DESCRIPTION DU PROJET DE RECHERCHE

Problématique:

Transferring knowledge between musical and scientific communities is a process that involves combining empirical data from musicians' movements with theoretical models to develop evidence-based recommendations for optimizing music practice and performance. This can be done through interdisciplinary research efforts that involve collaboration between biomechanics, music performance, musicology, acoustics, and music technology. These research initiatives significantly enhance the practical application of research outcomes in the realm of music practice and performance by establishing a closer relationship between musicians and scientific knowledge. For instance, this approach can help reduce the risk of injuries among musicians by optimizing their technique and gestures. Moreover, by combining the knowledge and expertise of both the musical and scientific communities, researchers can formulate research inquiries that are better aligned with the requirements of musicians and develop innovative solutions to the challenges faced by musicians.

Hypothèse(s) et objectif(s):

The main objective of the proposed Ph.D. thesis will be first to simulate pianists' whole-body gestures and develop playing strategies that reduce the distal joint load using the optimal control theory. Second, this study allows the comparison of digitally simulated gestural strategy to the results obtained through the experimental research approaches previously used at the S2M laboratory. The specific objectives (SO) are the following:

SO1. To develop a dynamic digital model of pianists' whole kinematic chain, from the pelvis to the fingertip.

SO2. To feed the developed model with data collected in former studies and compare the results of these studies and the optimization strategies proposed by digital simulation.

SO3. To apply a mixed research approach integrating digital simulation and experimental methods to a research question that will emerge from the musical community in the context of an ongoing knowledge transfer project lead by Dr. Verdugo (supervisor of the proposed Ph.D. thesis).

Approche(s) expérimentale(s)(préciser notamment si ces approches sont maîtrisées dans le laboratoire d’accueil):

A group of expert pianists (N=12) will be enlisted to perform several tasks on the piano. Pianists' kinematics will be recorded with a Vicon motion capture system composed of 18 cameras. A force plate will be placed under the piano bench to quantify contact forces between the bench and the floor. The upper body's muscle activities will be recorded with surface electromyography (Delsys TrignoTM Wireless system composed of 16 electrodes). Participants’ performances will be audio recorded. A grand piano equipped with sensors to capture key and hammer kinematics (Bösendorfer CEUS, Yamaha Disklavier C7) will allow the acquisition and quantification of different musical parameters. Data will be processed and analyzed in MATLAB and Python. The data collected will be used as (sub) optimal solutions that will feed digital simulations and the optimization process. The dynamic model of the pianist (from the pelvis to the fingertip) will be implemented in the form of an Euler- Lagrange equation under the Bioptim Python framework for musculoskeletal optimal control developed at the S2M lab. We will focus on minimizing several parameters of distal joints, such as eccentric joint torques and mechanical work. The results obtained from this optimization process will be compared to the initial ones collected from actual pianists' gestures.

Résultats prévus / impacts cliniques potentiels:

This research will help pianists develop innovative movement strategies that might help pianists optimize performance and reduce the risks of developing PRMDs. Particularly, developing a simulation approach based on optimal control theory will facilitate the investigation of new strategies that might remain unexplored by pianists. Comparing digital simulation and experimental results will allow a deeper understanding of available research on pianists’ biomechanics and injury prevention strategies. Integrating the proposed Ph.D. thesis in a more extensive partnership project on knowledge transfer activities between musical and scientific communities will generate extensive dissemination of the results. The project will impact the clinical field, as it will contribute to the development of research-based valuable knowledge for healthcare practitioners who work in the domain of musicians’ injury treatment and prevention. Finally, selecting a research question extracted from the musical community will ensure the production of knowledge that could be of high value for musicians’ professional activities.

ANNEXE 1 – LETTRE DE MOTIVATION

There are few researchers at the international level who focus on transferring knowledge between musical and scientific communities. The lack of scientific evidence-based performance approaches might contribute to the high rates of injuries among pianists and music performers in general. An interdisciplinary research effort is required between pianists, biomechanists, and healthcare practitioners to address this problem. My co-supervisors, Felipe Verdugo and Mickael Begon have unique combined expertise covering the fields of biomechanics, piano performance, injury prevention, performance optimization, and empirical musicology, making them ideal collaborators for my research project on pianist injury prevention. The research collaboration, hosted by the S2M laboratory, has made significant progress in understanding whole-body movements and distal muscle fatigue in pianists, two central areas of my research project. As several research projects related to musicians' health are currently in progress at the S2M laboratory, I will benefit from a dynamic and rich research environment in my field of interest. The S2M laboratory has an impressive research output (More than 40 papers in the last three years). The laboratory comprises national and international students from different cultural and academic backgrounds (such as kinesiology, biomedical engineering, and music), which promotes a diversity of research projects funded by Canadian and Quebecois research councils.

Furthermore, lab activities involve weekly group meetings, a journal club, and monthly meetings with statisticians. Clearly, not only does the research focus of the S2M laboratory fit my research interests, but it also has many resources to support my academic development throughout my doctoral studies. The S2M laboratory also offers access to the necessary high-level data collection infrastructure. The technology includes surface electromyography (EMG) (Delsys Trigno TM Wireless system; high-density TMSi system, Oldenzaal, Holland), a Vicon optoelectronic 3D motion capture system composed of 18 cameras, an XSens full-body system of 17 inertial measurement units, and various force plates and pressure sensors. The S2M laboratory also possesses a grand piano (Bösendorfer CEUS, lent by the International Laboratory for Brain, Music, and Sound Research) equipped with sensors to capture key and hammer kinematics. Capturing data on a grand piano ensures ecological validity, as digital pianos (generally used by researchers in the field) require significantly less force to depress a key and produce electronic sound, which might be confounding variables that alter pianists' motor behaviors. Through research at the S2M laboratory, I will be able to enhance my knowledge and experience in signal acquisition and processing methods of kinematic, kinetic, and muscle activity data, as well as in programming/scripting languages such as MATLAB and Python. As the laboratory is located in the Greater Montreal area, I would have access to a large population of expert pianists, as shown by a recent study conducted by my supervisors where 50 pianists took part in the experiment (an unprecedented population size in this field). Finally, the supervision of F. Verdugo will be that of a researcher and a professional pianist holding a doctoral degree in piano performance. This dual expertise will facilitate the transfer of knowledge between the fields of research and music.

La pertinence des expériences pratiques antérieures (laboratoire, clinique, stage, etc.) dans le cadre du projet de formation en recherche envisagé.

The proposed research framework for my Ph.D. thesis originates from my interdisciplinary attitude toward engineering, personal experiences in multidisciplinary projects, and previous research on neuro-musculoskeletal modeling in graduate /undergraduate education. Committing myself to the world of scientific research and exploring different realms of engineering has instilled an investigative mindset, a passion for the scientific process, and an appreciation for the results of multidisciplinary projects, which were useful in medicine. In the B.Sc. project, I focused on passive dynamic walker concepts to develop a new mathematical model of passive dynamic walking. This project included the insight of mathematical modeling of the passive biped robot and motor control that interested me in neuro-musculoskeletal modeling. To achieve more in-depth knowledge in BME, I decided to pursue higher education. I did my M.Sc. degree at the Amirkabir University of Technology, ranked 1st in Biomedical in Iran (GPA: 18.11/20). My M.Sc. thesis individualized the Hippotherapy sessions (HTS) as a treatment modality to choose the most suitable combination of horse and exercises for each patient. This Neuro-musculoskeletal modeling approach addressed how alternative physical activities, such as sitting position, reaching or throwing exercises, affect the patient's dynamic stability or core muscle activity during HTS. This research provided therapists with a tool to assess the effects of exercises before the HTS, resulting in one journal paper (International Journal of Engineering, Transactions B.) and two conference papers (CSB, Canadian Society for Biomechanics, Halifax 2018). In my M.Sc. thesis, I also did an experimental phase in direct interface with patients, which provided me with excellent experience dealing with individual subjects in laboratories and analyzing human neuro-musculoskeletal modeling. I also was a teaching assistant for Continuum Mechanics, Engineering Statics, and Biomechatronics, both on undergraduate and graduate levels, for three consecutive years. Moreover, I have co-written a book published in Oct. 2021 ("Biomechatronics Systems, Volume one: Bond Graph Methodology, Authors: A. R. Arshi and M. A. Shahiri, Language: Persian), which enhanced my knowledge of the modeling principles and approaches. During 2021-22, I worked as a researcher in a study on the Opto-biomechanical self-adjustment model of the human eye at the Wroclaw University of Science and Technology (Poland) (Outcome: one published journal paper [Biomedical Optic Express], one conference paper [VPO, Visual & Physiological Optics, 2022], and one submitted manuscript). This study found the most proper and demanded combination of biomechanical circumstances (an optimization problem) to satisfy the self-adjustment hypothesis, which compensates for the variation to reflect the image on the retina. In addition, I have done two product-oriented projects at Iran's National Elites Foundation to design and manufacture an underwater scooter and a hybrid bicycle, which boosted my teamwork and real-life problem-solving skills. I am a dedicated and hardworking student with a strong desire to conduct innovative research and achieve academic excellence. Pursuing a proposed Ph.D. thesis in rehabilitation solutions/kinesiology will contribute to my personal development and enhance the life quality of individuals with playing-related musculoskeletal disorders (PRMDs). The great opportunity of researching as a Ph.D. student in biomedical engineering helps me extend my knowledge in my field of interest, strive to know the unknown, and extend the borders of science only a little bit. This is my greatest desire and expectation, which could be satisfied through this program in developing recommendations for clinical applications of research on musicians' health by integrating the interdisciplinary research team on musicians' injuries.

Expliquer comment cette bourse s’inscrit dans le montage financier que vous proposez à l’étudiant pour l’année 2023-2024

Mohammad is conducting a research project at the S2M lab that aims to optimize pianist movements by combining experimental and numerical simulation approaches. Mohammad's work is framed by a series of ongoing interdisciplinary research projects on piano performance that I lead at the S2M lab. He will receive an integrated funding package (18,000/year from the research funds (2022-2025 SSHRC Partnership Development Grant), but due to the high living costs and studying in Canada, he is worried about covering his expenses. However, if he receives a Merit Scholarship from the Faculty of Medicine, he will be able to devote his full attention to his studies (leading to better grades and knowledge) and research activities (project development, written/oral communication of results, and involvement in S2M lab activities, among others) without any financial concerns. The scholarship would also enable him to improve his French language skills and enhance his communication and integration skills both personally and academically.

In conclusion, the research directors strongly recommend Shahiri's application for a Merit Scholarship from the Faculty of Medicine. Mohammad has demonstrated excellent organizational skills, responsibility, and interest in the academic and research environment at the University of Montreal. The directors are confident that Mohammad's outstanding background in biomedical engineering will be an excellent addition to our interdisciplinary team (kinesiology, musicology, music performance) working on optimizing pianists' playing strategies.

We are at your complete disposal if you need additional information and would be happy to assist you.

Best regards,

Felipe Verdugo, Associate Professor

Mickaël Begon, Full Professor