Nowadays, we are experiencing a social transformation: the world population is ageing [1]. A longer life brings new opportunities but it can cause an increased incidence of diseases such as stroke. Worldwide, stroke is the third leading cause of disability [2].

A stroke can be defined as a neurological deficit due to a central nervous system infarction or haemorrhage. Among its numerous consequences, there is the central paralysis of the hand [3]. This symptom hinders many activities of daily living. Many stroke survivors are involved in rehabilitation therapy with medical experts for years after the disease. It has a high social and economic impact both on patients and society. Literature review shows that moving towards a home-therapy with mechatronic devices seems promising. However, there still numerous open challenges in literature such as the comfort, the portability/packability, the cost, and the usability for nonexpert users [4].

The first outcome of the thesis is the prototype of hand exoskeleton named HANDY. The glove (Figure 2) is designed to extend the movement of the hand. It is a combination of different flexible and rigid parts obtained using additive manufacturing processes.

The remote actuation unit includes linear actuators, electronic components (including a PCB realized on purpose, a LiPo battery, and a dedicated router for wireless communication). Also, some security elements such as an end-exoskeleton named PCB realized on purpose, a LiPo battery, and a 3D virtual assistant (MAIA)

The second result of this thesis is a 3D virtual assistant named MAIA (Figure 4). It was born to deal with some therapy abandon causes: loneliness, need of expert assistance, and discouragement.

Starting from the appearance decided with preliminary focus groups with therapists and patients, I created the final 3D model and animated character. MAIA can interact with users using natural language. It combines some AI-based features (Figure 5) to capture the user’s need, convert it into a machine-readable input, classify the context and the main concepts (intents/entities) of the request, choose and perform the appropriate actions, generate a textual response for the user, and synthesize it with a neural voice.

The cognitive and motor rehabilitation system for the hand has been designed to assist post-stroke patients during their rehabilitative therapy towards regaining their autonomy. Users (therapists and patients) have been actively consulted during the whole development. This led to several advantages:

- **HANDY** is lightweight (only 190g) on the hand, permitting repetitive rehabilitative exercises without fatigue. The glove material minimizes skin abrasion and its shape prevents misalignments and finger hyperextension.
- **Portability** is ensured by the small backpack and wireless dedicated connection.
- **MAIA** enables some interactions using natural language (avoiding predefined keywords) such as asking assistantship and instructions. It provides a more hearty and non-invasive feedback compared to traditional ones.
- **The application** provides users with customizable passive, active and cognitive exercises based on the patient’s condition.

During the preliminary tests with post-stroke patients, these aspects led to promising results in terms of usability and willingness to use of the system.

Objectives

- **Hand exoskeleton** (HANDY)
  - Portable, affordable, comfortable, customizable, and easy-to-use prototype
  - Performing rehabilitative hand exercises for post-stroke patients defined with medical professionals
  - 3D virtual assistant (MAIA)
  - Understanding human natural language using AI-based algorithms
  - Interactive 3D character that offers assistantship and encouragement to patients to reduce the current therapy abandonment rate

Global desktop application

- Providing an integrated desktop application for both therapists and patients that includes passive and active rehabilitative exercises

Results

The application provides users with customizable passive, active and cognitive exercises based on activities of daily living (ADL). Figure 6 shows an example of this last case. The Leap Motion controller tracks the user’s hand, HANDY assists the patients performing the grasping movement, and MAIA provides feedback and encouragement.

![Figure 2. 3D printed and flexible hand exoskeleton of HANDY](image)

![Figure 3. Global setup of HANDY](image)

![Figure 4. 3D model of MAIA](image)

![Figure 5. Natural Language Processing algorithm](image)

![Figure 6. Cognitive and motor exercise based on ADL with the Leap Motion controller](image)

References


