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Development of a novel autonomous lower extremity exoskeleton robot for walking assistance

Key words: Lower-limb; Exoskeleton; Self-balancing; Bipedal walking; Modular design

Corresponding author: Xin-yu WU
E-mail: xy.wu@siat.ac.cn

ORCID: http://orcid.org/0000-0001-6130-7821

Motivation

1. Exoskeletons are widely applied to provide walking assistance for patients with lower limb motor incapacity. Most existing exoskeletons are under-actuated, resulting in a series of problems, e.g., interference and unnatural gait during walking.

2. We propose a novel intelligent autonomous lower extremity exoskeleton (Auto-LEE), aimed at improving the user experience of wearable walking aids and extending their application range.

Main idea

1. Auto-LEE has 10 degrees of freedom, and all the joints are actuated independently by direct current motors, which allows the robot to maintain balance in aiding walking without extra support.

2. The new exoskeleton is designed and developed with a modular structure concept, and multi-modal human-robot interfaces are considered in the control system.

Method

Biomechanical analysis of the human body:

To achieve the most natural human gait possible and increase the application range of the exoskeleton, we analyze human biomechanical properties.

Design of the exoskeleton:

(1) Description of the overall view of the exoskeleton system;

(2) Design of the exoskeleton with modular structure;

(3) Design of the plantar pressure detection system;

(4) Design of the control system.

Preliminary research on self-balanced walking of the exoskeleton.

1. Overall view of the exoskeleton system

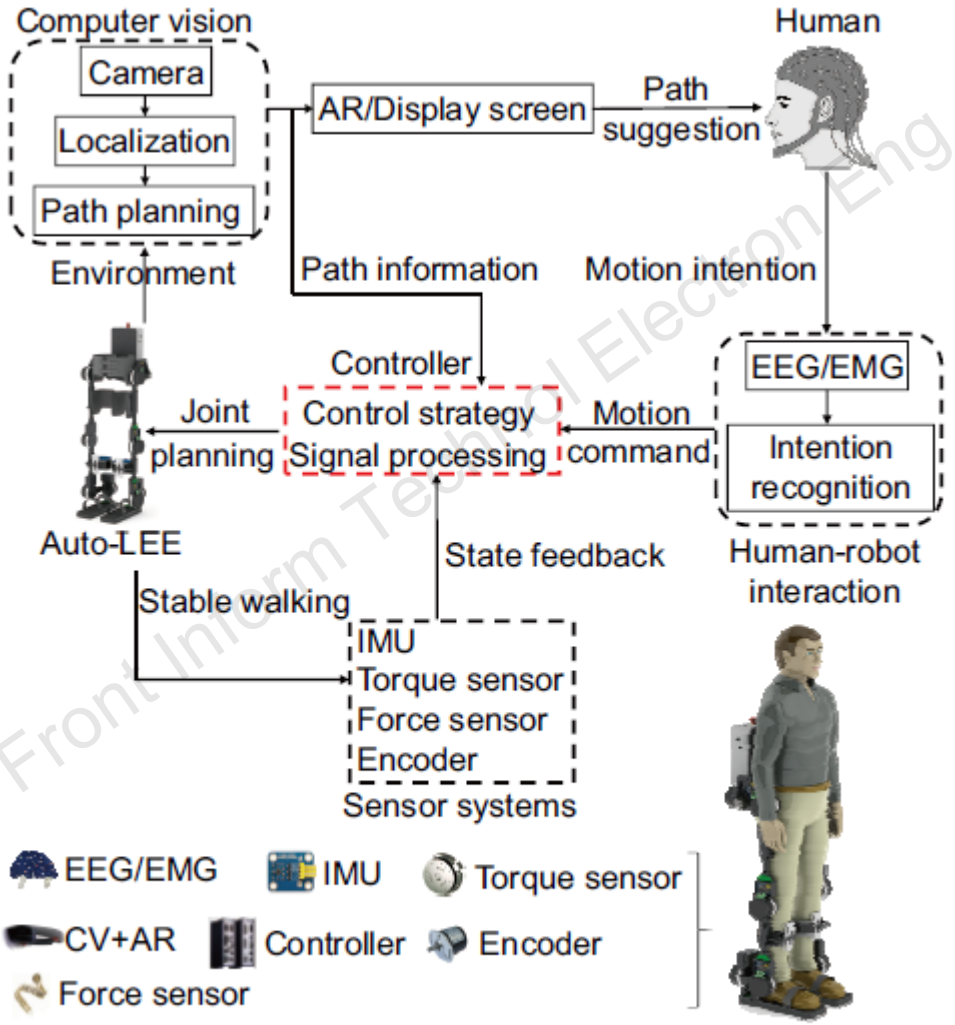

Fig. 3 Overall view of the exoskeleton system

2. Design of the exoskeleton with modular structure

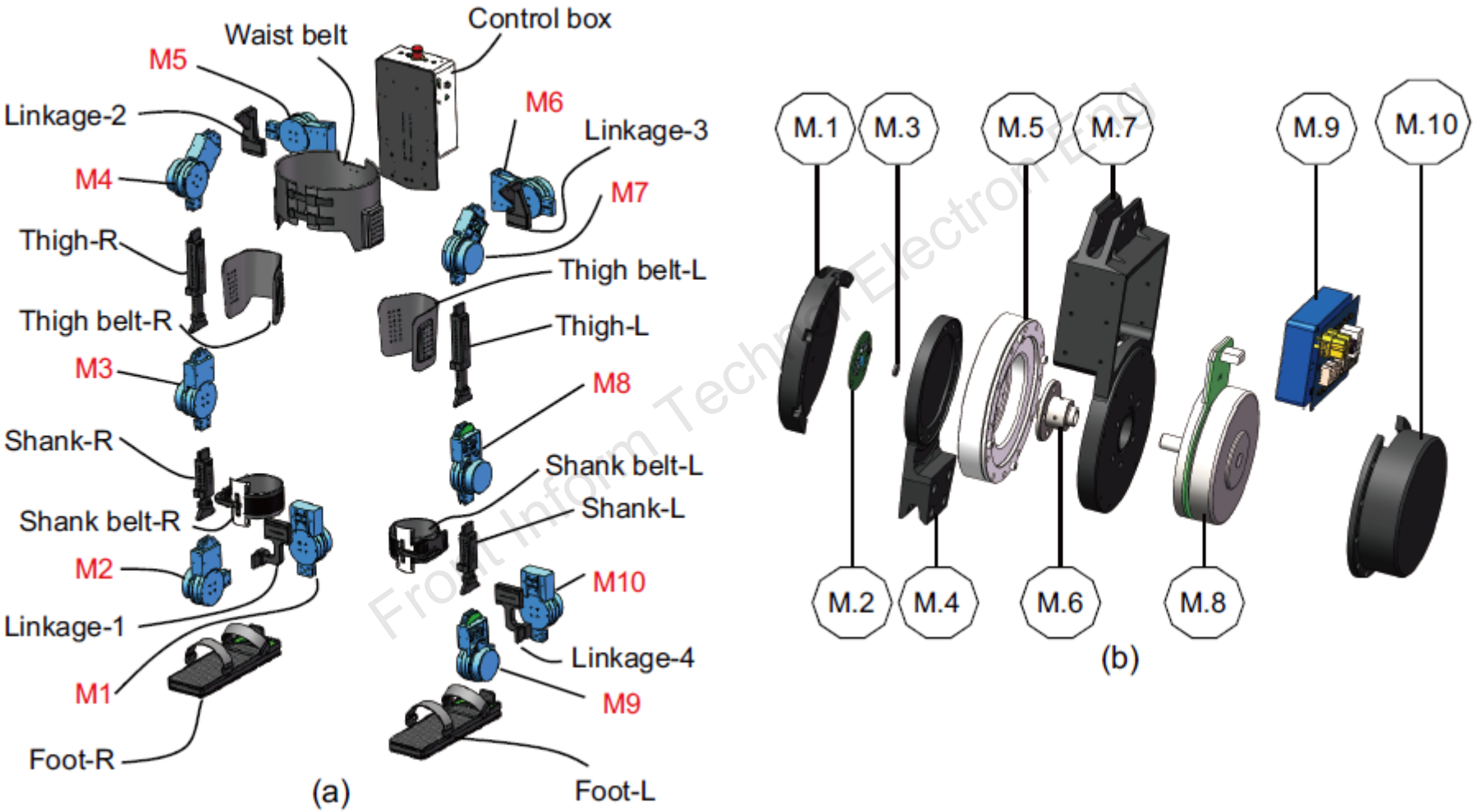

Fig. 4 Exploded views of the exoskeleton (a) and the modular drive unit (b)

3. Design of the control system

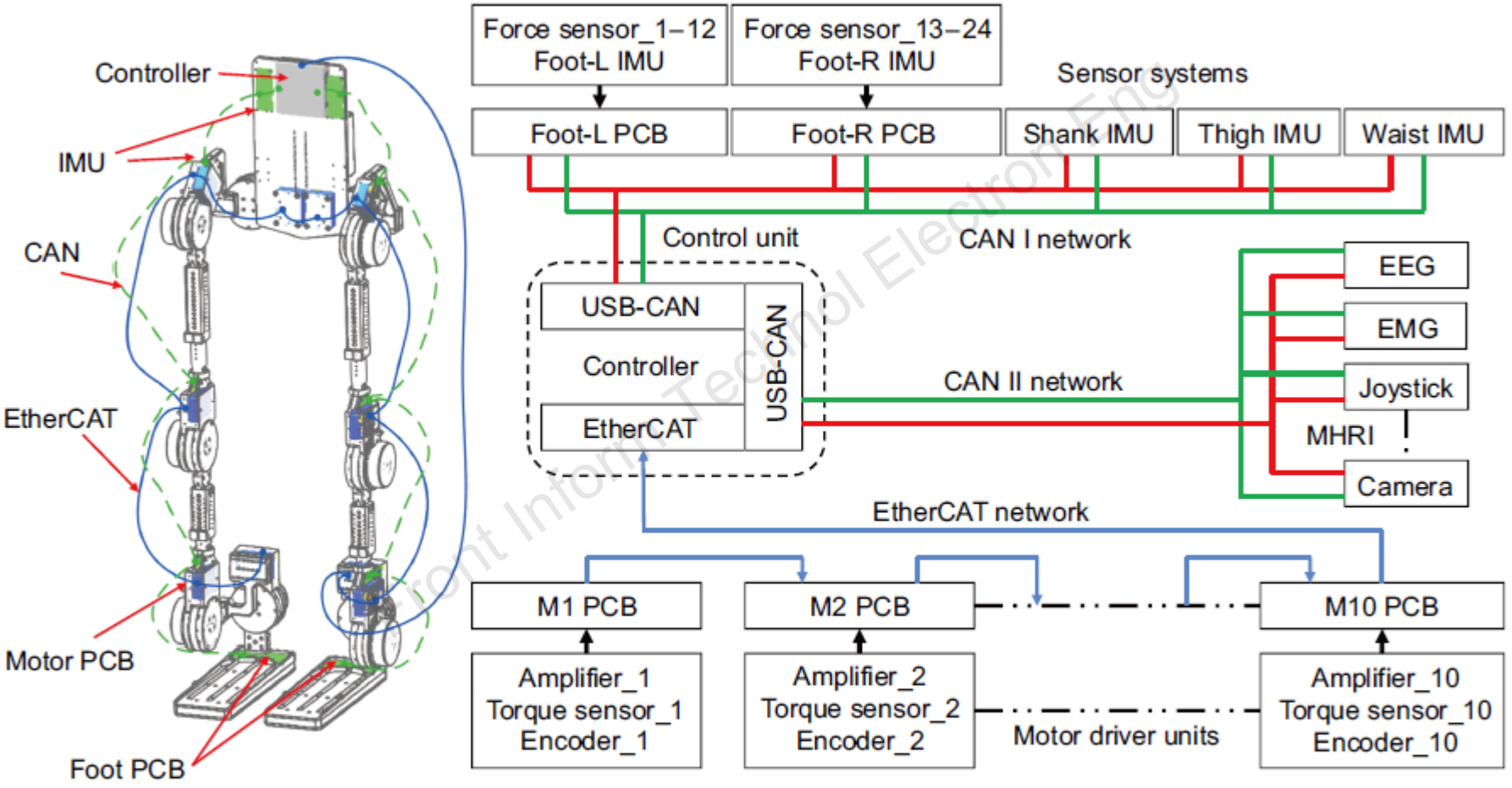

Fig. 6 Overall view of the control architecture

Preliminary experiments

Fig. 15 Snapshots of a self-balanced walking experiment on a flat terrain

Fig. 16 Snapshots of self-balanced walking experiment with a dummy on a flat terrain

Conclusions

1. Biomechanical analysis on the human body has been performed, which indicates that the abduction/adduction motions of the joints in the coronal plane play an important role in maintaining balance in bipedal walking.

2. With modular structure design and multimodal human-robot interfaces, the exoskeleton can be applied to users of different sizes and with different conditions. For example, a paraplegic can handle a device with a joystick, and a tetraplegic can control a device with EEG equipment.

3. Three general algorithms for bipedal walking have been researched, and the preliminary experiment on a flat terrain has validated the self-balanced walking ability of Auto-LEE. However, deviation from the origin occurred during the experiment, which could be caused by the absence of a stabilizer controller and the simplification of the dynamical model.