A History of LARMbot Humanoid

Marco Ceccarelli(✉)

Department of Industrial Engineering, University of Rome Tor Vergata, 00133 Rome, Italy
marco.ceccarelli@uniroma2.it

Abstract. The historical-technical development of the LARMbot humanoid is presented with its design and functional characteristics referring to low-cost and user-based laboratory solutions for applications with limited operational capabilities. The concept of the humanoid LARMbot has been developed since 2001 with the aim of aggregating design solutions and prototypes of partial robotic structures in manipulation and locomotion until reaching the conception of a unitary project still with a modular strategy for a high-performance functional laboratory prototype with innovative cable-actuated structures built in 2016. The latest developments have been published in improvements and expansion of parallel cable-actuated structures for the torso and also for the upper limbs to ensure high-load capacity compared to the weight of the LARMbot humanoid structure.

Keywords: History of Robotics · History of Humanoid Robots · History of LARMbot Humanoid · Humanoid Designs · Humanoid Prototypes

1 Introduction

Nowadays, humanoid robots are developed with significant developments both in research and applications, even with market solutions. The earliest humanoid robot was the WABOT-1 developed in the early 1970s at Waseda University in Tokyo, Japan, [1], with a significant mechanical structure over the other components for sensing and control. Examples of today's famous humanoid robots can be indicated in ASIMO, [2], WABIAN, [3], HRP, [4], Johnnie and Lola, [5], HUBO, [6], ATLAS, [7], and BHR, [8], just to cite few in a growing robot population worldwide.

Humanoid Robotics is an important branch of Robotics since humanoids show special advantages over other robots due to their close similarity to the human body. They can operate in complex environments for a wide variety of complex tasks. Today, most of the humanoid robot laboratories are interested in the research of robot capabilities such as walking on various terrains, fall protection, and interaction with the environment, with solutions that can span from very sophisticated and complex ones up to very simple low-cost solutions, even in the form of toys. The activity ranges from research activity in design and operation investigation up to the development of solutions for specific tasks in applications and experiences with prototypes. Within this last area, the LARMbot humanoid is a solution that is characterized by low-cost efficient design based on parallel mechanism architecture, [9].

This paper introduces the history with main achievements in the development of the prototype of LARMbot humanoid in about twenty years of activity.

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2 Conceptual Design of LARMbot Humanoid

The current LARMbot prototype responds to the conceptual design which is summarized in Fig. 1 with structural modules for the anatomical part integrated by the actuation systems composed of servomotors and cables and additional sensor systems for the control of the operation but also for the possibility to know how to interact with the environment. The modular architectures can be recognized for the legs equipped with a foot, in the arms with a hand, the central body composed of trunk and waist, and the neck with a head. Each module is designed with an independent structure to have independent functionality that is controlled and programmed by its own control unit based on specific programming codes and powered by specific power units in terms of batteries of adequate size and voltage.

The concept in Fig. 1 consists in the design of modules even with similar structures with independent functionality that can be easily integrated to have a synergistic coordinated operation of all the parts for the purpose of functioning as a humanoid robot.

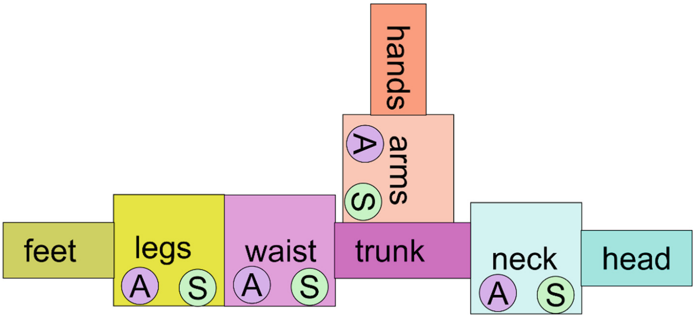
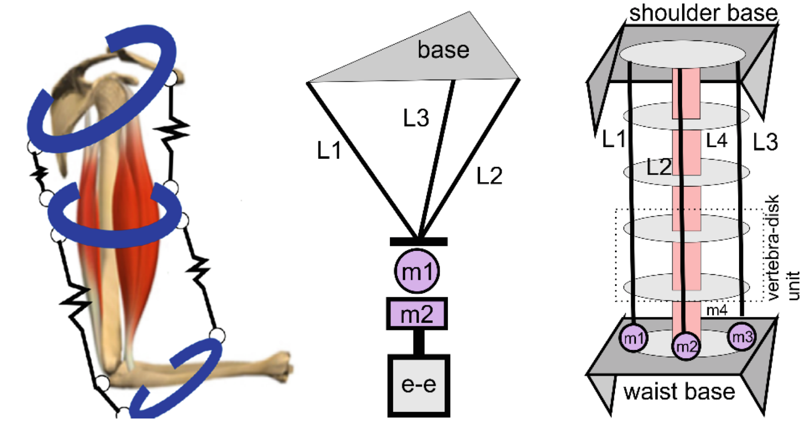


Fig. 1. A conceptual scheme for modular design of humanoids. (A is for actuator system; S is for sensing system).

Figure 2 shows the structural and functional diagrams of the modules that refer to and are inspired by the human anatomy in the musculoskeletal structure, [10], which is synthetically modeled in Fig. 2a) as a parallel manipulator with antagonistic drives of the muscle cables. Figure 2 b) presents the characteristic implemented tripod structure that can be implemented and is implemented for the leg and arm structures considering that the functionality of the wrist and ankle joints are achieved by the mobile platform equipped with two servomotors that allow orientation of the foot as leg end-effector or of the wrist as arm end-effector by exploiting the high translational capacity of the tripod. Figure 2c) represents the design concept of the parallel-serial hybrid structure for the trunk thought of as a combination of rigid bodies reproducing the vertebrae and intervertebral discs, [11], that are actuated with cables with antagonistic operation by servomotors installed on the platform that has the function of waist. Therefore, it can be noted that the humanoid robot LARMbot is characterized by a structure with modules with parallel architecture that respond to the models in Fig. 2 b) and c).



. a) b) c)

Fig. 2. Conceptual design for modular solution of LARMbot humanoid: a) a scheme of the inspiration from human anatomy, [10]; b) module for legs, arms and neck-head; b) torso design with vertebra-disk units with cable actuation

3 LARMbot Designs

The humanoid LARMbot was developed trying to create the main structures according to the human anatomy for functionality in easy mobility and high payload capacity with respect to its own weight without excessive design and operational sophistication. With this aim, the LARMbot humanoid has been designed and can be used for applications with non-high performance service tasks and not in complicated environments when suitable covers are shaped for a proper human-robot interaction. Typical service applications for the LARMbot humanoid can be identified in tasks of companionship and assistance of human beings in normal or uncomfortable conditions, and in service tasks in structured environments such as for example in domestic environments, industrial workstations, offices, healthcare centers, and cultural venues.

Greater efficiency and expansion of performance can be thought with adequate developments of capabilities in autonomy, control, and artificial intelligence supports when adequately integrated and combined with the mechanical capabilities of motion and action. Examples of such further applications can be identified in tasks of surveillance, accompanying and helping human beings, in manipulation and movement tasks in domestic environments as well as in industrial and non-industrial ones.

Figure 1 summarizes the main development of solutions of the LARMbot humanoid as design solutions developed for small size in the years from 2001 up to today with the characteristics as outlined above in terms of functionality and applications, [12–18].

In particular, the 2001 design in Fig. 3 a), [12], shows the assembly of structures developed for other applications in specific activities in different previous periods considering the useful functionality in a humanoid. One can recognize the locomotor leg system with articulated linkages actuated via pantograph, the hybrid parallel-serial robot based on the CAPAMAN parallel manipulator, and the LARM hand with articulated mechanisms with 1 DOF finger mechanism. This first solution was conceived using previous

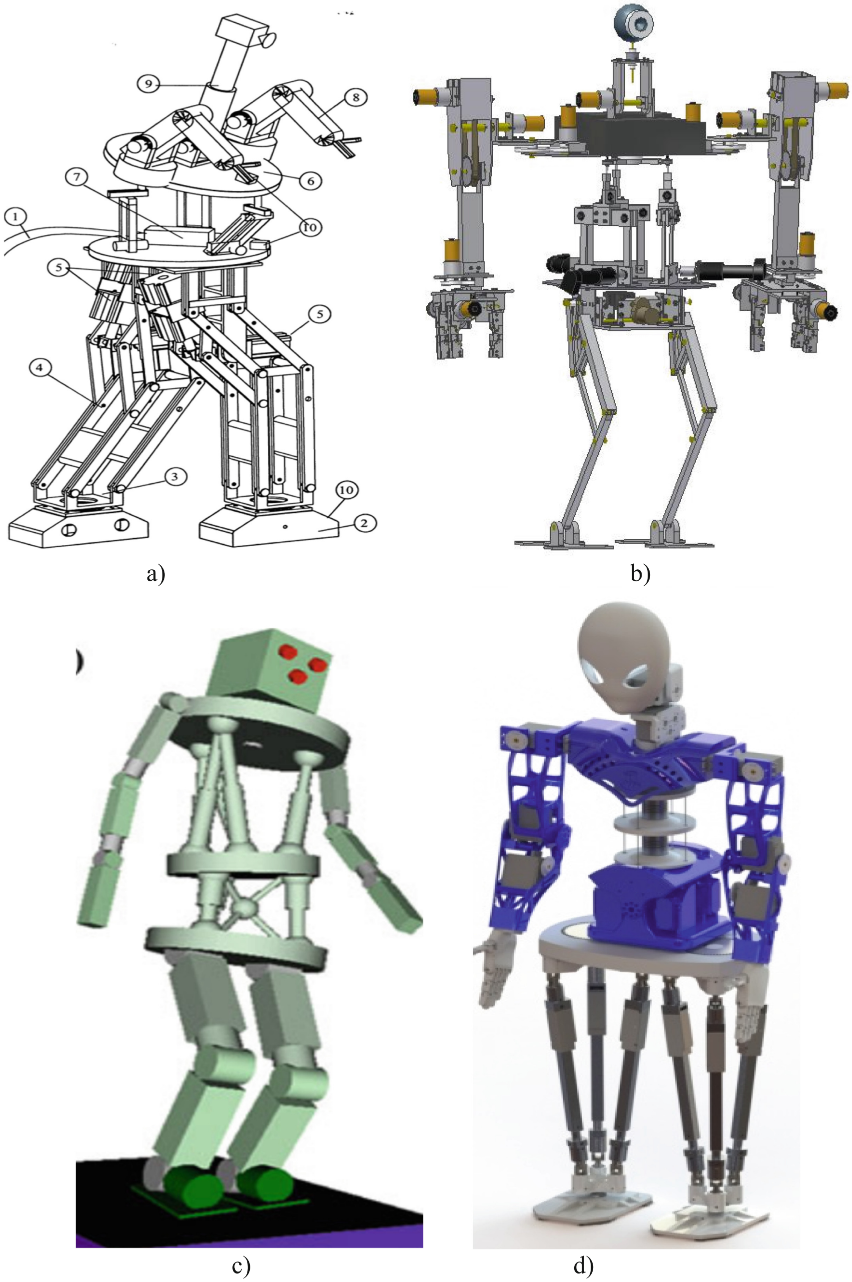


Fig. 3. Design solutions of LARM humanoid over time: a) early concept in 2001, [12]; b) CAD design in 2006, [13, 14]; c) waist-trunk based design in 2012, [15]; d) locomotor-trunk based design in 2016, [16–18].

solutions of sub structures and corresponding experiences on their functionality in the previous decade to adapt them to a humanoid structure and functionality from a mainly mechanical point of view. The 2006 design of Fig. 3 b), [13, 14], was designed by particularizing the previously specified sub structures while still using mechanisms that were only partially successfully tested. With the solutions in Fig. 3 a) and b) it was possible to create prototype elements to verify and characterize the synergy and coordination of parallel structures and serial mechanisms. The 2012 solution in Fig. 3 c), [15], represented in a CAD used for a detailed dynamic simulation, is based on the centrality of the trunk created with two parallel architectures. Prototype construction was tested with only this trunk structure to verify and characterize a trunk with high mobility and high load capacity, [19]. The experiences accumulated over those years have finally permitted to define in 2016 the humanoid LARMbot design with its own peculiar and original structure, [12, 16–18], as represented in Fig. 3 d) with the characteristic of combining structures with parallel architecture both in the legs and in the trunk to ensure a high load capacity of about 10 kg which however was limited by the anthropomorphic serial structure of the arms.

Figure 4 shows an attempt in 2010 with a different solution for the leg system inspired by particular situations in nature referring to walking methods such as that of the elderly or some animals using their tails, [20]. Although it is an attractive solution to facilitate the stability of locomotion without having the bulky quadruped configuration, the compact structure and flexible operation were not convenient for a humanoid. In the solution was still used the leg module with the same characteristics as the previous solutions based on a mechanism actuated by a pantograph.

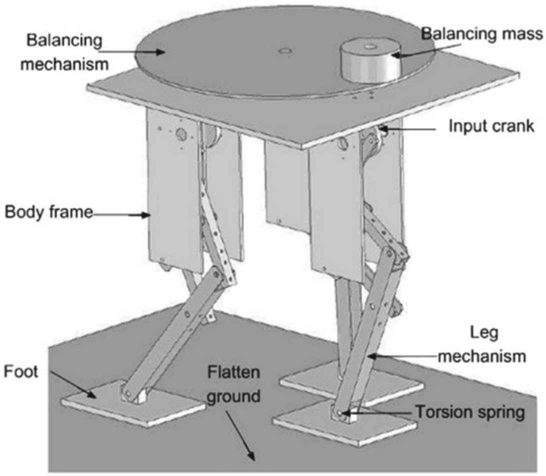


Fig. 4. A design solution for the leg module for LARMbot humanoid with three legs, [20].

4 LARMbot Prototypes

Specific prototypes were developed once the specific architecture of the LARMbot in Fig. 3d) was defined starting from 2015. In particular, a first complete prototype of the humanoid of an overall size of about 80 cm tall and 40 cm width with a weight of about 3 kg was assembled by combining the tripod leg system with the trunk parallel-serial hybrid architecture to which arms and a neck with head have been added as shown in Fig. 5, [16–18]. It is to note that in the first prototype of the humanoid LARMbot no particular attention was paid to the structure and functionality of the arms that were designed and realized with an anthropomorphic configuration. Furthermore, the tripod leg was not equipped with an ankle joint and there was no convergence of the three actuated links in a physical point of the mobile platform, which acts as a foot.

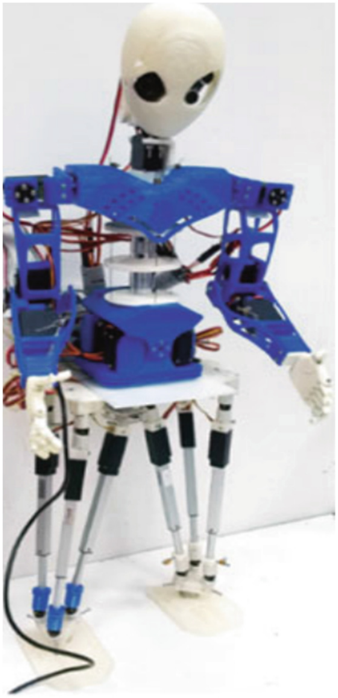
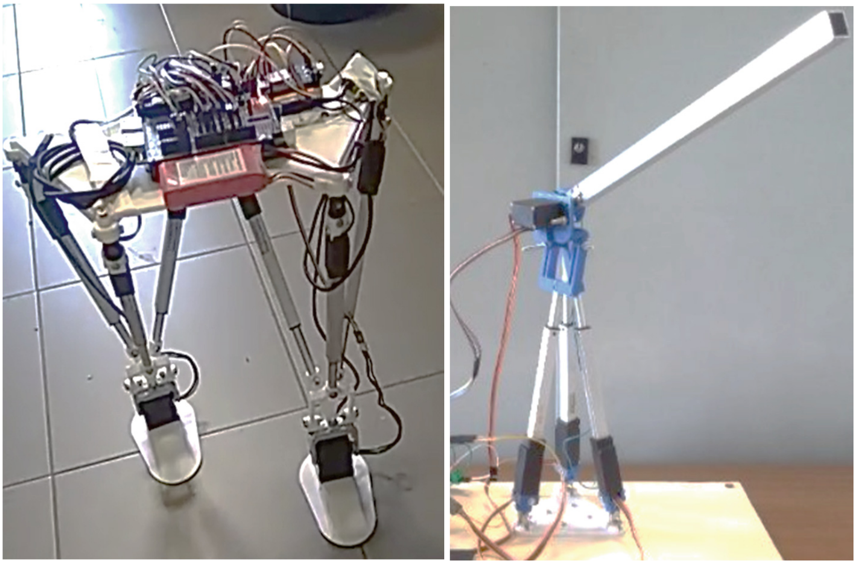


Fig. 5. The built prototype of LARMbot humanoid in 2016, [16–18].

Subsequently, the need to improve the functionality of the leg structure was recognized by equipping it with an ankle joint which also required a better design of the tripod with a specific new mechanism that would ensure the convergence of the three actuated links, thus achieving the realization of the prototype in Fig. 6 a), [21]. This prototype was built and tested separately also with the aim of designing the actuation and power system as a separate and independent module from the rest of the humanoid structure with experimentation of various walking programming modes.

The anthropomorphic structure of the arm was abandoned, and it was decided to also design the arm with a tripod structure which would ensure greater load capacity through a design strategy common to the structure of the legs. A first prototype of this solution is shown in Fig. 6 b) following this activity also with experimental tests starting from the year 2018, [22]. It is to note that this first arm prototype was designed in the two segments that reproduce the human anthropomorphic structure with forearm and arm using the arm mobile platform with an elbow joint with the mechanism specifically designed for the ankle of the legs in order to design the forearm with a simple link for the purpose of structural lightness.

In the improvement of the structure, attention was also paid to the trunk which in the original version was designed with only three disc-vertebral elements which allowed insufficiently wide mobility. The prototype of Fig. 7, [23] has been designed since 2020 with the same architecture of the disc-vertebra unit but increasing the number of units up to six, achieving a wide mobility of the trunk and creating a structure of adequate for proportionality with the arms and legs.



. a) b)

Fig. 6. Prototype modules for a new LARMbot Humanoid: a) leg with ankle assisted foot,[21]; b) arm with elbow actuated joint, [22]

5 Towards New Updates and Novel Solutions

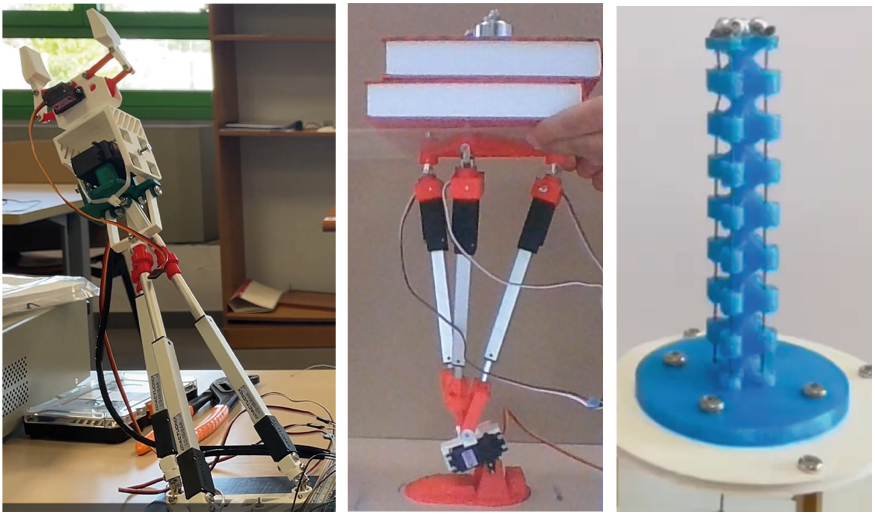
A more careful consideration of the musculoskeletal structure of the human anatomy with the results in [11] also motivated design inspiration for the arms with extension of the concept of modularity using the tripod structure for the legs. This new reinforced attention

Fig. 7. Prototype of the vertebra-disk unit torso for a new LARMbot Humanoid, [23]

to parallel architectures with muscular cables has also produced in 2023 a revisitation of the solution already adopted for the legs and torso. In particular, the structure of the legs was redesigned with adequate sizing by equipping the mobile platform with an ankle joint, Fig. 8 a) just as the structure of the tripod arms was equipped with a wrist joint equipped with a two-finger gripper, Fig. 8 b). The structure of the torso has been redesigned with a continuum parallel manipulator solution with a larger number of vertebral units, Fig. 8c) maintaining the actuation with antagonistic cables with only two motors, by increasing mainly the range of movement capability.

Figure 8 summarizes the latest developments with the new prototypes designed for the structures mentioned above using commercial components for actuators and sensors manageable with Arduino and partly from parts produced with 3D printing. These solutions, in addition to ensuring not high management complexity, ensure low-cost levels for the entire humanoid even at less than 300 euros, with the peculiar characteristics of the humanoid robot in wide ranges of mobility of the limbs and torso with a high capacity of estimated payload proven to be approximately three times the weight of the entire humanoid.

Further developments are planned for a coordinated and synergistic assembly of these new components with the aim of having a second laboratory prototype of the LARMbot humanoid that can be a platform for investigating and testing the feasibility and performance of entire system as well as of the individual parts.



. a) b) c)

Fig. 8. Prototype modules for a new LARMbot Humanoid: a) tripod-based arm with wrist, [23]; b) tripod-based leg with ankle, [23]; c) torso design, [24].

6 Conclusions

The technical development of the LARMbot humanoid robot is presented in its historical profile that takes into account the problems and solutions developed over twenty years with the main characteristics referring to design features of low-cost, high load capacity, and user-friendly operation. The initial modular characteristic of the LARMbot humanoid that was based on specific robotic structures developed for other specific applications was then adopted in subsequent versions with functional-structural module solutions for locomotion in the legs, for manipulation in the arms and in the central body for the trunk. Inspiration from the human anatomy suggested parallel architecture solutions with an innovative tripod structure for the legs, recently extended to the arms, as well as a hybrid serial-parallel structure with cable actuations for the trunk.

The historical analysis allows not only to highlight a timeline profile of the development of the LARMbot humanoid but also the peculiar technical-scientific development in the structure and functionality of the humanoid LARMbot.

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