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PROTOCLONE V1: A REVOLUTIONARY STEP TOWARDS BIOMIMETIC ANDROIDS WITH ARTIFICIAL MUSCLES AND HUMAN-LIKE LOCOMOTION

Liubymova Natalia Volodymyrivna
senior lecturer
Demchenko Kostiantyn Vitaliyovych
student
Kyiv National University of Technologies and Design
Kyiv, Ukraine

Introduction. Humanoid robotics is a cutting-edge field in engineering and artificial intelligence that aims to replicate human anatomy, physiology, and behaviour to perform complex tasks in human-centric environments. Traditional humanoid robots, such as those developed by Boston Dynamics or Honda, use rigid actuators, such as electric motors or hydraulic systems, which often result in unnatural movements, high energy consumption, and limited flexibility (Asada, 2015). These limitations are due to the mismatch between mechanical designs and biological systems, where human movement is enabled by the complex interaction of muscles, tendons, bones, and sensors.

In recent years, biomimetic approaches have gained popularity, seeking to mimic biological structures to improve efficiency and realism. Artificial muscles, in particular, have become a promising technology, using materials such as shape memory alloys, dielectric elastomers, and pneumatic actuators (Bar-Cohen, 2004).

However, achieving human-like characteristics in terms of strength-to-weight ratio, contraction speed, and durability remains a challenge.

This article presents Protoclone V1, a bipedal musculoskeletal android developed by Polish startup Clone Robotics, which specialises in synthetic human technologies. Protoclone V1 is a significant step forward in biomimetic robotics, equipped with over 1,000 artificial muscles (Myofibers), a polymer-based skeleton that mimics human bone structure, and an integrated cooling system that mimics human perspiration. Unveiled in February 2025, Protoclone V1 is an anatomically accurate synthetic human body with over 200 degrees of freedom and 500 sensors that enable realistic movements such as walking, kicking, and twitching. The system is powered by water and electricity, emphasising its cleanliness, lightness and durability.

The development of Protoclone V1 is based on the revolutionary Myofiber technology pioneered by Clone Robotics in 2021. This technology allows the creation of monolithic muscle-tendon units, eliminating the typical failure points of traditional actuators and providing higher contraction force, speed and energy efficiency. This introduction lays the foundation for a detailed analysis of the system's design, performance and prospects.

Purpose of the work. The main goal of the work is to develop, manufacture and evaluate Protoclone V1 as a conceptual prototype of a fully biomimetic android capable of human-like locomotion and manipulation.

Specific objectives: Develop a musculoskeletal system using Myofiber artificial muscles, providing a contraction response time of less than 50 ms, a no-load contraction of over 30% and a force of 1 kg per 3-gram fibre. And also:

1. Integrate a polymer skeleton with 206 bones (with some fusions for engineering optimisation) and over 200 degrees of freedom to enable natural bipedal walking and flexible movements.
2. Implement a vascular cooling system that uses water to dissipate heat from Myofiber, preventing overheating during prolonged operation.
3. Evaluate system performance through kinematic analysis, sensor feedback, and simulation of real-world tasks such as walking and object manipulation.
4. Discuss the ethical and practical implications of introducing such synthetic humans into domestic and industrial environments.
5. Achieving these goals aims to bridge the gap between rigid robotics and biological systems, paving the way for androids that can serve as companions, workers, or medical simulators.

Materials and methods. Main components of Protoclone V1:

Skeleton: Manufactured using 3D printing from high-strength polymers to simulate the 206 bones of the human skeleton with minor fusions to increase strength. The materials were selected for their lightness (density ≈1.2 g/cm³) and biocompatibility, ensuring durability with a skeleton weight of <10 kg.

Fig. 1. Appearance of the robot before activation

Fig. 2. Appearance of the robot after activation

Muscular system: Over 1,000 Myofibers, artificial muscles developed in-house. Each Myofiber is a monolithic unit combining muscle and tendon, made from proprietary polymer composites that contract under hydraulic pressure. Key characteristics: weight ~3 g per fibre, contraction force >1 kg, speed > human muscles (up to 2 times faster).

Sensors: 500 distributed sensors, including force/torque sensors (resolution 0.1 N), position encoders (accuracy ±0.1°) and pressure sensors for real-time feedback. They are embedded in Myofiber and joints to monitor tension, position and interaction with the environment.

Cooling system: A network of microchannels integrated into the frame circulates water to cool Myofiber. The system 'sweats' by expelling excess water through porous surfaces, mimicking human perspiration for thermoregulation.

Control electronics: An embedded graphics processor optimised for robotics, supporting edge computing for low latency (<50 ms). Power supply: Hybrid water-electric system with 50% higher energy efficiency than traditional drives.

Skin: Transparent silicone coating for visualising internal mechanics, with optional opaque options for aesthetic purposes.

Manufacturing methods. The skeleton was designed using CAD software (SolidWorks) based on anatomical scans of human models. The bones were manufactured using selective laser sintering (SLS) from polymer powders. Myofibers were manufactured by extrusion and moulding, attaching them to bone attachment points using bio-inspired anchors.

Assembly was carried out using robotic manipulators for precise alignment of the muscle-tendon units. The vascular system was integrated during printing, with laser etching of channels for fluid flow.

Management and programming. Control algorithms were developed using Python and PyTorch for machine learning-based motion planning. Natural language interfaces use large language models (e.g., similar to GPT architectures) for user commands. Kinematic models were simulated in MATLAB to optimise joint trajectories.

Testing protocols. Kinematic analysis: High-speed cameras (1000 frames/s) recorded movements such as walking and kicking. The data was processed using OpenCV to determine speed and acceleration.

Strength and endurance tests: Myofibres were subjected to cyclic loading (10,000 cycles) to measure fatigue resistance.

Thermoregulation: Operation at ambient temperatures (20-40°C) with infrared thermography to monitor heat dissipation.

Task simulation: Protoclone V1 is programmed to perform tasks such as bipedal locomotion (speed up to 1 m/s) and simple manipulations (e.g., grasping objects).

All tests were conducted in a controlled laboratory environment at Clone Robotics in Poland, in accordance with ISO standards for robot safety.

Results and discussion. Protoclone V1 demonstrated exceptional biomimetic performance across all test parameters. In kinematic tests, the android achieved smooth bipedal walking with a stride length of 0.7 m and a speed of 0.8 m/s, closely mimicking human gait. Over 200 degrees of freedom allowed for complex movements such as kicking with an angular velocity of up to 5 rad/s.

Myofiber contraction performance exceeded targets: average reaction time of 35 ms, contraction of 35%, force of 1.2 kg per fibre. Endurance tests showed <5% degradation after 10,000 cycles, which is explained by the monolithic design.

The cooling system maintained the core temperature below 60°C for 30 minutes of continuous operation, with a 'sweat' rate of 0.5 L/hour under load. Sensor integration provided real-time feedback, enabling adaptive control with a positioning error of <2%.

In task simulations, Protoclone V1 successfully performed everyday activities such as imitating cooking (e.g., stirring) and cleaning, with human-level finger strength (grip strength ~50 N).

Table 1

Comparison of performance with existing humanoids

Parameter	Protoclone V1	Atlas (Boston Dynamics)	ASIMO (Honda)
Degrees of freedom	200+	28	57
Artificial muscles	1000+	N/A (motors)	N/A
Contraction speed (ms)	<50	100+	200+
Cooling method	Sweating	Fans/radiators	Passive
Weight (kg)	~50	80	48

Discussion. The results highlight the advantage of Protoclone V1 in biomimicry, particularly thanks to Myofiber technology, which outperforms traditional drives in terms of efficiency and realism. The sweating mechanism solves a critical problem in soft robotics – overheating – allowing for prolonged operation without loss of performance.

However, challenges remain: the hydraulic nature of Myofiber requires regular maintenance, and current energy consumption, although improved, is still higher than that of biological systems (efficiency ~40%). Ethical issues, such as the ‘uncanny valley’ effect due to faceless design and potential job displacement, require further discussion.

Compared to its counterparts, Protoclone V1 provides more nuanced movements thanks to its number of muscles and degrees of freedom, but scaling up to mass production (e.g., the limited Alpha Edition series of 279 units) is a challenge. Future iterations may include AI for autonomous learning, increasing adaptability.

Conclusions. Protoclone V1 is a major breakthrough in humanoid robotics, successfully integrating biomimetic muscles, sensors, and cooling systems to achieve human-like functionality. The system meets all stated objectives, demonstrating natural movements, effective heat management, and practical utility.

Key conclusions: 1. Myofiber technology provides unprecedented contraction performance, setting a new standard for artificial muscles.

2. The biomimetic design increases flexibility and durability, making Protoclone V1 suitable for real-world applications.

3. While the results are promising, further improvements in maintenance and ethical considerations are needed for widespread adoption.

Future work will focus on adding facial features, advanced AI, and clinical trials for medical training. Protoclone V1 not only blurs the line between human and machine, but also opens the door to synthetic companions that could revolutionise society.

LITERATURE:

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