Context.
In daily practice, common methods of assessment in patients suffering from foot and ankle pathologies are observation, anamnesis, clinical assessment and medical imaging. In rare cases, a 3D gait analysis are performed to quantify the foot motor performance during activities of the daily living that cannot be measured with the aforementioned assessments’ methods. If gait analysis is now considered to be the gold standard for the functional assessment of lower extremity pathologies and their respective treatments, the outcomes have been impeded for decades because of the simplified representation of foot as an unique functional entity (Davis, 2004). The development of three-dimensional multi-segment foot models partially tackled this major shortcoming and showed their clinical value for the detection of intrinsic foot impairments (Deschamps et al., 2011). Foot and ankle kinematics vary from one person to another. Thus there is a growing body of evidence pointing out the existence of anatomical foot variations in terms of joint surfaces, muscle insertion sites, presence of accessory muscles or ligaments, ligament insertion sites and their potential impact on the mechanical behaviour of the foot (Alonso-Vázquez et al., 2009; Bonnel et al., 2013, 2011; Guiotto et al., 2013). However, due to technical limitations of current external measurement systems, the anatomic complexity of foot and ankle had to be simplified in a few functional segments providing an estimation of the true function of the foot and ankle.

Objective.
This research project aims to enhance patient-specific 3D gait analysis measurements with patient-specific medical imaging information to provide further insight in the function of the foot and ankle. The study will be focused on understanding the subtalar joint and the mechanical function of talus which cannot be measured (or inaccurately) with external measuring systems, but which are of major interest for subjects suffering from foot and ankle pathologies.

Supervising team.
To address this clinical need, a multidisciplinary team will supervise the project. A. Naiim (Research Engineer) has a strong experience in in vivo experiments, gait analysis measurements and modeling. He is in charge of the protocol from which the data will be used in this work. Y. Lafon (Assistant Professor) focus his research on model personalization from medical imaging. Dr Besse, full-time orthopedic surgeon, specialized in foot and ankle surgery, is the main investigator of the study. Paul André Deleu coordinates many research on foot and ankle pathologies as clinical scientist at the Foot and Ankle Institute in Brussels (Belgium).

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**Expected work.**
A database from 3D gait analysis has been processed for subjects suffering from foot and ankle pathologies. The work consists in creating a workflow to fuse patient-specific data from imaging (weight-bearing x-rays and CT-scan) with 3D gait measurements. First, a generic geometrical model of the foot and ankle joints will be built (bones with origins and insertions being tagged). Then, it will be parametrized/personalized using information from imaging. The kinematics will be imposed to the patient-specific model from 3D gait analysis data. Finally, clinical and functional parameters will be quantified to evaluate the coherence of the subject-specific bony kinematics. This project is the first stepping stone toward a full 3D kinematic model of the foot and ankle that could be routinely used in parallel of the 3D gait analysis in order to visualize and measure more precisely foot and ankle kinematics.

**Challenges.**
The first challenge will be related the personalization of the geometrical model from non-weight-bearing CT-scans. The second challenge will be on changing the foot and ankle configuration according to static information from weight-bearing x-rays. It could require to identify methods or existing tools based on an exhaustive literature review. The last main challenge will be related to obtain a functional model despite the fusion of noisy data (due to uncertainty on the image reconstruction and the sliding of external skin markers). According to the first results, the purely geometrical approach used for simulate dynamics could be replaced by an approach based on a rigid multi-body models.

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**Ideal scientific profile.**
Ideally, the candidate will have a degree in mechanical engineering or computer science, and an experience (or at least interest) in numerical or experimental biomechanics. An interest in programming (Matlab, Python, FE software) would be a plus.
At the end of the study, the candidate will have acquired both skills in image processing, subject-specific modeling, programming and in vivo experiments.

**References.**
- Guiotto A et al., The role of foot morphology on foot function in diabetic subjects with or without neuropathy. 2013 Apr;37(4):603-10.

**Keywords.**
Gait analysis, kinematics modelling, medical image processing, joint kinematics, patient-specific, foot and ankle pathologies