D3.4 – EnTimeMent platform and software libraries for multi-time analysis, entrainment, and prediction - Phase 3

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[1] **PU** = Public, **PP** = Restricted to other programme participants (including the Commission Services), **RE** = Restricted to a group specified by the consortium (including the Commission Services), **CO** = Confidential, only for members of the consortium (including the Commission Services).

Contents

Abbreviations

EU	European Union
EC	European Commission
WP	Work Package

1 Introduction

This deliverable consolidates the software modules designed and developed by the EnTimeMent partners. In continuation to the previous deliverable D3.3 – here we provide short descriptions and direct links to access the contributions.

1.1 EnTimeMent GitHub repository

To disseminate software developed and data collected in the EnTimeMent project, a public repository has been created on GitHub.com, a website that provides a cloud-based service for developers to store and manage their code. In recent years, GitHub has become the most important tool for open-source collaboration and is often used as the first go-to point for both professionals and students in search of related software development projects. In Stack Overflow's annual development survey from 2020, 82.8% out of 65'000 responding developers claimed they used GitHub as their primary tool for collaborative work. GitHub has as many as 73 million registered developers with more than 200 million repositories. Since 2018 GitHub.com is a subsidiary of Microsoft.

GitHub is based on Git, an open-source version control tool originally developed by Linus Torvalds, the creator of the Linux operating system. Unlike most earlier version control systems, Git is distributed such that the entire codebase and history is available on the computer of every developer. This allows for easy branching and merging, which simplifies the process of reusing existing components from different projects into new projects. It also makes it easier to work offline without a connection to a centralized server, such as when working on private versions that are not yet ready for publication. Once committed to a central server, code can be made publicly available. GitHub is a platform that provides such a service. Git is currently the dominating version control system used by 93.4% of developers in the same survey from Stack Overflow.

GitHub includes additional functionalities to facilitate collaboration. Collaborators can raise issues to track todos, bugs and feature requests and create pull requests for suggested updates to be integrated with the codebase. It also provides functionalities for integration with commonly used development tools, as well as for tracking milestones, releases and packages. GitHub also keeps track of developers using the code and the amount of traffic that the repository generates.

2 Activities in Phase 3

2.1Hardware and Software platform modules for data collection

Title	Project Platform at UniGe defined at the Markerless Motion Capture Campaign
Partner	UniGe, Qualisys, EuroMov, IIT, UCL
Description	The system platform developed for the 2-week Markerless Motion Capture Campaign: https://entimement.dibris.unige.it/events/42-entimement-markerless-motion-capture-campaign-showcase It integrates the pre-existent platform described in D3.3 with the Theia software and 12 new mocap Qualisys cameras.
Link	NA

Title	Sensor System for Chronic Pain Data Collection in Participant Homes
Partner	UCL
Description	Commercially available wearable inertia sensors (Notch: www.wearnotch.com). Detailed description of the sensor setup can be found in the associated publication: Buono, Raffaele Andrea, Temitayo Olugbade, Nadia Bianchi-Berthouze, Santiago de Ossorno Garcia, Tao Bi, Nicolas Gold, and Amanda C de C Williams. “Movement as decision-making at multiple timescales: Opportunities for technological support and intervention from an exploratory study with people with chronic back pain” *in prep*
Link	NA

2.2 Software Libraries

Title	Software libraries for the study of the origin of movement
Partner and Author	UNIGE
Description	The software, written in Matlab, extracts movement features (speed, tangential acceleration, kinetic energy, angular momentum) for two skeleton models of the human body, which refer to two different spatial scales. Then, such features are filtered and combined to compute a dissimilarity measure for the joints, from which a transferable utility game on an auxiliary graph is constructed. Finally, the vector of Shapley values for that game is computed (for the case in which the Shapley value coincides with the weighted degree centrality) and normalized with respect to the maximum Shapley value. The software allows for the possibility of computing the Kendall correlation between different rankings of joints. Further comments can be found inside the code.
Link	https://github.com/EnTimeMent/Origin-of-Movement

Title	Software libraries for the analysis of qualities of movement
Partner and Author	UNIGE
Description	The purpose of this software is to analyse Motion Capture data in order to calculate the joint with the maximum Shapley Value, separately for three motion features (speed, acceleration and angular momentum). The software models the human body as a weighted undirected graph, and calculates the importance of each joint in movement. A Lowpass Butterworth filter is used on the data for cleaning and processing. Each movement feature is calculated separately for each frame of each MoCap segment. Spectral clustering on the weighted graph is applied, to compute for each frame the Shapley Values of all the joints for all the movement features. It is a mixture of Python (for the data processing, filtering, motion feature calculation and results analysis) and MATLAB (for the creation of the body as a graph and for the Shapley Value calculation).
Link	https://github.com/EnTimeMent/Analysis-Qualities-of-Movement

Title	Synchronization among temporal scales: the MECS algorithm
Partner and Author	UNIGE
Description	Event Synchronization analysis was originally conceived for providing a simple and robust method to measure synchronization between two time

	series. This algorithm, however, and those developed as extensions thereof do not directly deal with multiple temporal scales. We extended the state-of-the-art of Event Synchronization techniques by conceiving Multi-Event-Class Synchronization (MECS). MECS measures synchronization between events - belonging to different event classes - that are detected in multiple time series. MECS can compute synchronization between events belonging to the same class (intra-class synchronization) or to different classes (inter-class synchronization). Our technique can deal with macro-events, i.e., aggregations of events that enable analysis at multiple temporal scales. Publication: Volpe, G., Alborno, A., Mancini M., and Niewiadomski, R., Multi-Event-Class Synchronization (in preparation).
Link	https://github.com/EnTimeMent/MECS-Algorithm

Title	BANet machine learning architectures
Partner and Author	UCL/ Chongyang Wang
Description	Neural network architectures designed for automatic detection of affective behaviour from motion capture data. Detailed description of the architecture can be found in the associated publication: Wang, Chongyang, Min Peng, Temitayo A. Olugbade, Nicholas D. Lane, Amanda C. De C. Williams, and Nadia Bianchi-Berthouze. "Learning temporal and bodily attention in protective movement behavior detection." In *8th International Conference on Affective Computing and Intelligent Interaction Workshops and Demos (ACIIW)*, pp. 324-330. IEEE, 2019.
Link	https://github.com/EnTimeMent/BANet

Title	P(l)aying Attention sonification application
Partner and Author	UCL/ Nicolas Gold
Description	Application designed for sonification of motion capture data with respect to BAnet neural network attention weights for affective behaviour recognition from the motion capture data. Detailed description of the application can be found in the associated publication: Gold, Nicolas E., Chongyang Wang, Temitayo Olugbade, N. Berthouze, and A. Williams.

	"P(l)aying Attention: Multi-Modal, Multi-Temporal Music Control." In *Proceedings of the International Conference on New Interfaces for Musical Expression* (NIME) 2020.
Link	https://github.com/EnTimeMent/Playing-Attention

Title	Hierarchical HAR-PBD machine learning architectures
Partner and Author	UCL/ Chongyang Wang, Guanting Cen
Description	Neural network architectures designed for continuous detection of affective behaviour from motion capture and muscle activity data. Detailed description of the Hierarchical HAR-PBD v1 architecture can be found in the associated publication: Wang, Chongyang, Yuan Gao, Akhil Mathur, Amanda C. De C. Williams, Nicholas D. Lane, and Nadia Bianchi-Berthouze. "Leveraging activity recognition to enable protective behavior detection in continuous data." In *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 5, no. 2 (2021): 1-27.
Link	https://github.com/EnTimeMent/Hierarchical_HAR-PBD

Title	MiMT machine learning architecture
Partner and Author	UCL/ Temitayo Olugbade
Description	Neural network architecture designed for automatic detection of affective behaviour at multiple timescales based on motion capture data. Detailed description of the architecture can be found in the associated publication: Olugbade, Temitayo, Nicolas Gold, Amanda C. de C. Williams, and Nadia Bianchi-Berthouze. "A Movement in Multiple Time Neural Network for Automatic Detection of Pain Behaviour." In *Companion Publication of the 2020 International Conference on Multimodal Interaction*, pp. 442-445. 2020.
Link	https://github.com/EnTimeMent/MiMT

Title	huSync: Human Pose Estimation Architecture for computing Dyadic Synchronization
Partner / Author	UNIGE, WSU

Description	This repository contains python code to compute Dyadic Synchronization between co-performers in a small group of musicians. You will find two files: 1. **Module_DataExtraction**: After having used AlphaPose on the video-dataset, we proceed with using this file to extract the data for each performer by isolating them individually. It stores the output as a .csv file 2. **Module_DyadicSynchronization**: This file contains the code that extracts the data from the .csv file processed and provides the Dyadic Synchronization between all possible pairs in a musical ensemble. Both the files have been shared as a jupyter notebook since this should make it easier to execute the code with more control. The added control helps perform experiments carefully, particularly since the data from pose estimation algorithms can be noisy and sometimes requires manual intervention. Sabharwal, S., Keller, P., Varlet, M., Camurri, A., Volpe, G. (2022). huSync: A novel computational approach to quantify synchronization using pose estimation algorithms - A case study assessing the effects of leadership and task structure in musical group interaction. Manuscript in preparation
Link	https://github.com/EnTimeMent/huSync-DyadicSynchronization

Title	Raga Pose Estimation
Partner / Author	Durham University/ Clayton, M., Li, J., Clarke, A. R., & Weinzierl, M.
Description	This repository comprises a Colab script an associated python library to support the use of pose estimation algorithms with video recordings of Indian music performances. Post-processing options include the selection of data points, interpolation of missing data and smoothing. The repository forms part of a Open Science Framework corpus alongside input videos, saved pose estimation data and output overlaid (video plus skeleton) videos. See: Clayton, M., Li, J., Clarke, A. R., Weinzierl, M., Leante, L. & Tarsitani, S. (2021). Hindustani raga and singer classification using pose estimation. OSF. October 14. https://doi.org/10.17605/OSF.IO/T5BWA Clayton, M., Li, J., Clarke, A. R., and Weinzierl, M. (submitted). Hindustani raga and singer classification using 2D and 3D pose estimation from video recordings.
Link	https://github.com/DurhamARC/raga-pose-estimation

Title	Group behavior recognition using attention-and graph-based neural networks
Partner and Author	KTH/ Yang, F., Yin, W., Inamura, T., Björkman, M., & Peters, C.

Description	This repository contains Python code for analysing group behaviours in the case of conversational groups, where an approaching participant is trying to engage in an already ongoing discussion in a group with three members. From the analysis it is predicted whether the group will either include or disregard the newcomer. Two different kinds of neural network-based models are included as part of the code, one based on attention networks and another based on multi-spatial-temporal graph convolution networks. See: Yang, F., Yin, W., Inamura, T., Björkman, M., & Peters, C., Group behavior recognition using attention-and graph-based neural networks, ECAI 2020.
Link	https://github.com/EnTimeMent/Group-Behavior-Recognition

Title	Impact of trajectory generation methods for robot approaching group behaviors
Partner and Author	KTH/ Yang, F., Yin, W., Björkman, M., & Peters, C.
Description	This repository contains Python code for studying how the choice of robot trajectory generation methods impacts viewer perception when a robot tries to engage in an ongoing discussion between three human members in group. It includes a procedural model, which is used as a baseline, as well as a learned model based on imitation learning with graph convolution networks, a model with which the robot tries to mimic previously observed successful human approach behaviours. See: Yang, F., Yin, W., Björkman, M., & Peters, C., Impact of trajectory generation methods on viewer perception of robot approaching group behaviors, RO-MAN 2020.
Link	https://github.com/EnTimeMent/Impact-of-Trajectory-Generation-Methods

Title	EmoSync: human multi-scale group synchronisation during mirror game of four people
Partner and Author	EuroMov/ Janaqi, S., Smykovskyi, A. P., & Bardy, B.
Description	This repository contains Matlab code for the analysis of triad mirror game, with upper arm improvisation movement of three agents standing in a triangular typology. The first repository looks at analysis of behavioural synchronisation metrics based on the optical marker data recordings ("dancing arm") and the second repository looks at the gaze behaviour (based on the optical marker data recordings of the head position of the agents). Part of the code includes pipeline to extract synchronisation metrics (order parameter) from similar dataset, developed by Dr. Carmela Calabrese and published as:

	Bardy, B.G., Calabrese, C., De Lellis, P. et al. Moving in unison after perceptual interruption. Sci Rep 10, 18032 (2020). https://doi.org/10.1038/s41598-020-74914-z
Link	https://github.com/EnTimeMent/EMOSYNC_Behavioural_sync https://github.com/EnTimeMent/EMOSYNC_EyeGaze

Title	Spook'n'play: impact of acoustic, emotion-laden stimuli on disembodied group synchronisation
Partner and Author	EuroMov/ Janaqi, S., Bienkiewicz, M. M., & Bardy, B.
Description	This repository contains Matlab code for the analysis of synchronisation metrics (order parameter, level of sychronisation, time to reach synchronisation, time in synchronisation) and main kinematic features (movement cycle duration, frequency, number of cycles) in a disembodied mirror game for multiple human players. In this study participants coordinated their index finger movement in a cycling motion with other players using Chronos interface (see for more information: https://dibernardogroup.github.io/Chronos/about_us.html). During this task, all players were induced with acoustic, emotional stimuli pre-selected from IADS-2 battery (https://csea.phhp.ufl.edu/media/iadsmessage.html), to observe the impact on their individual motor behaviour and consequently group performance. Part of the code includes pipeline to extract synchronisation metrics from similar dataset, developed by Dr. Carmela Calabrese and published as: Bardy, B.G., Calabrese, C., De Lellis, P. et al. Moving in unison after perceptual interruption. Sci Rep 10, 18032 (2020). https://doi.org/10.1038/s41598-020-74914-z
Link	https://github.com/EnTimeMent/Spook-and-Play

Title	Ball Exchange: The Importance of Multiple Temporal Scales in Motion Recognition: when Shallow Model can Support Deep Multi Scale Models
Partner and Author	UNIGE/ D'Amato, V., Oneto, L., Camurri, A. & Anguita, D.
Description	This repository contains Python code for the analysis of human movement in dyad actions where two people exchange a ball of different weights (light and heavy) with different intentions (fair, aggressive, and deceptive). The scope is to automatically detect, just based on Mocap data, what is: • The weight of the ball, i.e., light or heavy;

	• The intention of the ball exchange, i.e., fair aggressive, or deceptive Part of the code includes the algorithms tested in the analysis; the preprocessing techniques followed. D'Amato, V., Oneto, L., Camurri, A., Anguita, D. et al. The Importance of Multiple Temporal Scales in Motion Recognition: when Shallow Model can Support Deep Multi Scale Models. Submitted to IJCNN (2021).
Link	https://github.com/EnTimeMent/Ball-Exchange

Title	Ellipses: The Importance of Multiple Temporal Scales in Motion Recognition: from Shallow to Deep Multi Scale Models
Partner and Author	UNIGE/IIT-FE D'Amato, V., Oneto, L., Camurri, A., Anguita, D., Zarandi, Z., Fadiga, L., D'Ausilio, A. & Pozzo, T.
Description	This repository contains Python code for the analysis of human movement in individual actions where people draw an ellipse under different conditions (speeds and hands). The scope is to automatically detect, just based on graphics tablet data, the person who drawn an ellipse. Part of the code includes the algorithms tested in the analysis; the preprocessing techniques followed. D'Amato, V., Oneto, L., Camurri, A., Anguita, D., Zarandi, Z., Fadiga, L., D'Ausilio, A., Pozzo, T.. et al. The Importance of Multiple Temporal Scales in Motion Recognition: from Shallow to Deep Multi Scale Models. Submitted to IJCNN (2021).
Link	https://github.com/EnTimeMent/Ellipses