Argos Project: Developing markerless motion analysis methods to enable quantitative performance assessment in children with cerebral palsy

Laboratoire de Biomécanique et Mécanique des Chocs (LBMC)
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Context and challenges

Cerebral palsy (CP) is the most common motor impairment in children. Resulting from a non-progressive brain lesion (pre-, peri- or post-natal), it leads to functional impairments that evolve throughout growth. It is therefore crucial to conduct regular and precise assessments in order to adapt care pathways among the many available therapeutic options.

For the lower limbs, Clinical Gait Analysis (CGA**)** using reflective markers or inertial measurement units (IMUs) has enabled significant advances in patient care, notably through gait analysis and the development of multi-level surgeries.

These benefits should be extended to the upper limbs. However, CGA protocols from the literature struggle to be integrated into routine clinical practice due to the complexity of the upper limbs (large number of degrees of freedom) and the variety of daily tasks. Clinicians currently have a multitude of tools and scales to assess function according to the concepts of the International Classification of Functioning, Disability and Health (ICF).

Proposed by the World Health Organization (WHO) in 2001, the ICF provides a framework to evaluate pathology beyond impairments alone, distinguishing:

Capacity: what an individual can do at their full potential (standardized measurements, rigid protocols).

Performance: what an individual does spontaneously in daily life (ecological measurements).

CGA has traditionally focused on measuring capacity via highly standardized protocols and cyclic tasks, often detached from everyday context. To become relevant for upper-limb evaluation, QMA must evolve towards measuring performance by instrumenting more ecological tasks. However, traditional solutions (markers or body-worn instrumentation) introduce technical limitations (marker occlusions) and conceptual limitations (less ecological, less natural measurement).

Markerless methods (RGB/depth cameras, computer vision algorithms, deep learning) offer a non-intrusive and more ecological solution to measure real-world performance.

However, they present methodological challenges:

- Limited set of anatomical landmarks for biomechanical models.

- Insufficient validation for 3D kinematics at clinical precision.
- Literature primarily focused on the lower limbs in asymptomatic adults.
- Critical lack of data dedicated to the pediatric upper limb in children with CP.

In this context, the ARGOS project aims to lift these methodological and clinical barriers:

- **Data Acquisition** and **Structuring**: Finalize the structuring and documentation of a unique database, enabling the validation of existing models and the retraining of new ones (database already collected).
- **System Validation**: Validate robust multi-camera configurations (precision, repeatability, occlusion handling) specifically adapted to pediatric clinical settings.
- **Algorithmic Improvement**: Integrate biomechanical constraints (e.g., multi-segment optimization) to enhance the coherence and accuracy of kinematic reconstructions.
- **Clinical Transfer**: Test and validate in situ reproducible pipelines that are transferable to clinical follow-up and research.

Postdoctoral objectives

The postdoctoral fellow will play a key role in rapidly leveraging the data (FAIR), designing multi-camera configurations adapted to pediatric constraints, stabilizing and ensuring the reliability of markerless pipelines, coordinating activities across sites, and increasing scientific visibility (publications, communications, demonstrators).

- Leverage and document the existing database (organization, labeling, quality control, metadata, traceability) for FAIR dissemination.
- Study and optimize camera deployment for measuring the upper limb in children: scenarios (positions, orientations, overlap), analysis of precision/robustness to occlusions, and targeted simulations and/or experimental validations.
- Implement and ensure reliability of markerless analysis pipelines: pre-processing, kinematic extraction, quality evaluation, statistical analyses, and scientific writing/reporting.
- Coordinate operations between LBMC and the Clinique des Massues (1–2 visits per week) to align clinical needs with methodological developments.
- Leverage data from LIA Evasym (LIO/S2M, Montreal) and strengthen common methodologies; contribute to publications.

Skills:

- Markerless motion analysis (e.g., computer vision, 3D kinematics); multi-camera calibration/geometry.
- Data management and data quality (FAIR principles, metadata, traceability).
- Python programming
- Statistics.
- Knowledge in AI and model re-training is a strong plus, with the possibility to orient the postdoc toward detector model re-training.

Expected outcomes

1) Database organized and documented in line with FAIR principles, guidelines and quality reference frameworks.

2) Validated multi-camera configurations for pediatric upper-limb measurement, with performance indicators (accuracy, repeatability, robustness).

3) Reliable and reproducible markerless pipelines.

Desired profile

PhD in biomechanics, biomedical engineering, computer vision / image processing, mechanical engineering, STAPS – biomechanics, or a related field.

Remote work

Remote work possible up to one day per week.