Case Study: **Simulation Reality Contest Winner – Vrije Universiteit Brussel**

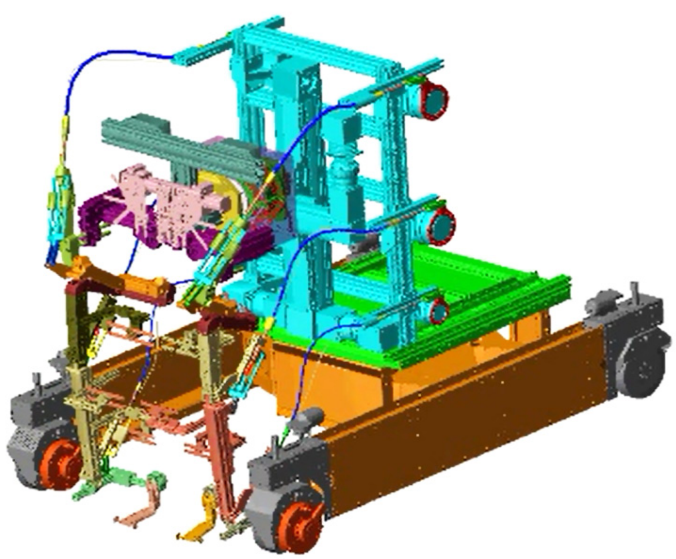
Adams Simulations Help Research in Robotic Rehabilitation Devices for Gait Abnormalities

Based on an interview with Svetlana Grosu, researcher in the Robotics & Multibody Mechanics Research Group at Vrije Universiteit Brussel

Overview

The medical industry is moving in a direction towards robotics to help patients in the rehabilitation process. Gait training (over ground or on a treadmill) has become an essential part of rehabilitation therapy in patients suffering from gait impairment caused by disorders such as stroke, spinal cord injury, and multiple sclerosis. A focus on the human in collaboration with a robot puts emphasis on the adaptability, safety, and task specificity of robotic assistance. Hence, in the development of novel rehabilitation prototypes engineers face the challenge of combining suitable design concepts, high performance actuator technologies, and dedicated control strategies in view of improved physical human-robot interaction (HRI). The improvements should lead to a better insight into effectiveness of robot-assisted rehabilitation and ultimately, lead to therapies that are more effective. One of the approaches to facilitate the design process, in terms of development time, functional and safety evaluation, is using computational multibody simulations.

Nowadays, multibody modeling and simulations are recognizable as an efficient and relative inexpensive evaluation approach. Due to the continuously increasing complexity of the wearable robots, almost any study conducted in the field of robotics can profit from a simulation of the system behavior, foregoing experiments on a real platform. Moreover, an advantage of using multibody modeling represented by the possibility to predict various outputs that are difficult, dangerous, or even impossible to reproduce in the real experimental setup.



Adams Model of CORBYS Gait Rehabilitation Device

"Simulations in Adams gave a powerful perspective to explore and gain additional insights into highly non-linear behavior of the push-pull cable actuation system. Thus, the results were very helpful in the accomplishment of research tasks of this project."

Svetlana Grosu, Researcher in Robotics & Multibody Mechanics Research Group at Vrije Universiteit Brussel.

Challenge

The medical industry is moving in a direction towards robotics to help patients in the rehabilitation process. Gait training (over ground or on a treadmill) has become an essential part of rehabilitation therapy in patients suffering from gait impairment caused by disorders such as stroke, spinal cord injury, and multiple sclerosis. A focus on the human in collaboration with a robot puts emphasis on the adaptability, safety, and task specificity of robotic assistance. Hence, in the development of novel rehabilitation prototypes engineers face the challenge of combining suitable design concepts, high performance actuator technologies, and dedicated control strategies in view of improved physical human-robot interaction (HRI). The improvements should lead to a better insight into effectiveness of robot-assisted rehabilitation and ultimately, lead to therapies that are more effective. One of the approaches to facilitate the design process, in terms of development time, functional and safety evaluation, is using computational multibody simulations Nowadays, multibody modeling and simulations are recognizable as an efficient and relative inexpensive evaluation approach. Due to the continuously increasing complexity of the wearable robots, almost any study conducted in the field of robotics can profit from a simulation of the system behavior, foregoing experiments on a real platform. Moreover, an advantage of using multibody modeling represented by the possibility to predict various outputs that are difficult, dangerous, or even impossible to reproduce in the real experimental setup.

Researchers at the Vrije Universiteit Brussel are on the cutting edge of finding a solution to help patients recover from various types of injuries. The EU project CORBYS - Cognitive Control Framework for Robotics Systems is a collaborative project sponsored by the FP7 program, a European government program that supports research and technological development. The Robotics & Multibody Mechanics research group at the university, headed by prof. Dirk Lefeber under which Svetlana Grosu is finishing her PhD work and other research projects, is fully engrossed in improving the gait rehabilitation process.

CORBYS target range of patients are patients with various gait abnormalities, such as sensory loss, spasticity, lack of coordination, involuntary movement, pathological gaits such as toe walking, crouch gait (knee flexion & increased hip flexion), and stiff knee. CORBYS goal was

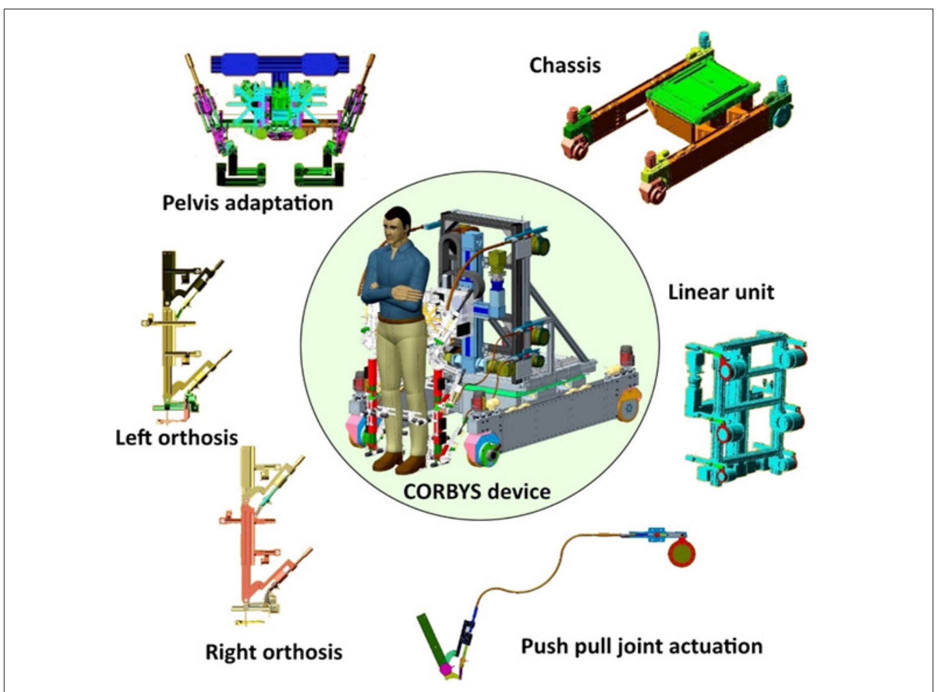
Key Highlights:

Product: Adams

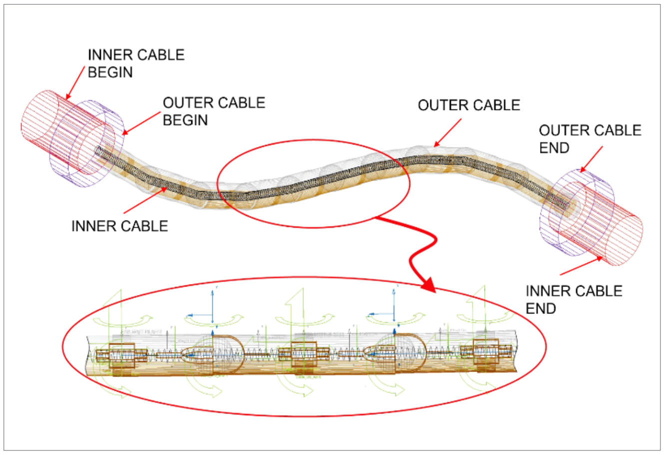
Industry: Robotics

Benefits:

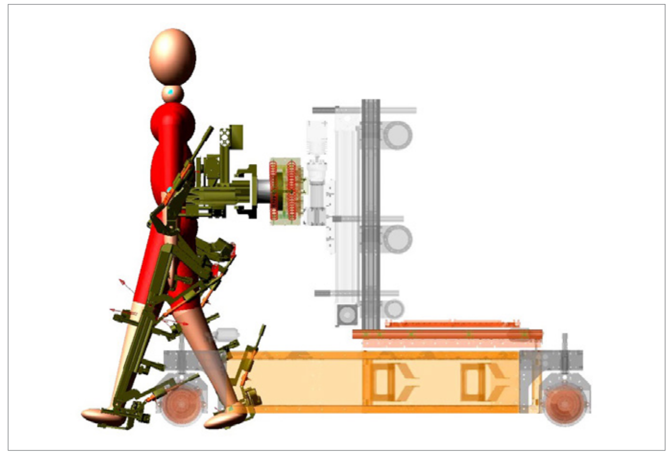
- Studied human-robot interaction forces during walking exercise
- Simulation helped make sure the working prototype met the safety requirements for patients
- Evaluated the push-pull cable actuation system followed by control strategies optimization



Design implementation of gait rehabilitation device in Adams



PPC multibody dynamics model representation developed in Adams



Adams computational model of the human body interacting with CORBYS robot

to research and develop new collaboration principles, in a scope to assure an effective human-robot interaction while sharing their cognitive capabilities. They needed a multi-body dynamics simulation tool that could accurately replicate real system particularities and had the necessary efficient processing capacity for modeling the complex (biomechanical systems) in a co-simulation with human body models.

Their software tool of choice was Adams. Modeling and simulation was needed in various evaluation scenarios of the human-robot interaction, to observe the behavior of the robotic system and interaction of the robot with the environment.

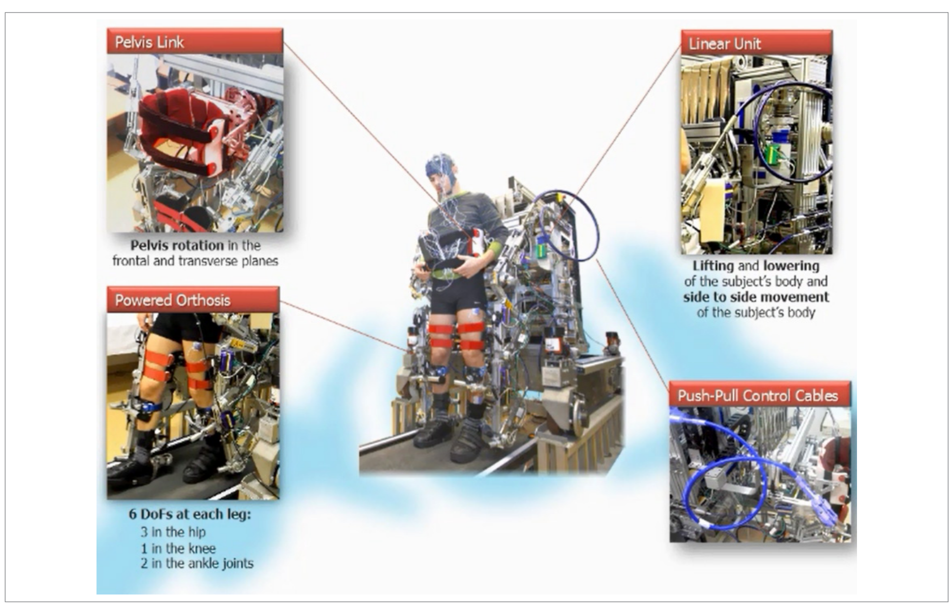
Solution

Based on CAD models, the multibody simulation software Adams was used to develop the models of the robotic rehabilitation device and the human body. The mass and center of mass positions were adjusted and/or computed for each rigid body. Afterwards, the researchers implemented the constraints between the mechanical parts in conformity to the real system design. Due to the considerable complexity of the CORBYS system, the modeling approach was dividing the system in individual sub-systems. Followed by testing dynamic parameters for each sub-system separately and then combining all the sub-systems. The mechanical design of the robot consists of powered orthoses, actuated at the ankle, knee, and hip levels by push-pull cable based actuation system and, attached to the mobile platform. For the simulation scenario, the mobile platform was considered unmovable while the human legs were attached to the robotic orthoses. The orthoses provide 100% support to human legs in a walking exercise on a treadmill. Human lower limbs connected to the exoskeleton orthoses by using BUSHING forces on pelvis, upper legs, lower legs and feet levels. The actuation of robotic orthoses were implemented by using joint trajectories from previous data.

The complexity of the human body model usually depends on simulation scenario goals and research points of interest. In this study, the human body was developed using TKC Toolbox and consisting of 15 segments joined together by ideal joints and including 22 degrees of freedom (DoF). Each lower limb consisted of three segments: thigh, shank and foot, in form of frustums with homogeneous mass distribution. While revolute joints are additionally constrained by applying a general 3-component force vector in order to obtain characteristics of a human body hold and drive properties. Human limbs lengths were adjusted to orthoses dimensions; as well as, legs joints were aligned to exoskeleton joints. The weight of the human body model is 65 kg. The treadmill was represented by a flat rigid surface moving in opposite direction to walking, with the averaged velocity as the one of the human model.

Push-pull cable modeling:

The initial curvature of the push-pull cable model was described using the spatial SPLINE object. It was based on the end locations and orientations of the tendon and the conduit (sheath). By applying a SPLINE fitting method integrated in a dedicated macro, the equidistant points were created on the SPLINE. Geometrically,



CORBYS Gait Rehabilitation Robotic Device