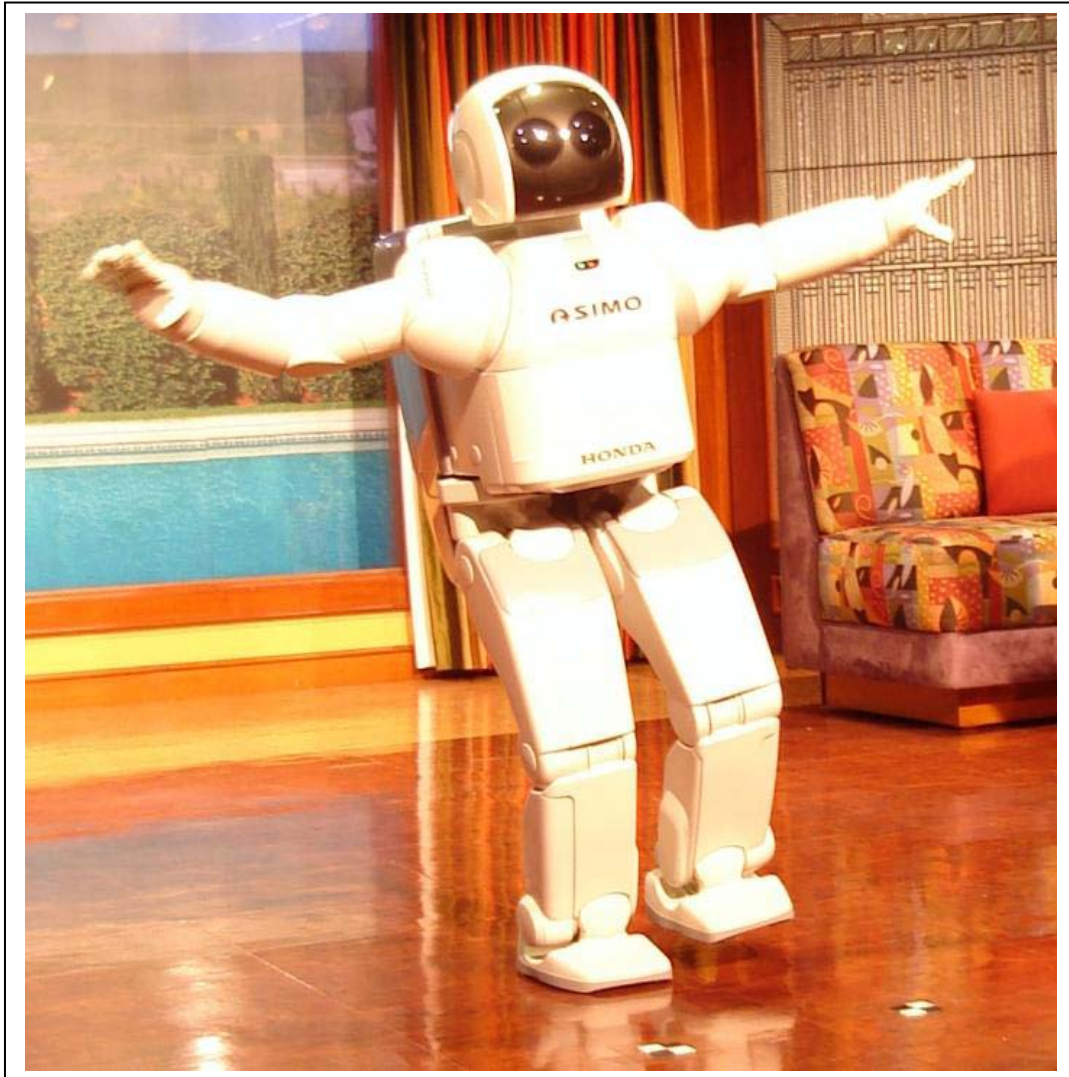
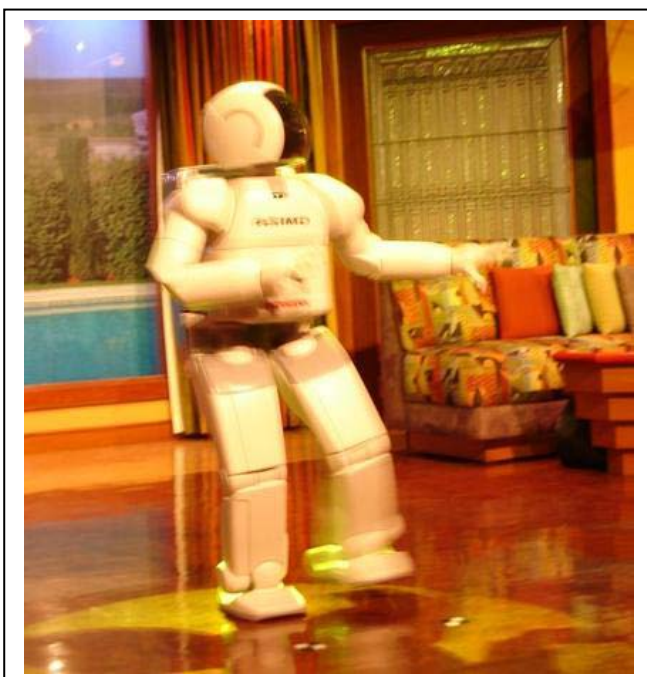


Fig. 10 *ASIMO's incredible balance on one leg*



In figure 10 is it clear what ASIMO can do on balance performance. He does what man sometimes fails: to stay in equilibrium on one leg! Like man, he helps himself by arms to achieve an outstanding performance: a perfect balance on one leg.

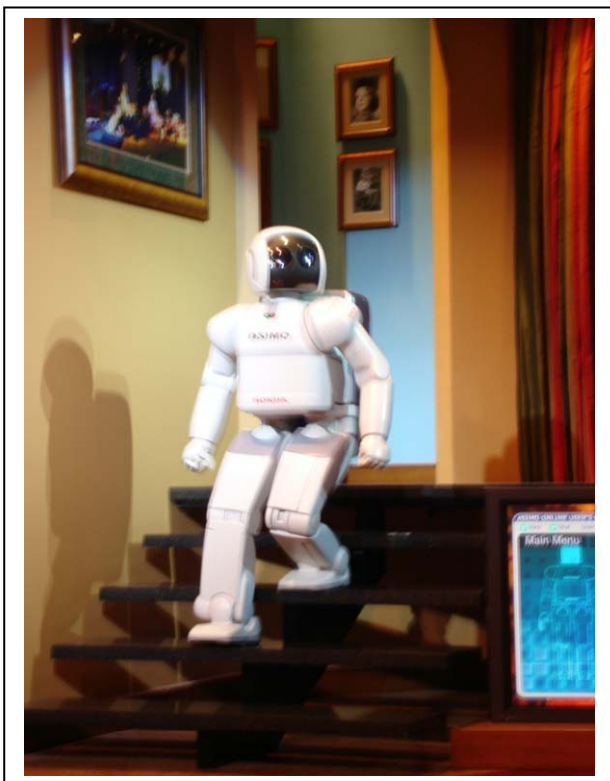
But this is not all. As he can be seen in figure 11, ASIMO can dance as man does. He is able to coordinate the movements of legs, arms, body and head by choosing a proper style of dancing accorded to the music. The head can be rotated in two planes: horizontal and lateral.

Due to the fact that he has not (yet!) tarsi, metatarsi and phalanges on feet, his walking is a little tremulous but safe.

Fig. 11 *ASIMO's dancing performance*



Fig. 12 ASIMO's upstairs climbing



In figure 12 and 13, ASIMO gives a great demonstration of climbing up and down on stairs. The balance on steps is very good making him the ultimate humanoid robot.

6. Conclusions

ASIMO can orientate himself in space by observing two positioning marks on the floor (home position). Also, when he climbs he needs to see these kinds of marks on every step in order to measure the distance and to act correctly up or down.

The next step in walking developing would be the design of a human foot with fingers having phalanges and tarsi (even meta-tarsi) "bones", like the human ones. More fingers and tarsi he would have, more smooth stepping he would make.

We all remember the movie "Star Wars" made in 1977. Who thought that in less than 30 years the humanoid robot could become reality? Not many!

Fig. 13 ASIMO's downstairs climbing

One by one the human science-fiction ideas will become, one day, reality. The man imagination could take shape and be part of our everyday life.

Therefore, ASIMO is the "living" proof that human mind has unlimited possibilities.

Reference

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