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# Slow walking model for children with multiple disabilities via an application of humanoid robot

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ABSTRACT

Walk training research with children having multiple disabilities is presented. Orthosis aid in walking for children with multiple disabilities such as Cerebral Palsy continues to be a clinical and technological challenge. In order to reduce pain and improve treatment strategies, an intermediate structure – humanoid robot NAO – is proposed as an assay platform to study walking training models, to be transferred to future special exoskeletons for children. A suitable and stable walking model is proposed for walk training. It would be simulated and tested on NAO. This comparative study of zero moment point (ZMP) supports polygons and energy consumption validates the model as more stable than the conventional NAO. Accordingly direction variation of the center of mass and the slopes of linear regression knee/ankle angles, the Slow Walk model faithfully emulates the gait pattern of children.



## 1. Introduction

Many technological devices can help people with brain or spinal chord injuries to acquire or recover physiological capabilities of walking. For an adult, robotic relearning of movements has been used to re-write walking patterns. For example in the market of today, Lokomat is a motorized lower extremity exoskeleton for spinal cord injury patients on a treadmill [1]; Mechanized Gait Trainer (MGT) is a one degree-of-freedom powered machine that drives the foot [2]. Can similar devices allow real psychomotor progress in children with multiple disabilities who have never acquired walking patterns? Although Lokomat–Hocoma, HAL-fit and HSR-Toyota have already exoskeleton products for children, they are only for the normal disabilities. Patients with Cerebral Palsy (CP) or multiple disabilities are different from people with other neurological disorders [3]. "Multiple disabilities" is a term for a person with several disabilities, such as a sensory disability associated with a motor disability. Individual usually has more than one significant disability, such as movement difficulties, sensory loss, and/or a behavior or emotional disorder. Persons with severe and multiple disabilities may carry a variety of diagnostic labels, including (1) severe or profound levels of mental retardation (IQ scores below 40); (2) mental retardation

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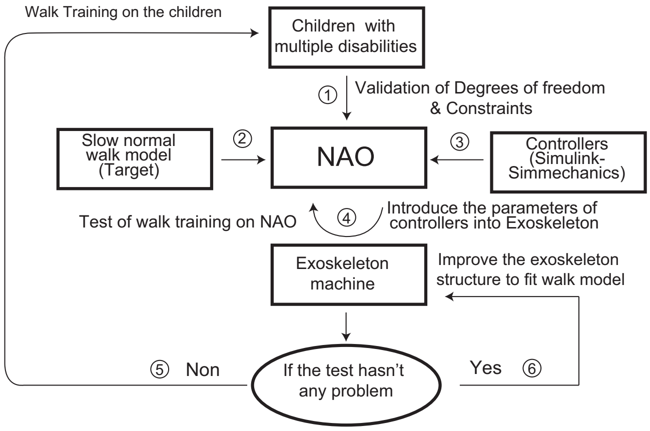


**Fig. 1.** Schema of the application of NAO in the research.

that requires extensive or pervasive supports for an extended time; (3) autism, childhood disintegrative disorder, or Rett syndrome (several types of autism spectrum disorders); and (4) various genetic disorders accompanied by extensive mental retardation (e.g., Tay–Sachs disease, untreated phenylketonuria, tuberous sclerosis, Lesch–Nyhan syndrome). Though the children might have four complete limbs, they do not have the opportunity to walk.

As such, a project called "MOTION" has been launched in France to design a motorized exoskeleton to educate movement to children who lack the ability to walk, suffering from multiple disabilities, cerebral palsy and neurological injuries or disorders, those least affected by musculoskeletal impairment. This is an integrated part of the rehabilitation process (sessions of 20–30 min) according to individual Central Nervous System (CNS) function [4], not meant as a palliative support for permanent use. This study provides an evaluation of promoting psychomotor development, where it is naturally blocked in disabled children, by using special technological means of motor education.

Therapeutic management in children with multiple disabilities is much more difficult than in adults [5]. In fact, children may be unable to communicate, perhaps difficult to understand or to comprehend or unable to voice experienced feelings of pain or discomfort. Only caregivers and family may fully understand such feelings and distinguish them from moodiness or other conditions. It is thus dangerous to place such children in motorized robotic orthoses. To reduce risks and save time, NAO [6] has been used as an intermediate platform. NAO replaces the children. As shown in Fig. 1 the step ①, first needs to ensure that a degree of freedom of the robot NAO so as to imitate walking children and also to simulate additional pathological constraints NAO, then simulate the walk mode as the step ②, which is controlled by control PID as shown in the step ③.

This walking mode is different from the general humanoid robot walk which is always with the knee bended, so as to easily maintain the stability about zero-moment point (ZMP) [7] and control the state of robot at all times. The walk mode with knee always bended consumes more energy than the mode with the knee intermittent straight [8] which is the normal walk mode of human. Thus, the first phase of project "Motion" was to achieve a slow walk mode with knee intermittently straight, which is the objective of the walk training of children with multiple disabilities. This walking model needs to minimize stress of joints and avoid sudden, jerky movements.

There are many exoskeletal machines available, some of which are versions of leg bones and muscles, and the pelvic girdle, and thus have a more modest aim to restore user's power and strength [9]. An example is "ReWalk" [10], which can train the disabled to walk. But in general, they are simple gait-repeated machines. Although they might furnish sensors and controllers for security [11], they cannot be adapted to fit the individual user. If the machine uses one single walking model to fit all, its use will lead to discomfort and pain. The intermediate structure NAO is thus used to optimize the management of balance by reducing the ZMP polygon support and to ensure that the walking trajectory is suitable for the individual child. NAO obtained parameters of controllers are then introduced into a virtual exoskeleton machine, as shown in Fig. 1, steps ④ and ⑤, reducing the time of adaption. On the contrary, if the exoskeleton cannot perfectly simulate the training walk, the exoskeleton structure should be improved to fit the walk model, as step ⑥.

This paper is divided into six sections. Section 2 gives a brief summary of the biped cinematic model of NAO. In Section 3, a slow walk model is described and compared with the walk model built-in ('Aldebaran' mode). Section 4 shows the experimental platform and results of test. Finally, a Conclusion and future work section provides a brief summary on this paper and our current and future research projects.

## 2. NAO, mathematical model and controller

### *2.1. NAO and kinematic model*

NAO is a humanoid robot developed by Aldebaran Robotics. His height is a child size 58 cm. It has 25 degrees of freedom (DOF): 2 in the head, 6 in each arm, 5 in each leg and 1 in the pelvis. All the joints are type of Pivot joint. As shown in Fig. 2,

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