WHOLODANCE

Whole-Body Interaction Learning for Dance Education

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Final Exploitation Plan

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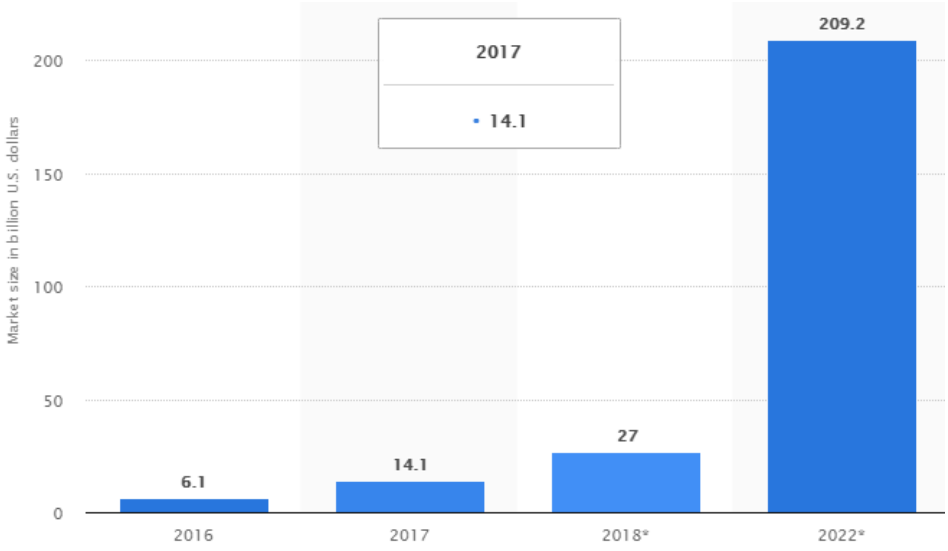
1. Introduction: at the crossroad of Next Generation Internet

Technology-wise, the WhoLoDancE project did start at a very appropriate time, anticipating the virtual reality (VR) and augmented reality (AR) boom that has been unrolling since 2016.
It is, in fact, since 2016 that, according to IDC, worldwide spending on virtual and augmented reality has started to roughly double each year, and is expected to do so through 2021, increasing to $215 billion in 2021, with a compound annual growth rate (CAGR) of 113.2 percent.
See Figure 1, quoted from Statista.com (https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/)



As well as the forecast, issued on 2018 by the international technology M&A advisory firm Hampleton Partners

This was happening while the more traditional technology of 3d motion capture (relying – as it was – on expensive hardware, time, effort, and skills, and needing dedicated professionals to operate multi-camera setups, studio environments, and a large collection of sensors or markers placed on an actor's body) was expected to grow at a CAGR of 10.28% to reach USD 204.0 million by 2022.
The latter estimate was not taking into account the then still unforeseen exciting possibility of combining motion capture with AI developments, using Generative Adversarial Networks (GANs) for approximating

generative models, or probabilistic techniques and recursive learning for detecting and reconstructing what a single 2D camera cannot see, in order to be able to represent human motion in virtual 3D space.
These developments became apparent only in 2018, but all the same, happening to be at the crossroad of such disruptive technological changes was surely both a great opportunity and a huge challenge for WhoLoDancE.
In September 2017, the World Economic Forum began issuing a series of papers on the disruptive effects of several technologies, dedicating one to "Augmented and virtual reality: the promise and peril of immersive technologies" (https://www.weforum.org/agenda/2017/09/augmented-and-virtual-reality-will-change-how-we-create-and-consume-and-bring-new-risks).
In August 2018, voicing the wish by many for a "best motion captured performance award" to be added to the Academy Awards, the Venice Biennale started having a special session on virtual reality:

WhoLoDancE focus had thus become fashionable, even though still highly innovative.

2. Parallel endeavours: FLAMBOYANT and CULTINSIGHT

Certainly it had not yet become mainstream, as some of WhoLoDancE's technological partners, together with significant actors of the European fashion industry, were painfully led to acknowledge when, in April 2017, they ventured to submit a proposal, called FLAMBOYANT, in response to an EU H2020 call for a Research and Innovation Action (RIA) on the topic of "Tools for smart digital content in the creative industries".

FLAMBOYANT focused on innovative technologies for fashion creation, production, sales, and consumption, brought together into a smart tools platform which would have been tested and validated in three use-cases, representative of different scales of enterprise, ranging from large to medium, to very small. The three selected brands would have allowed to assess and quantify the innovation impact both at a local and global level, based on their very different market share and online presence.

While aiming at both researching and innovating contemporary visualization and simulation paradigms, building on advances on human motion synthesis, fabric and garment dynamic simulation, real-time immersive user experiences in mobile, virtual & augmented reality, FLAMBOYANT planned to apply machine learning analytics to consumer interaction, as well as blockchain technologies for IPR protection, quality and sustainability insurance, and counterfeiting prevention, finally supporting the composition, re-use, and distribution of interactive content creation, implementation and services, with assessment and feedback functionalities.

FLAMBOYANT's smart tools would have been developed following an industry-led approach in close cooperation with academia, within the emerging public-private partnerships paradigm, for modernizing and

improving fashion conceptualization, design, product development, production & manufacturing, sales and consumer interactions. This would have responded to the growing demands, of both the commercial and creative communities, to overcome the limitations of traditional photography-based advertising, of geographical borders, of high costs of skilled labour, and to support strategic time-to-market processes.

FLAMBOYANT was meant to facilitate collaboration and exchange of relevant knowledge within and throughout the fashion community and to encourage the procurement of innovative solutions to address the needs of the digital adaptation ecosystem.

Unfortunately, the total score achieved by the proposal was 11.50 (out of 15.00), because of failing significantly in the evaluation of the expected impact of FLAMBOYANT (the score was just 3.00), where it was remarked in the ESR that "there is a less clearly evidenced need for the use of simulations in place of classical representation methods, such as photography and fashion shows". A further shortcoming in the plan (leading to a score of 4.00 in the Quality and Efficiency of the Implementation) was considered the fact that, in a project lasting 36 months and implying first the development and setup of highly innovative technologies, "testing with end users is scheduled too late [month 15] in the project to make best use of the planned involvement of users as required in the call".

FLAMBOYANT had been submitted in April 2017, with Lynkeus as coordinator, and it envisioned some features by which it would have allowed to facilitate direct-to-consumer online shopping, by providing personalised experiences and products, making it possible for consumers to select their personalised avatar and have it moving around, virtually wearing their chosen garment, on the Fitting-Room section of a dedicated app; furthermore, by uploading all purchased digitally defined garments into the My-Wardrobe section of the same dedicated app, it would have been possible for consumers to experiment social interaction usages of such garments (such as checking with what other garments would they best match, or getting ratings and comments by trusted third-parties, socially sharing on specific occasions, etc.).

In January 2018 Amazon came forward with patenting "a mirror that dresses you in virtual clothes" (https://www.theverge.com/circuitbreaker/2018/1/3/16844300/amazon-patent-mirror-virtual-clothes-fashion), while IKEA has recently launched an AR app that allows users to scan the room and see furniture in 3D in that same room. They can position the furniture and change its colour, which allows users to engage with furniture like never before.

Before the submission of FLAMBOYANT, several partners of WhoLoDancE, having again Lynkeus as coordinator, had engaged in submitting by February 2017 a proposal also for the 2020-SC6-CULT-COOP-2017-two-stage call.

The proposal was titled CULTINSIGHT (Cultural heritage connection and exploration through advanced analytics in music and dance) and moved from the assumption that huge parts of the nonverbal cultural heritage were stored in databases sparsely annotated and oriented towards preservation rather than interactive exploration and discovery.

The amount of metadata describing the artefacts was deemed to be usually minuscule compared to the size and richness of the data itself, making it very hard, in the absence of crucial information about the mutual relevancy and inter-connectivity of artefacts, to effectively navigate the vast repositories of the preserved knowledge in an efficient way.

CULTINSIGHT would have tackled this issue by generating metadata from cultural artefacts through similarity search focusing on two domains with different, but interrelated conceptual models: dance and music.

Focusing on large scale feature extraction and indexing of cultural data, CULTINSIGHT aimed at developing paradigms enabling navigational approaches maximizing the learning experience (nonlinear, interactive, enabling discovery, adaptive, personalisable).

The emphasis was on creating metadata in the form of connections between various media types and deriving new insights into the domain from data mining the connections produced.

CULTINSIGHT would have made each artefact a starting point of a path of cultural discovery for its users. A mobile application allowing for text, audio, video, and gesture input would have captured an object of user's interest and provided relevant context.

CULTINSIGHT would have leveraged several existing information retrieval technologies and software prototypes developed earlier by its partners. A significant innovation would be based on the adoption of a data transaction system assigning to each digitised element taken into account within CULTINSIGHT a unique, fully traceable, digital Persistent Identifier, allowing to explore the potentiality of making use of the Blockchain technology and of associated Smart Contracts as a way of controlling the use each digitized element online.

In this case as well, the proposal got an insufficient though more flattering Evaluation Summary Report, with a score of 9.00 out of 10.00, and was not allowed to proceed to the second stage.

A shortcoming was considered to be the fact that "partners to use the technologies are indicated but their motivation to deploy the results into the wider sectors is not evident, which limits the impact", and "plans to attract a stable user base are not sufficiently elaborated". However, it was remarked that "the proposed adaption of software and data-mining techniques for movement, more usually developed in the sports domain, is particularly innovative. In addition the project's intentions towards persistent identifiers and the automation of IPR management offer important new innovations. The proposed platform / information aggregator, together with the app, are new products that can be expanded or commercially explored".

This twofold experience in submitting unsuccessful innovative proposals had the effect of discouraging, for the time being, further efforts in the same direction. It appeared that WhoLoDancE partners' commitment would have been more profitably focused on first completing the assessment of a series of tools, allowing to establish the proof of concept of a dance-dedicated platform for e-learning and chorographic creation, and then reach out, if possible, for direct market support.

3. Looking out for direct market support

This approach, which implied the goal of eventually devising how to issue digital tokens, for launching an Initial Coin Offering (ICO), was prompted by the consideration that the internet has been forcing virtually all industries to upgrade their economic models and to transform assets that were not traditionally exchanged into economic goods or services. Such a process would probably be fitting in due course also for WhoLoDancE ambitions, and its partners agreed to entrust Lynkeus with the task of starting studying ways and means for eventually getting there.

The idea was to follow the trend by which ICOs were becoming the financial foundation of choice for many platforms, where participants exchanged useful services paying for them through specially issued electronic coins (tokens), tied to a specific purpose.

The implicit assumption was that spreading currency issuance would spread also value creation. In fact, tokens provide a specialised means of exchange and mediation capable of incentivising demand and supply of new digital goods, implementing through a blockchain concertation layer a precise traceability of all transactions, thus securing attribution and property of both the token and the transacted asset.

This in turn makes them both scalable and secure, attracting further data, generating demand, and lowering distribution costs.

By giving permanence to all pertinent digital information in the platform economy, well-designed tokenomics not only enforced full transparency by default, but also allowed the alignment of incentives of various players operating on the platform and contributing to its growth.

In the last couple of years, ICOs had been successfully launched by a significant number of innovative businesses in several economic and geographical areas, succeeding to leverage two main economic functions. On one side, ICOs had provided start-ups with a crowd-funding mechanism for raising capital at a much faster speed than private or institutional investment. Shorter time to liquidity in turn had allowed acceleration of development plans, increasing the chances of success. At the same time, ICOs had also initiated the establishment of communities of stakeholders who would become the initial set of players in the target marketplace.

Therefore, while this recent phenomenon of ICOs appeared to be a method of fundraising which was still in its infancy and just beginning to gain shape, allowing the emergence and the financing of new businesses in innovative technology sectors, it showed signs of leading to a new form of engagement in businesses, with a capacity of attracting new investors so that the investor base would no longer be limited to a closed circle of a few specialists.

Ultimately, the recent successes encountered by some ICOs showed how the emergence of new types of innovative issuer, the democratisation of a new way for investors to engage in a corporate vision, and the possibilities of disintermediation offered by the blockchain technology, could be interpreted as signs that there was a place for this new fundraising process along with more traditional channels.

4. The Intermediate Periodic Review and the subsequent focus in high level dissemination and tools validation

These considerations were discussed during the First Periodic Review, held in Luxembourg in September 2017, and the EC reviewers clearly acknowledged that “it was proposed to use a very innovative route to sustainability, built around the emerging ICO approach to raise funding”, which however was deemed to be also a “potentially high-risk strategy”, leading to the final remark that “the plan of using the ICO method (that actually is an unregulated means of crowd funding) in order to co-finance the future development of the platform, needs to be thoroughly researched and perhaps reviewed in order to not abuse the confidence in the project of potential users”.

On the whole, the EC reviewers deemed the WhoLoDancE project to be, however, “promising in terms of developing the implementation of new technologies in dance and choreography... and … in terms of creating new tools for both professional and amateur use, with some potential for the preservation of non-tangible heritage”. Furthermore, they stated, “there is a possibility that the work within the project could be an open resource for developing a new teaching scheme for dance as well as new impact on neurological research on movement and its representation” […] “The results and the work itself has the potential of ‘social attraction’ […] not only within the dance community but also within other movement related fields (e.g. sports, medicine), new technologies and virtual reality”.

This overall technical evaluation was received as a significant encouragement by WhoLoDancE partners in furthering their project’s integration and progress, and in reinforcing their determination to look for initial business opportunities which could substantiate such a bold step as that of credibly launching a crowd-funding initiative.

In the meantime, they concentrated their efforts in organising a wide spectrum of qualified dissemination events: WhoLoDancE Metabody Toulouse 2017: A meeting at the crossroad of Art, Science and Dance, in December 2017; WhoLoDancE performing workshop at the International Living Arts Centre Naves Matadero, March 2018 in Madrid; Digital Echoes Symposium 2018, in Coventry, 5th International Conference on Movement and Computing (MOCO'18) in Genoa, June 2018; WhoLoDancE: body motion analysis with applications to dance education and beyond, at the 26th European Signal Processing Conference, September 2018, in Rome; WhoLoDancE Experience: Lab & Performance, at the RomaEuropa Festival, October 2018, in Rome; Festival della Scienza, October 2018, in Genoa; Virtual reality for innovative usages of movement analysis at ICT 2018, December 2018, in Vienna.

These events were targeting, on one hand, the community of professional teachers and chorographers as well as learners, and, on the other hand, the scientific community of academia and technology developers. In both cases the WhoLoDancE tools were strongly appraised for their novelty, and they were received with general acclaim.

Eventually, the last months were dedicated to a systematic validation of these tools, the outcomes of which are described in D5.4 Final Release, testing and validation data management platform report, D6.5 Report on validation process, and D7.3 Personalisation Evaluation Report.

5. The concept of a multi-sided platform

Given these technological outcomes, WhoLoDancE's ambitious goal, inspired by the multi-sided platform (MSP) concept, as developed by the 2014 Nobel Laureate for Economics, Jean Tirole, has been moving from proof-of-concept to an incipient operational reality for dance (possibly one of the most complex human bodily activities).

The subsequent exploitation idea entails that a similar approach can be applied to other types of dance genres (as well as social dances) and to adjacent areas, like wellness, sports, martial arts, crafts and work ergonomics, body movements for rehabilitation, and even robotics.

WhoLoDancE partners have worked on converging on an integrated web-based and Unity-based platform, leveraging the technical developments already accomplished and having recourse to Unity as cross-platform engine of choice. Additionally, it was also agreed that enabling a wider use of less costly low-end devices would be useful, hence, deciding to go for a multi-layered software licensing approach. This will allow to implement a freemium general access policy, providing browsing of and some limited access to the platform for free, in addition to a fee-based access to all WhoLoDancE functionalities. These fees will be expected to trigger a feedback mechanism to support further acquisition of motion captures, broadening the content database and ensuring its sustainability, while providing, through blockchain and smart contract applications, an economic return not only to the technology developers but also to the artists contributing to the motion capture sessions.

The ambition is to establish the first scalable, decentralised library of annotated motion capture files along with tools to edit, blend, sell, and distribute real world body motions and the tools to leverage them into an algorithmic marketplace. The shared hope is that this platform will allow artists, craftsmen, athletes or anyone else able to perform skilful movements to capture their performance in local motion-capture environments, to upload these contents into a quality controlled, integrated environment, and to share them with a global audience.

The shared goal is that WholoMovE can represent a "first" in the dynamic exploitation of a successful EU-funded H2020 project. It is also meant to act as a highly visible testimony of the financial attractiveness that the outcome of a project may eventually have, given the strong scientific and entrepreneurial background

guaranteed by the highly competitive EU selection process, such as the one that WhoLoDancE went through, for being funded in the first place, and being evaluated during its unrolling.

Now, here is a list of 16 tools, most of which have been undergoing a process of community evaluation described in D7.3, by which they were made temporarily available to a wide selection of dance experts among those who candidated as evaluators.

6. WhoLoDancE tools

6.1 Movement Library and Annotator (technological partner: Athena RC)

The Movement Library and Annotation tool is the web-based system which allows to browse, search and annotate the synchronized multimodal recordings (motion capture and videos) that have been created during the WhoLoDancE motion capture recording sessions held in Amsterdam and Genoa.

It consists of a web-based interface, data, metadata and annotation management back-end as well as a user-management system. Users can sign-in, register and access the tool through the link in order to:

a. browse and search the recordings using keywords related to the metadata, as well as the annotations
b. see the recordings in a synchronized view where video and mocap are viewed next to each other, through a player with all standard functionalities
c. create their own playlists where they can add particular recordings of interest
d. annotate the recordings using both free text and controlled vocabularies based on the conceptual framework of WhoLoDancE and edit them later on
e. see their annotations in two views, a tabular and a timeline one.

The system integrates a simple visualization of the recordings with an avatar in the form of a stick figure. In addition, a further visualiser is available, the Choreomorphy viewer, developed in Unity and integrated through WebGL, which allows to see the exact same recording in different avatars.

6.2 Segmentation (technological partner: PoliMi)

The segmentation tool has been designed to allow manual segmentation of motion capture sequences into simpler movement segments. The resulting data - together with its annotation - constitute the ground-knowledge for the development and evaluation of algorithms for automatic segmentation.

The segmentation tool is the web service to collect manual annotations; the segmentation techniques are the automatic algorithms which leverage those annotations.

The tool can be used to inspect and manually correct the result of an automatic segmentation, contributing to the continuous refinement of the algorithm.

The tool includes three interconnected modules: a 3D scene where the user can rotate the scene, zoom in/out and switch to/from full-screen view, with the avatar changing colour at the beginning of a new segment; a player to follow the execution or jump to specific frames of interest, showing segments as coloured progress bars; a table to show the annotated segments, with labels and commands to add or modify annotations.

The tool is currently a web-based application that users can access from anywhere.

6.3 Movement Analysis Software Library (technological partner: UniGe)

A set of software modules for the real-time extraction of movement qualities are available for different tasks: from the (off-line) automated annotation of the dance fragments stored in the repository, to the real-time tasks of a dancer or practitioner, to support interactive sonification visualization, and improvisation.

The library includes a wide set of software modules to analyse movement qualities that range from low-level kinematic-related features (e.g., speed of joints, accelerations) to higher-level qualities (e.g., energy, lightness, symmetry, origin of movement).

It is available as a software library for the EyesWeb platform, as well as a separate software library, in both cases integrated with Unity and the other WhoLoDancE modules.

The developed analysis modules are designed to be integrated with various tools: real-time modules are used in the Movement Sketching Tool, and mapping strategies from movement to interactive sonification and visualizations, the modules can be integrated with Unity-based applications and other environments (i.e., sonification environments).

Off-line modules provide the ability to analyse recorded sequences of dance for further analysis and visualization.

The modules can receive streams of data from UNITY applications, live streams from devices or read FBX files of recordings (either from the repository or freshly recorded by users).

Output of the modules can be streamed back to UNITY for real-time visualization or fed into the similarity search engine for training or for querying similar sequences.

6.4 Data-driven extraction of movement qualities (technological partner: PoliMi)

Data-driven methodologies involve using manually-annotated examples to train machine learning techniques to understand the relationship between a low-level representation of the motion and its high-level description.

This implies collecting manual annotations from dance experts on the movement qualities on performances, and using techniques for feature extraction and selection, machine-learning algorithms and metrics of evaluation.

Collecting annotations from dance experts constituted the ground base data for the implementation and training of machine learning-based algorithms.

This procedure presented a primary, technical difficulty, as various experts, coming from diverse dance specialties, showed a different - subjective and cultural - perception of movement qualities, such as fluidity or heaviness, which made it hard to reach the consensus values required for an effective algorithm training.

To balance this subjectivity bias, there was the need to re-design and simplify the annotation tool before opening it to a larger community of dance experts and amateurs on the web.

6.5 Movement quality annotation by comparison (technological partner: PoliMi)

The movement quality annotation by comparison (MQA) tool is meant to make the annotation procedure sensibly lighter and easier, allowing experts from the dance community to contribute with little or no training.

With this tool, it becomes possible to collect a high amount of annotations from a large community, to be used for the training of algorithms capable of automatically describing dance performances.

Given a movement quality, say fluidity, the tool displays a 3D representation of two short dance movements represented by a black and a white avatar, in a loop, and asks the user to make a comparison between them and select which one is expressing a higher level of fluidity.

Users can choose between five levels, or even skip the comparison if they decide the comparison is not meaningful or they do not feel confident enough to express a decision.

6.6 Search and similarity engine (technological partner: Peachnote)

The search and similarity engine implements a set of methods to measure the similarity between dance performances modelled using different data formats.

A web-based interface has been developed that allows to identify similar motion sequences to any sequence indexed by the search engine and to play back both the query and the identified similar sequences at the same time.

The search and similarity platform supports automated submission of recordings and time-series data by authorized users. It supports flexible querying scenarios, in which users can specify the features to be used for searching and their weights by themselves. The functionality is exposed via a REST API that consumes and produces data in JSON format.

The API is documented and easily usable in a variety of environments. A simple authentication scheme is employed. Multiple deployment instances of the engine are available to technical partners for experimenting with the API, the low-, mid- and high-level features that they can generate and submit to the search engine on their own, and the custom weighted templates without interfering with other partners or the production deployment. The deployments are easily upgradeable to support short development and deployment cycles.

The Search and Similarity Engine is implemented as a stand-alone Java application that can be interacted with over a REST API. The API implements a Swagger API definition, from which client implementation in multiple languages can be automatically generated.

For real-time applications WebSocket connections can be used for streaming motion and HLF data to the search engine and receiving a stream of pointers to the search results. WebSocket connections are supported for both Unity and Web-based clients.

The application hosts its own documentation that is available at the root endpoint of the API, e.g. http://search.wholodance.peachnote.com. The documentation describes all available REST endpoints and the data structures consumed and returned by the API.

6.7 Blending engine (technological partner: Motek Entertainment)

The UNICA blending engine proof of concept is an interactive blending and composition tools of the motion capture data that are already available in the Movement Library. The sequences can be assembled in a linear setup, or used for parallel blending, where the consecutive segments are a superposition of segments from the Library.

Users can assemble choreographies or blend sequences and save those as new FBX files. These files can be read and displayed inside the UNITY engine using any of the created avatars (Choreomorphy).

Given its high complexity, the tool is still in early stage of development and will require further efforts to mature into a fully usable platform.

6.8 Movement Sketching Software Tool (technological partner: UniGe)

The Movement Sketching Tool enables users to access, browse and query the Wholodance repository by means of movement qualities. For example, a user can perform a “fluid” and “open” movement with a limb, and the system extracts these expressive movement qualities to retrieve similar movements by using the Similarity Search tool.

The tool is scalable: it works with motion capture systems as well as with low-cost systems such as IMUs (e.g., xOSC, Notch sensors), to enable dance practitioners with the possibility to capture a dancer’s movement sequence, analyse it in terms of the desired qualities, and search similar movements through the Similarity Search Engine. In this way, the tool compares the user’s movements with those of professional dancers stored in the Library, and the query results can be visualized with both standard and virtual reality devices. Additionally, sonification techniques can be used to generate a sonification of the performed and retrieved movements.

The tool can receive streams of data from UNITY applications, live streams from devices or read FBX files of recordings (either from the repository or freshly recorded by users). Output of the tool can be streamed back to UNITY for real-time visualization.

6.9 Low-End VR (technological partner: PoliMi)

The low-end VR platform allows the user to visualize the motion capture of a dance performance as an immersive VR experience by using a low-cost VR support, such as the Google Cardboard (10$) and an everyday smartphone.

The platform supports the tracking of the orientation of the head, so when the users looks around, the visualization of the virtual 3D environment changes accordingly.

6.10 Real-time mobile movement search application (technological partner: Peachnote)

The real-time mobile movement search application allows anyone with a mobile device and a second screen to find movements captured within the Movement Library, as well as external video recordings based on camera input.

The focus of the system is on accessibility (any mobile phone with a camera and a cellular connection can be used as a capture device), simplicity, and non-disruptiveness of the application (the search is running in a streaming fashion, continually delivering results based on the motion captured by the camera). Since no special hardware or software beyond a browser is necessary, the system doesn’t require any technical expertise to operate and the setup time is very short.

In the minimal configuration, the user capturing a movement points a mobile phone or a tablet towards a moving person and receives on his/her own screen a stream of images from recordings that have been indexed by the search engine and that correspond to places in the recordings that are similar to the motion captured in real time. The latency of the system is about one second under regular conditions. The user can at any point decide to stop the search and switch to one of the search results, playing it back from the identified offset.

In a more extensive setup, the search results can be projected onto a wall using a beamer, so that the captured person can also see the search results in real time and inform his/her movements based on them.

An even more extensive setup includes the dancer wearing a Hololens device and seeing the search results streamed in 3d in the space around him/her. This is possible for recordings that have been 3d captured before, like the ones from the WhoLoDancE Movement Library.

The system is built in a modular fashion and consists of several components: a video streaming service for ingesting the client video streams into the system, a service for extracting skeletal motion information from the raw video streams using GPUs, the search engine that indexes existing repositories of motion captured data or video and finds similar sequences given the real-time stream of skeletal motion provided by the previous pipeline component, and the presentation layer that visualizes the search results for the users.

The system can work with both 2- or 3-dimensional streams (motion capture and video sources and queries), mixing them as required by a particular use-case. For example, a smartphone delivering a low-resolution video stream can be used to query for 3d motion capture data of high accuracy that can be projected onto a 2d canvas or streamed in 3d into a VR application. Vice versa, data streams from motion capture equipment can be used to find videos containing similar gestures, or other 3d captured motions.

A more advanced version allows to have easy availability on a large number of simultaneous clients, by processing the video on the client and not having to stream and process it on a dedicated server.

6.11 Real-time motion-based collaborative mobile game (technological partner: Peachnote)

Players collect points based on the closeness of their movements to those of other players who are moving to the same music or generally any audio stream - think of a radio broadcast listened at different places at the same time.

The players are supposed to share only a common audio context. They are not expected to be in one place, see or even know each other.

This is an input-agreement type game created in order to elicit and capture human face and body motion responses to audio stimuli, but it can also be used in dance education contexts where measuring similarity of motion or its features is useful.

The app is very simple to operate: open the app, press start, stand in front of the phone's camera and start moving. The presented mobile implementation (currently Android-only) extracts skeletal motion from the camera stream on device in real-time and streams it to the backend, along with a stream of audio fingerprints also extracted on the device.

The implementation aims at preserving privacy of the players: neither audio nor video streams are uploaded to the backend, only their fingerprints.

The backend automatically groups clients based on the similarity of the audio fingerprint streams and for each group computes pairwise distances in recent body motion for all pairs of clients belonging to the group.

Clients continuously receive their score calculated as a weighted sum of similarity values with the most similar other client over time - the greater the similarity of movement, the higher the score. In the presented version the score is displayed using a green bar under the camera image.

6.12 Sonification of movement qualities in real time (technological partner: UniGe in collaboration with Stocos)

Multimodal feedbacks are fundamental to highlight details or different aspects of a dancer's movement in a variety of contexts, such as rehearsal, performance or choreographic production.

While a visualization may offer more information, a dancer cannot focus on a screen while performing: in this case, sonification enables to have a real-time, responsive feedback on the movement without causing distraction.

The sonification tool relies on a movement quality library: while different sensors (e.g., Kinect V2, XOSC IMU, MYO, etc.) capture dancer's movements and positions on stage, several EyesWeb-based analysis modules analyse them and stream the extracted qualities to a sonification environment (e.g., supercollider, Max) that maps movement qualities with various elements of sonification.

6.13 Choreomorphy (technological partner: Athena RC)

Choreomorphy is a Unity based application which can be accessed through various modes of interaction:

a. Choreomorphy whole-body experience
b. Choreomorphy HoloLens experience
c. Choreomorphy desktop app.

The design idea is that different avatars and visualisations of movement highlight different aspects and eventually trigger different qualities and patterns of moving, which is meaningful from both a paedagogic as well as creative and aesthetic perspective.

In other words, Choreomorphy allows the user to easily change and personalize her or his view of the movement.

More specifically:

I. Choreomorphy whole-body interaction experience allows the performers/users to see themselves in different avatars, visualizations and environments while moving in real-time through wearing an inertial Motion Capture suit, thus it can be used as a tool for self-reflection and dance improvisation.
II. Choreomorphy HoloLens version extends the same functionalities in AR. The users can see the pre-recorded movement in three-dimensional avatars in the physical space using the HoloLens devices, so that they can follow the movement in physical space.
III. Choreomorphy desktop app is a downloadable application built in Unity, which runs on both MAC OS and Windows, and allows to see the recordings in a variety of avatars, visualisations, effects and environments.

The Choreomorphy viewer, developed in Unity and integrated through WebGL, allows to see exactly the same recording in different avatars.

6.14 Hololens UNITY (technological partner: Motek Entertainment)

The UNITY custom environment is the base for integration for all other partner tools. Applying it here with Hololens, it serves as a key outcome of the project in as far as it can be used as a learning device, by enabling a dance student to be inside or vis à vis a holographic projection of an avatar driven by motion capture data of a dance master.

This UNITY environment also offers multi use capacity, so a teacher / choreographer can also see the real dance student immersed inside the avatar. The UNITY environment also offers feedback per body part to the student, letting him/her know when respective body parts are outside the avatar volume.

6.15 Tools for Music Analysis (technological partner: PoliMi)

Within WhoLoDancE, a set of algorithms for music analysis was also developed, aiming to automatically extract low-level features, like spectral and waveform features, and mid-level features, like music beats and chords.

Given the set of music pieces, the algorithms extract a large set of features. The feature extraction procedure is integrated with the web-based framework and the Unity framework through client-server data exchange.

6.16 Educational Platform and Kinect-based exercises (technological partner: Athena RC)

The Educational Platform is a web-based application which showcases the various WhoLoDancE tools and scenarios from a paedagogic perspective. It complements the Movement Library, and it extends the WhoLoDancE Conceptual Framework.

The Educational Platform combines specific scenarios to design learning courses and activities for a particular Dance Genre (Contemporary, Ballet, Flamenco, Greek Folk), objective (Movement principle, quality, actions), context (Creativity, learning steps and Forms, improvisation, etc.), and tools (Sonification, Choreomorphy, Annotator, Movement Sketching, Kinect based activities etc.).

The Learning Activities described in the Educational Platform require particular hardware depending on the tool.

As a proof of concept, specific examples of paedagogic scenarios were built for low-end devices like Kinect, in particular, for interactive exercises relating to Alignment and Directionality.

The WholoMove platform will have the ambition to serve all industries concerned with, or making use of, human movements in digital formats, including technology developers and service providers working in those markets.

On the demand side, the platform will leverage current trends in the wide-spread use of motion capture content in industries such as animation, gaming, virtual reality, digital fashion, performance training systems, rehabilitation and other clinical applications.

The system will support multiple content access modalities, ranging from simple browsing to on-platform manipulation, e.g., making use of search and comparison, annotation and assembly engines, to select, analyse, modify, and publish, new content files from the aggregation of pre-existing ones.

7. Key individual exploitable results (based on the outcome of the individual questionnaires)

7.1. The UNICA Blending Machine (Motek Entertainment)

The product engages in interactive blending and composition of sequences of movements based on motion capture data available in the WhoLoDancE Movement Library. Movements can be assembled in a linear setup, where the combined movement segments appear in their original form and the transition between one movement and the other is blended. Movements can also be blended in parallel, so that different body-parts which contain movements from different sequences can be blended into one. This allows users to create new movements that were never captured.

The capacity to create a realistic human movement which was never captured or animated, and which is treating a movement library as a "sandbox" where an infinite number of new movements can be generated, is a non-incremental innovative step in the entertainment, animation and game industries.

The current status of the tool is in an early beta prototype phase (TRL7-8). The concept and its usability in have been proved in the context of the WholoDance project, by blending and assembling different sequences from the movement repository created for the project.

There are several gaps on the way to exploitation. These are:

- Full implementation of biomechanical human movement limitations.
- Platform speed and robustness
- Import and export of additional file formats, avatars and stages.

As far as technical risks are concerned, one of the technical issues in this approach is that the virtual human model used inside the blending machine does not fully take into account the biomechanical limits of the human body. This effectively means that a blending could lead to a sequence of movements that are technically impossible for humans. Further development work (outside of the Wholodance project scope) will be developed by Motek Entertainment in-house.

In regard to market and exploitation perspectives, at start the target user will be digital animation professionals and game developers. Once the product is installed at a wide user base from those industries, Motek Entertainment aims to expand its usage to the areas of: Architecture, Engineering, Training, Education and Sports. The entertainment industry (primarily films, animation, games, virtual environments, and advertising) is growing at around 30-40% per year globally, while demand for special effects in this industry is increasing dramatically (20%-30% on average, some up to 80%).

The hottest demand is for digital special effects based on motion capture - a technique for animating realistic computer-generated characters. The estimated global budget for digital special effects in major film productions was 2.5 billion for 2017 of which approximately 30% was allocated for effects using motion capture.

Despite the significant interest in motion capture, it is currently prohibitively expensive for all but the largest productions. This presents a strong use case for a tool like the UNICA™ blending engine.

Most large studios (Pixar, Universal, Disney, Amblin, Lucasfilms, etc.) have their in-house motion capture stages. There are few hundreds of mid-range motion capture studios worldwide. Mostly used for AA games

and independent productions. While most commercial 3D animation packages offer tools for assembling motion capture data, none has the potential capacity of the blending engine in its full.

This market is relatively small, currently it has about 16 major players. These players can be grouped as follows:

- Motion capture studios:
  - Most studios target their motion capture facilitates at the game developers and movie-makers
  - Several have their own proprietary hardware/software for capturing and editing
  - Motion capture of multiple performers real-time with several cameras is relatively new
- In-house motion capture studio:
  - The big movie and game production companies have their own in-house motion capture studios
  - These studios are mainly for internal use only and mostly unavailable for third-parties
- Software plug-ins for motion capture:
  - Several players provide specialised plug-ins for motion capture (e.g. AutoDesk)
- Motion capture content services:
  - Few companies sell their motion capture data
  - A limited number of players are moving into the online marketing and distribution of pre-captured motion

In view of exploitation, IPR management has also been considered. An initial hint to something approaching the blending engine was patented as early as 2004 (US Patent # 6,738,065 Even-Zohar). Motek Entertainment plans to develop it further in the future, subject to availability of funds.

As far as access is concerned, the custom build of the blending engine for the Wholodance project is available to all consortium partners. The Wholodance movement repository is also available online.

7.2. The Movement Library and Annotator (Athena RC)

This tool is a web-based complete data management system and interface (maturity level: TRL 6), which allows browsing, searching, annotating the multimodal recordings, editing and enriching metadata. The system also includes a user management system with particular roles and integrating a visualizer of the motion capture recordings (developed by POLIMI), and Choreomorphy viewer.

One of the most interesting features provided is the search by movement keywords, integrating a conceptual framework form movement analysis and domain-specific ontologies. Other key benefits include the fact that the system is easy to use, web-based, complete and evaluated and validated by domain experts.

As far as risks and limitations are concerned, a key issue can be represented by the IPR and access models to the contents of the library, which will require additional discussion with the dancers and the annotators, in order to outline a proper business model.

As far as market and exploitations are concerned, the key target users can be dance practitioners, teachers, students, amateurs, choreographers, while the system can be further expanded to include other dance genres and movement practices, including sports, martial arts etc.

The system provides some unique characteristics, compared to existing similar tools, in particular:

- Content of the library has been created by experts, and consists of one of the main – if not the first library with this large amount of high-quality data.

- Intangible Cultural Heritage content e.g. Greek Folk dances
- Synchronized view of motion capture + video, integrating domain specific vocabularies and functionalities which allow the easy search, browse and annotating of the content using controlled vocabularies

Additionally, the system can have a potential social impact as it enables the preservation and research of intangible Cultural Heritage.

In any case, for the moment – rather than focusing on direct commercial exploitation – the creators of this innovation are currently considering it as a basis for further research development, and for internal use.

7.3. Choreomorphy (Athena RC)

Choreomorphy is a tool (TRL 6) aimed at customising the visualization of one's movement through changing avatars, effects and environments in real time. The tool has several modes of interaction depending on the available hardware:

1) live, whole-body interaction using motion capture and motion sensing devices,
2) a stand-alone desktop mode to visualize pre-recorded motion capture data,
3) a WebGL version to access motion capture through a web-based repository, and
4) augmented (AR), mixed (MR) and virtual reality (VR) mode using devices such as Microsoft HoloLens or HTC Vive.

Among the key features of the system, the fact that it allows real time visualization of human body, its movement and environment, and that is interoperable with more than one device for motion sensing and motion capture as well as AR/VR and MR hardware.

Additionally, Choreomorphy enables real time customization of visualization through easy to use interface. At the same time, it provides extensibility of assets such as avatars, scenes and effects within the Unity platform.

Thanks to all these features, it has great potential for creativity support and other applications of whole-body interaction within educational, creative, or entertainment context.

As far as potential commercial applications are concerned, the biggest potential is to be identified in all the fields where body representation, mirroring, self-perception in movement, dance and other embodied activities are significant added values. Additionally, it is possible to further enhance the system to make it compatible with other dance genres and movement practices, including sports, martial arts etc., gaming, entertainment and other creative contexts such as dance, theatre and playful interactions. Target users could be dance practitioners, teachers, students, amateurs, choreographers.

With regard to IPR management and current risks and challenges, it can be said that IPR regarding content for the pre-recorded mode (e.g. already existing on the platform) need to be clarified among those who contributed to the initial implementation. At the same time, complexity and cost of hardware need to be taken into account before considering for wider audience outreach.

7.4. Web-based Educational Platform (Athena RC)

The Web-based Educational platform is an online educational platform (TRL 5) for learning scenarios through multimodal content and recommendations for whole-body interaction scenarios using a variety of modalities that have been developed in the project.

Among its key features, it is worth mentioning the possibility for the users of getting recommended courses and activities based on preferences, dance genre, learning background, available hardware, focus, movement

principles, etc. Additionally, the platform is very intuitive, web-based (no specific hardware requirements needed) and already validated by domain experts.

It is worth noting that, while existing online educational platforms are widely available, e.g., MOOCs, the focus of the WhoLoDancE Web-based Educational Platform is on dance and movement-based activities. In this sense, it is meaningful to consider possible further development and content creation (also possibly leading to commercial exploitation) in the field of education of dance, sports, intangible cultural heritage activities, preserving teaching and learning practices next to movement forms.

7.5. The motion similarity search engine and mobile interface

The (Body and face) motion similarity search engine and mobile interface (TRL 4) is a tool allowing for motion capturing using mobile phones, thus extracting motion either locally or on the backend, eventually allowing for similarity search in a database of indexed motion recordings (either motion captured or extracted from video).

The easy content-based access to motion database, makes it possible to retrieve relevant motion sequences by example instead of resorting to reduced high-level metadata descriptions. Ease of use and accessibility are other important benefits provided by this tool.

Commercial exploitation might target dance and music researchers, dance practitioners, music enthusiasts, providing a tool for music conductor training, and also for allowing music enthusiasts to create music, even without a formal music training. In particular music making appear of great interest, as current solutions are either shallow, providing little real control to the user, or cumbersome and not fun to use.

In this field, a comparison can be made with Nintendo Wii Music (rather than other famous music games like Guitar hero or Rock band, which are solely based on the correct performance of motion and relevant scoring), which allows the user to actually influence the music by playing – also in a creative way – the various musical instrument available, experimenting various ways of performing a song.

At the same time, Nintendo Wii Music can be assimilated to a sort of more accessible musical instrument, which can be played without any formal training, but doesn't allow for original composition, but rather to conduct how existing music is played.

More professional alternatives, such as Finale or Sibelius, basically score editors, allow for creation via scores and then – thanks to the export function – the "execution" of the written piece in an audio format, available for further direct manipulation. In this case, the procedure is very difficult and cumbersome, beside requiring formal knowledge of music scores, while the availabilities of libraries of whole orchestra instruments results in very expensive tools.

In this sense, the tools implemented in WhoLoDancE allow for new way of creating music, while also providing a radically improved interface for making music creation much more natural. At the same time, it is worth noting that, in the case of conductor training, a comparable application doesn't exist yet.

In order to fully express its potential, this tool needs to be improved also taking into account that lower-end devices cannot extract motion from video in high quality quickly enough and the only option for such devices is streaming video to backend for analysis, which is not ideal from the point of view of data privacy and also the increased cost of processing the data on the backend and its complexity. Additionally, the backend needs to support multiple low-end devices seamlessly, scaling the processing infrastructure on demand. The on-device motion analysis algorithms would benefit from reduction in computational complexity and increase in accuracy.

Peachnote, the partner responsible for these tools, got some additional funding also for further enhancing them, within the EU-funded project TROMPA (Grant Agreement Nr. 770376).

It is worth mentioning, finally, that the tool and its content are available through the Petrucci Music Library (imlp.org).

8. Market and competitive analysis in digital tools applying to dance and adjacent areas

8.1 Dance basic use cases

A variety of use cases can be envisioned for WhoLoDancE outcomes already at this stage.

Dance use cases can be related in the first place with teaching and learning, using high- or low- end VR/AR tools and environments to provide teachers with a powerful resource for improving their capacity of communicating in the most effective way a movement and its key quality, and to learners for improving their understanding of a movement and the most appropriate way of executing it.

The learning process can take place both in an educational environment (such as a dance school) or at home, without giving up the benefits of an interaction between teacher and student, while providing the learner with a new one-to-one experience which it would be difficult to guarantee in a crowded dance class.

Teachers, in this sense, may be able to give one-to-one support by "multiplying" themselves in each student's device, providing on-the-spot support and advice when needed. For the learners, the resulting environment would hopefully also be more engaging and immersive, thanks to the relevant VR/AR tools.

Alternative use cases can be envisioned in the process of choreographic creation, for direct usage by dance professionals. As exemplified above, using WhoLoDancE tools the choreographer can be able to communicate more easily with the dancers, providing them with previously non-existing ways of understanding a movement and the "vision" of the choreographer for a given performance.

This is something that was impossible before, when the choreographer was entrusted to transfer his/her vision either through notations (depending on scarcely agreed upon systems of notation, often based on very personal ways of translating and interpreting a choreography) or through the direct personal demonstration of a given movement, resulting often in misunderstandings with the dancers and in the need of very long rehearsals for a performance.

Although this traditional type of interaction is certainly not expected to wither away with the introduction of WhoLoDancE's tools, also in consideration of artistic free inventiveness and of the individuality of each dancer in any resulting performance, still it can be estimated that WhoLoDancE approach can represent an important way of improving the interaction between choreographer and dancer, possibly allowing to devote more time to the artistic creation rather than on discussions around the execution of a specific movement.

A tentative demonstration of this approach ("can choreographic creation be technologically supported?") has been given with the video "WhoLoDancE: body movement and technology for enhancing choreographic creation" with choreographer Jean-Marc Matos and dancer Marianne Matos, accessible at http://www.wholodance.eu/Videos/.

WhoLoDancE can allow the choreographer to create new and original choreographies with the support of the blending engine, starting from an existing set of movements and manipulating them in order to arrive at new ones. Additionally, the movement sketching tool, the similarity search and the quality analysis tools,

may facilitate the creation of a new choreography by making it possible to browse specific sub-sets of movements which can contribute to define how to render a specific emotion or how to look for alternative ways of expressing what the choreographer has in mind.

Similarly, WhoLoDancE's tools can be used to virtually stage a performance before its implementation on an actual stage. The benefits span from an easier implementation of the stage – thanks to the possibility of simulating a variety of options beforehand – to a more precise evaluation of the space, lights, and relevant position of objects and dancers on the stage itself.

Finally, leveraging the interaction and integration among the various tools, WhoLoDancE could also be used to experiment completely virtual, and to some extent autonomous, performances, which could be executed in an Augmented Reality space, to be experienced by the public through either making use of AR devices, or with future more advanced holographic renderings.

A further use case can be based on continuing to use the technologies developed within the WhoLoDancE to preserve elements of intangible cultural heritage, and of strong touristic attraction, providing the appropriate national and regional institutions with the tools needed for digitising their traditional dances.

8.2 Current technology matureness, competitors and market, with regard to dance, motion capture, and VR/AR

The application of technologies in the dance domain is not something new, even if the last couple of decades there has been a steady increase in technological applications in a variety of use cases, stemming from education, to performances, to choreography, and research.

It is more and more common to find technology elements within formal dance education curricula, and dance is increasingly used – in particular within contemporary dance – as an integral part of performances: let it suffice to refer to celebrated choreographers like Merce Cunningham and Wayne McGregor, but this trend may be appropriately witnessed also by two WhoLoDancE partners, K.Danse and Stocos, which are dance companies representing bright examples of this phenomenon.

At the same time, it can't be said that the relevant market has reached a full matureness, and the intersection of technology and dance is still somewhat of a niche field. Interestingly, though, many applications appear to have envisioned lines of research which are somewhat in analogy to those suggested by WhoLoDancE. It would be difficult to provide here a complete and exhaustive overview of all the initiatives in the field, but the following paragraphs may give an account of the ones that look more interesting from the WhoLoDancE perspective.

Among others, research projects like WebDANCE (completed in 2007) pioneered the experimentation of 3D animation and Web technologies, for the implementation of a dedicated web-learning environment (equipped also with lessons for traditional dance e-learning) specifically designed for high-schools[1].

In an analogous vein, a European project, Open Dance[2], developed a learning tool based on a 3D platform, focusing on an education framework for folk dances, aimed at allowing teachers and students to interact with the "animated dancers" (as were called the avatars) and better understanding each dance and the key

[1] Proceedings DVD of the 21st World Congress on Dance Research, Athens, Greece, Greece 5-9 September 2007, International Dance Council CID-UNESCO, 2007, "Teaching Traditional Dance using E-learning tools: Experience from the WebDance Project".

[2] Nadia Magnenat-Thalmann, Dimitrios Protopsaltou, and Evangelia Kavakli, Learning How to Dance Using a Web 3D Platform, Advances in Web Based Learning - ICWL 2007, 6th International Conference, Edinburgh, UK, August 15-17, 2007.

features of its movements. Interestingly, their long-term objective was to create an online dance learning community and allow dance teachers to create their own dance lessons online.

Along similar lines, Chan et al (2011)[3] proposed a new dance training system based on the motion capture and virtual reality (VR) technologies. The system, similarily to WhoLoDancE, allowed the student to imitate the (virtual) teacher's movement, while a motion capture tool records, analyses, and provides feedback to the student, although not in real time.

A more recent American initiative, worth mentioning here, is the Middlebury Motion Capture Lab (http://sites.middlebury.edu/mocap/), which is a lab space meant to facilitate class use and experiments in interdisciplinary and interdepartmental projects and research for faculty, staff and students at Middlebury College, in Vermont. It was launched in Fall 2016 by dance professor and lab director Scotty Hardwig, with sponsorship from the Dance Program and the Fund for Innovation (FFI), as a laboratory for exploring the potential of digital tools which might provide an integration point between the arts, sciences, humanities and athletics through the digital study of human motion. The lab's goal is to provide a space for kinetic learning and creative applications across the disciplines of dance, film, music, computer programming, and animation.

Similarily to WhoLoDancE, this lab makes use of full body motion capture suit and relevant software, for implementing avatars and live-capturing digital movement, and also of Kinect. It allows integration with a variety of third-parties software such as Blender, 3Ds Max, Cinema 4D, Ableton live, etc., making it possible "to create animated avatars from real movements of actors and dancers, or to create live performances where dance becomes an instrument for creating live electronic music performances".

An international (though now mainly European-based) research project which has deservedly acquired great renown, and with which WhoLoDancE has been closely interacting, is Motion Bank (motionbank.org/), initiated by the Forsythe Company in 2010[4].

Its main focus has been on the creation of on-line digital scores (based however not on motion capture but on lower-end devices, such as Kinect, or on video cameras), in collaboration with guest choreographers to be made publicly available in open source via the Motion Bank website.

Motion bank is located, since 2016, at Hochschule Mainz — University of Applied Sciences and is co-directed by Florian Jenett and Scott deLahunta.

Together with partners worldwide, it is dedicated to researching the documentation and translation of contemporary dance practice into digital form, focusing on questions regarding the relationship between embodied and machine-based knowledge forms.

Motion Bank is developing low-threshold, standard-compliant open source and free systems designed for use in a variety of contexts, including dance education, creation, research and archiving.

In addition to the design and development of these systems, Motion Bank is engaged in ongoing methodological research into the practice of annotation, the documentation and presentation of processes involving tacit, collaborative and embodied forms of knowledge and bringing these this into alignment with research into linked data, semantics and ontologies from information science.

[3] A Virtual Reality Dance Training System Using Motion Capture Technology, IEEE Transactions on Learning Technologies 4(2):187 – 195, July 2011.

[4] Letizia Gioia Monda, *Choreographic Bodies: L'esperienza della Motion Bank nel progetto multidisciplinare di Forsythe*, Dino Audino editore, Roma 2016.

Other initiatives, created by digital artists such as Universal Everything, FIELD, and Memo Akten & Quayola, have used motion capture to translate human movement into abstract forms performing in virtual environments, but this type of experiments is to be understood more like digital performances/pieces of art themselves than as tools to be used by dancers.

Similarly, and more recently, a Japanese collaborative team of artists, researchers and designers Masahiko Sato + EUPHRATES, implemented the Ballet Rotoscope, which is an experimental short clip, which follows a ballerina's movement using a rotoscope animation method, which focuses on joints' step-by-step trajectory.

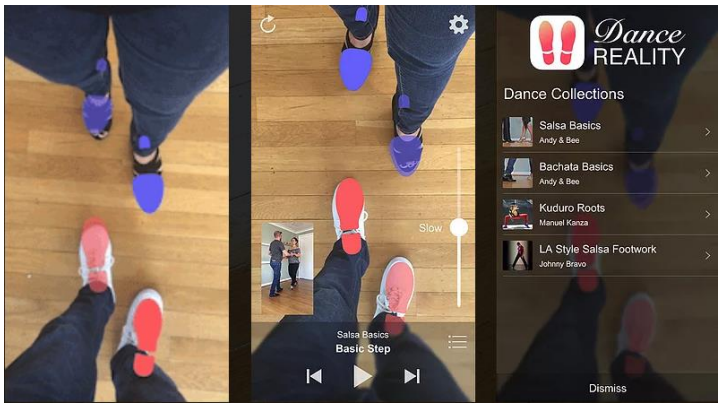
In this case as well, it is more a performative piece of art rather than a tool to be re-used by the relevant community.

Concluding this brief analysis, it is worth mentioning two initiatives which leverage VR/AR tools and mobile phones for improving dance self-learning: Dance Reality and Salsa-virtual.

Dance Reality is a mobile application available for iOS-based mobile phones, leveraging AR (specifically, the ARKit demo launched by Apple in 2017) to provide learners with a virtual footprint to follow for learning specific dance movements.

The aim, rather than substituting traditional dance schools, is to allow students to practice steps and rhythm in any environment, also enabling couple practice, permitting the student to choose its role (lead or follow), and providing some videos demonstrating the steps performed by professional dancers.

Dance Reality boasts of having beta-tested by more than 1,000 individuals and of being currently adopted by thousands of users worldwide.



Interestingly, Dance Reality recently started in 2018 a collaboration with the Augmented World Expo (AWE), designing and implementing for the Expo held in Santa Monica (CA) in May 2018, an experience titled “The World’s First Dance Lesson in Augmented Reality”, which was featuring, for users wearing an Aryzon 3D AR Headset, life-size holograms of dance teachers, capable of interacting with the attendees, teaching them popular dances, such as Salsa.

Aryzon 3D AR, based in The Nederlands, and branded as “the world’s first affordable AR headset” (it costs 30 $), is in fact a cardboard augmented reality headset which supports Android and iOS as well as SDK’s like ARCore and ARKit.

User reviews have commented that the comfort is not ideal and may be irritable after prolonged use. Furthermore, community user feedback is that there was limited content available at the time of release.

In a similar vein, Salsa-virtual is a very cheap computer software (it costs 16,79 €), which requires a VR headset for being used. It aims at helping individuals to learn dance in their home environment, with a virtual-reality partner always ready to teach steps, rhythms, variations, etc., and implying the use by the learner of motion controllers to ensure he/she is performing the steps correctly. The tool has been designed with the cooperation of professional dancers and is available on the software platform Steam since November 2018.

These recent developments show that a market for dancing VR/AR devices has already begun to mature and competition is quickly going to grow, even if the WhoLoDance platform can still potentially benefit of a competitive edge.

Beyond a strict reference to the dance field, it is however the whole outlook of 3d motion capture which is likely soon to be revolutionised by having recourse to AI applied to 2d videos.

One indirect example is the news, appeared in August 20185, that a University of California Berkeley deep learning based algorithm can convincingly show real persons mirroring the moves of their favourite dancers. The model allows anyone to portray themselves as a very experienced dancer.

The team first trained their conditional generative adversarial network on videos of amateur dancers performing a range of poses filmed at 120 frames per second. Each subject completed the poses for at least 20 minutes. The team then extracted pose key points for the body, face, and hands using the architecture provided by a state-of-the-art pose detector OpenPose.

[5] C. Chen, S. Ginisar, T. Zhou, A.E. Efros, Everybody Dance Now: Motion Retargeting Video Subjects, UC Berkley, 2018, in: https://news.developer.nvidia.com/ai-can-transform-anyone-into-a-professional-dancer/.

The outcome is an algorithm which can create reasonable and arbitrarily long videos of a target person dancing given body movements to follow through an input video of another subject dancing.

A second and more striking example is the news6 that a team of researchers affiliated with several institutions in Germany and the U.S. has developed a deep learning algorithm that can be used for motion capture of animals of any kind. In their paper published in the journal Nature Neuroscience, the group describes their tracking tool called DeepLabCut, how it works and how to use it.

The goal was to capture the intricacies of all the tiny movements that together make up a larger, more noticeable movement "such as a single dance step". Being able to track such movements in animals offers some clues regarding their biomechanics and how their brains work. Being able to do so with humans can aid in physical therapy efforts or improvements in sports performance.

The current process involves video recording the subject and carrying out a laborious process of tagging images frame by frame. In this new effort, the researchers have developed a computer automation technique to carry out the process, making it much faster and easier.

To create DeepLabCut, the group trained a neural network using information from a database called Imagenet that contains a massive number of images and associated metadata. They then developed an algorithm that optimized estimations of poses. The third piece was the software that runs the algorithm, interacts with users and offers output of results.

The result is a tool that can be used to perform motion capture on humans and virtually any other creature. All a user has to do is upload samples of what they are after, with its major parts labeled and some videos demonstrating how it moves in general. Then the user uploads video of a subject doing an activity of interest. The software does the rest, producing motion capture of the activity.

9. The plan to widen the scope of the platform to make it blockchain-based and potentially extending to adjacent areas

A great amount of work still needs to be performed for acquiring sufficient market matureness, and new technological challenges are surfacing, but on the whole, at the end of its three-years development, WhoLoDancE has demonstrated a capacity of recording, reconstructing, and preserving the representation and heritage of priceless movement skills, providing an incipient digital technology by which a growing community of users can expect to acquire relevant in-depth knowledge and experiment with new ways of learning and teaching, as well as of designing new anatomically sound movements and choreographies.

The innovative tools which have been created can already support, in their current early stage, the implementation of an incipient platform allowing to easily access and deploy motion capture recordings and self-produced low-end and easy-to-use comparison tools for movement analysis and e-learning experimentations, based on multiple representations with avatars, an increased awareness of quality of movements with self-generated sonification, Hololens immersion, and similarity search and blending engine functionalities which can powerfully support chorographic creation.

The attainment of this outcome has prompted the vision of what could become the extension of such a platform to wider areas, with the support of an appropriate blockchain system allowing to execute Smart Contracts by which content contributors would be able to define terms and conditions under which their

[6] B. Yrka, Applying deep learning to motion capture with DeepLabCut, in: https://phys.org/news/2018-08-deep-motion-capture-deeplabcut.html#jCp.

work can be purchased, used, and distributed, while data fingerprinting, time-stamping and other data protection technologies could enforce the proper and legal use of content files.

This vision has taken among WhoLoDancE partners the name of WholoMove, indicating the willingness to go also beyond the dance domain.

In such an advanced WholoMove platform, motion-capture services (or possible future AI meaningful substitutes) would be advertised by qualified providers whose technologies would be directly compatible with the system, where movements correlated with metadata would allow to capture authorship, content descriptions, file specifications, etc., and provide rich classifications and easy navigation.

WholoMove would aim at establishing for the first time a marketplace to share motion-capture files in creative and scientific contexts, and at the same time to foster the creation of new content by providing users with tools to search, compare, select and finally, when fully developed, blend human movements in novel dynamic sequences. Generating new, anatomically sound movements and forms will in turn activate a content-based network effect increasing the value of the user experience and guaranteeing the creation of sound body dynamics with the highest creative flexibility for users to experiment and, in the process, enrich the content repository.

A variety of applications would be conceivable on this basis, leveraging the current convergence of technology-push and consumer-pull jointly acting as drivers for increasing the demand for digital special effects in movement-based human activities. In fact, growing computing power, increased bandwidth and software/hardware advancements mutually interact prompting consumer expectations of digital technologies implying the fusion of VR, AR, and MR.

Especially the breadth of applications for digital special effects in sports industries and wellness is rapidly increasing and currently encompasses advanced features such as screening and evaluation, performance enhancement, functional training, and new “social” sport platforms.

In general, the demand for assets based on motion capture is high, and growing 20%-30% annually, even reaching 40% in the sports games’ area. The digital special effects business is being further stimulated by the rapidly growing number of hardware and software vendors (VR, AR and MR related) supporting the capture and manipulation of motion data, with major international players such as: Facebook (Oculus) HTC (Vive) Sony, Microsoft, Autodesk, Vicon, Magic leap, Industrial Light & Magic, Pixar, Disney, Namco, and others. Digital asset production budgets are under price pressure with the arrival of cheaper and faster hardware, and industry players (especially those on more modest budgets) are looking for new and affordable differentiators.

All movement-based activities require motion analysis. This applies especially to athletics, where all too frequently incorrect movement can result in less than optimum performance or even in injury.

Using advanced motion analysis technology, athletes’ biomechanics, movement, displacement, impact forces, velocity and acceleration can be appropriately analysed, and complex athletic motion data can be reduced to simple visualizations to recommend improvements, better techniques, and injury prevention awareness.

Assessing athletes' movement patterns is critical to achieve optimal functioning and being competitive. By screening such patterns through advanced computer technology allowing to measure movement, force production, and oxygen consumption, the athletes’ or the wellness practitioners’ functional limitations and asymmetries can readily be identified and consequently the most beneficial exercises and movement modifications to achieve or restore proper movement and build strength can be determined in a precise and personalised way.

The aim will be to attain a complete functional and wellness evaluator motion capture database and training software for any chosen sport or activity. This will imply feedback training, using the recorded motion capture data, and other movement analysis technologies, to assist whoever is involved in movement activities and would like to improve his/her performance, increasing agility and movement appropriateness, reinforcing overall flexibility and muscle strength, power, and speed, while minimizing biomechanical risk factors related to potential injuries.

This can be complemented with patient-specific rehabilitation or return-to-sport or wellness training programmes, bridging the gap from injury to optimal activity participation. Currently sports and wellness rehabilitation entails a full biomechanical evaluation with comprehensive physical therapist evaluation, and individualized training regimen programme. Being able to rely on customised motion databases with authoring software aimed at specific rehab tasks can partially replace this, or augment treatment, attracting potential users (besides the directly interested athletes and practitioners) among sport and wellness trainers and medicine experts, such as Orthopaedic Surgeons, Sports Medicine Physicians, Sports Physical Therapists, Certified Athletic Trainers, Biomechanists, Kinesiologists, Certified Strength & Conditioning Specialists, Sports Nutritionists, etc.

Further applications can be thought of in ergonomics, as well as in robotics meant to smoothly interact with human movements.

The methodology initially developed in WhoLoDancE would therefore find a very wide area of further application, where to adapt and enhance the initial range of tools now available for an incipient usage in dance teaching and choreography.

The experience accrued by Lynkeus in running in parallel the MyHealthMyData EU-funded H2020 project (www.myhealthmydata.eu) could be used for selecting the blockchain ledger of reference for transacting WholoMove services and executing the relevant Smart Contracts.

This attractive vision implies, however, the need of guaranteeing the sustainability of what has been achieved until now with WhoLoDancE, beyond the basic commitment by Athena RC to retain the platform operational and the data available for at least 2 years after the end of the project.

It needs to find an anchor either with the support of some institutional reality available for joining forces, or some renewed EU funding aimed at guaranteeing the capacity of attaining further goals.

10. A significant opportunity: an e-learning platform for Balletto di Roma

In October 2018 WhoLoDancE was given a significant opportunity to showcase its results in a live workshop and performance within the Educational Section of the International Festival RomaEuropa of contemporary dance (a video, “WhoLoDancE Experience: Lab & Performance”, highlighting key moments of the event, is available at: http://www.wholodance.eu/Videos/).

The event attracted a significant audience, largely composed of dance experts, and a lively debate took place in the Festival theatre, where it was animated by a well-known author and journalist, Leonetta Bentivoglio, and by Edwin Morley-Fletcher, coordinator of WhoLoDancE and CEO of Lynkeus.

After this prestigious introduction to the Roman dance stage, there were various encounters with a number of interested personalities, and in particular a series of meetings with the CEO Luciano Carratoni and the artistic director Francesca Magnini of **Balletto di Roma** (https://www.ballettodiroma.com/en/), the famous

company and school of dance which represents a key Roman public institution in the dance world, with almost 60 years of activity.

As outcome of those talks, Edwin Morley-Fletcher has formally proposed, in December 2018, a draft for a collaboration agreement in view of establishing a joint e-learning platform based on WhoLoDancE technological outcomes (see, in Appendix 1, “Una piattaforma di e-learning per Balletto di Roma sulla base dei risultati tecnologici conseguiti da WhoLoDancE”).

If enacted, the collaboration with Balletto di Roma will allow the availability of WhoLoDancE tools for studying, practicing, and creating movement exercises for class-room teaching and for individual practicing, launching as well a first remote experimental course, and possibly leading from there, and from an initial work on the quality of movements and on various genres, to the creation or the learning of a specific new choreography.

The note delivered to Balletto di Roma terminated with the hope that the further interaction with **Lazio Innova**, the financial agency in charge of promoting innovation on behalf of the government of Regione Lazio (and at same time one of the main sponsors of Balletto di Roma), will be able to act as a key supporter in pursuing the ambitious strategy of WholoMove.

An initial very positive reply has kindly come on December 27th from the artistic director (see e-mail exchange between Balletto di Roma and Ewin Morley-Fletcher in Appendix 2).

In her communication, Francesca Magnini expresses her appreciation for the variety of tools developed by WhoLodancE, remarking how close all of this is to her own academic research interests.

As per the learning side, with regard to their dance school, which is dedicated to the education of younger recruits, she deems that it will be highly beneficial to expand/create tools capable of providing greater awareness and precision to performed movements, and to use them either within collective lessons or in self-practicing exercises or in remote personalised teaching.

She feels therefore entitled to adhere to possible joint initiatives aiming, on one hand, at providing both teacher and pupil with tools for capturing and visualising correlations and combinations deriving from different genres, and on the other hand at experimenting with new creative forms.

Francesca Magnini states as well her availability to discuss also further tools addressing the dance company and consequently their creative/productive side, for expanding the company horizons and its operational modes.

A fortunate coincidence is also the fact that she is personally a teacher of floor-barre in the new section of the Balletto di Roma school dedicated to Wellness. Floor-barre is a technique which takes the basic ballet barre training from the standing position to the floor.

This personal commitment with an activity which provides a bridge towards wellness and sport leads Francesca Magnini to conclude by saying that further aspects which she finds as highly appealing, and to which she looks having in mind the possibility of developing new areas of work for Balletto di Roma, are WholoMove and the area of wellness, which they have called “Benessere” (wellbeing) and which they are struggling to expand. She is very much interested in prursuing this perspective, together with enquiring on advanced functionalities such as screening and evaluation, improvement of performances, functional training and new social sport platforms.

These remarks by the artistic director of Balletto di Roma are all effectively encouraging, and may be seen as a promising premise to successful developments, for which operational plans are expected to start being discussed soon.

However, Francesca Magnini is due to give birth to her second child in the next weeks, and resuming our talks will necessarily imply some amount of disruption in the immediate forthcoming time, at least in as far as it concerns her personal involvement.

11. Looking at further enhancements by qualified external third parties

Some highly qualified external partners have expressed their willingness to contribute with technological additions to the WhoLoDancE/WholoMove platform.

Discussions on possible cooperation have been going on with:

1. Philippe Pasquier, School of Interactive Arts and Technology of Simon Fraser University's Faculty of Communication, Arts and Technology, Vancouver, Canada.
   His expertise is in computational creativity developing human-competitive movement generation systems using machine learning techniques and motion capture data, including high-level movement characterization, training data, features representation, and evaluation methods. Statistical movement generation can be described as synthesizing new movements by learning a movement model from a group of recorded movement segments.
   Walknet and DanceNet are already movement style-imitation systems that use deep learning to learn from motion capture data. GrooveNet is a multimodal deep neural network for teaching a virtual agent to dance on any music.

2. Olga Perepelkina, Neurodata Lab, Moscow, Russia. Neurodata is expert on emotion recognition technology through multimodal affective computing, distinguishing 20 scales of affective states and social behaviour patterns: Happiness, Sadness, Anger, Disgust, Surprise, Engagement, Disengagement, Hostility, Friendliness, Contempt, Admiration, Pleasure, Self-confidence, Self-disclosure, Self-presentation, Mental Effort, Neutral, Shame, Pride, Anxiety.

3. Sotiris Manitsaris, Centre for Robotics at École des Mines ParisTech, France. He leads the Post-Master's Degree AIMove (Artificial Intelligence and Movement in Industries and Creation) and is an expert on motion capturing, machine learning, motion pattern recognition and movement-based interaction with machines, connected objects and sensorimotor human learning.

Such collaboration projects could be envisioned in a perspective in which the WhoLoDancE platform were to acquire the nature of a Digital Learning Incubator defining a roadmap of possible promising projects for further developments in the provision of smarter, open, trusted and personalised learning solutions to optimise digital learning and to allow learners to engage and interact with content and with peers, along a line of thought somewhat similar to the one currently indicated by the ICT-30-2019 EU call for Innovation Action within the topic "An empowering, inclusive Next Generation Internet".

This possible development, aiming at bringing together a larger number of qualified stakeholders and at attaining further achievements to be integrated as additional elements in a joint endeavour for establishing a user-friendly multisided e-learning platform for a growing variety of bodily-movement activities, will possibly depend on the further discussions with Balletto di Roma which we are presently planning.

12. The ongoing discussion about ICOs regulation

To concretely start having WholoMove realizing its potentialities in the adjoining areas which can be reached out moving from dance, there is the already mentioned need of triggering an adequate crowd-funding mechanism.

This is the reason why the outlook for WholoMove is tightly linked to understanding how an Initial Coin Offering (ICO) approach can be enacted. This is why, while sharing what was over a year ago the concern of The Economist that "ICOs may indeed be a bubble, but perhaps a mostly healthy one, generating much innovation" (What are initial coin offerings?, 22nd August 2017), Lynkeus has been tracking the work of regulators, appreciating their pragmatic stance on the issue. This can be summarized as leading to the basic assumption that, while at least some of the tokens that are distributed in ICOs can be considered securities, which need to be regulated as such, many are novel but legitimate ways to reduce cost and time for generating value-driven economies for predefined intangible assets, provided that compliance is strictly enforced.

In July 2017, the American Securities and Exchange Commission issued a report specifying what types of offerings need to be registered (or apply for an exemption). The SEC argued that the technology is irrelevant, and when tokens are used to raise funds, they should be dealt with as securities.

The burgeoning ICOs community, however, maintained that, although such tokens are initially used to raise funds, they normally also have a precise function in the projects they finance, as the specialised medium allowing supply and demand to appropriately meet, and hence should not be treated as securities. In addition, while securitization converts illiquid assets into financial securities, tokenization allows the representation of an asset by a unique identifier, allowing the ownership rights to be transferred and recorded on a digital medium, e.g., the blockchain distributed ledger.

In November 2017, the European Securities and Markets Authority (ESMA) published two statements on ICOs, one to highlight the risks for investors ("while the tokens may appreciate in value and provide a strong return, they also expose investors to substantial risks of losing their entire investment"), and one on the rules applicable to firms involved in ICO. For instance, the 4th Anti-Money Laundering Directive will reduce anonymity and increase traceability of transactions by requiring cryptocurrency exchanges and custodial wallet providers in the European Economic Area to carry out customer identification and due diligence requirements. Altogether, the aim declared by ESMA is to ensure a fair and transparent framework in order to make Europe a leading actor in developing new ways to fund rapidly growing enterprises.

In February 2018, the Swiss Financial Market Supervisory Authority FINMA issued special Guidelines for enquiries *regarding the regulatory framework for initial coin offerings (ICOs)*, where Utility Tokens are clearly distinguished from Payment Tokens and Asset Tokens.

1. Payment Tokens are defined as synonymous with cryptocurrencies and as tokens which are "intended to be used, now or in the future, as a means of payment for acquiring goods or services or as a means of money or value transfer". Such cryptocurrencies give rise to no claims on their issuer.
2. Utility tokens are "intended to provide access digitally to an application or service by means of a blockchain-based infrastructure".
3. Asset Tokens represent assets such as a debt or equity claim on the issuer, by promising, for example, a share in future company earnings or future capital flows. In terms of their economic function, therefore, these tokens are analogous to equities, bonds or derivatives.

Utility tokens will not be treated as securities if their sole purpose is to confer digital access rights to an application or service and if the utility token can actually be used in this way at the point of issue. In these

cases, the underlying function is to grant access rights and the connection with capital markets, which is a typical feature of securities, is missing.

According to the current policy, given that payment tokens are designed to act as a means of payment and are not analogous in their function to traditional securities, also payment tokens will not be treated as securities.

Asset tokens, on the contrary, constitute securities if they represent an uncertificated security and the tokens are standardised and suitable for mass standardised trading. Uncertificated securities are defined as identical rights which are issued in large numbers, with the only formal requirement to keep a book (which can be accomplished digitally on a blockchain) where details of the number and denomination of the uncertificated securities issued and of the creditors are recorded. In the case of the pre-financing and pre-sale phases of an ICO which confer claims to acquire tokens in the future, these claims will also be treated as securities (i.e. in the same way as asset tokens) if they are standardised and suitable for mass standardised trading.

Funds raised in an ICO generally do not qualify as deposits, unless there are liabilities with debt capital character, for example a promise to return capital with a guaranteed return, in which case such an ICO would require the organizer to obtain a banking license. Provisions on combating money laundering and terrorist financing, which give rise to a range of due diligence requirements, apply to the ICO of a payment token (cryptocurrency) as soon as the tokens can be technically transferred on a blockchain infrastructure. In addition, the exchange of a token for fiat money or a cryptocurrency as well as the offering of services to transfer tokens if the service provider maintains the private key (custody wallet provider) equally trigger the due diligence requirements according to the Anti-Money Laundering Act.

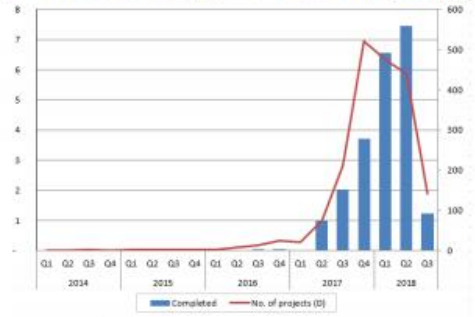
In November 2018, a further ICO regulation was issued by the Maltese government. A specialised authority – the Malta Digital Innovation Authority (MDIA) – is now tasked with dealing with all issues related to blockchain technology adoption and use. Besides the bill establishing the Malta Digital Innovation Authority[7], two more regulations (the Technology Arrangements and Services Bill[8] and the Virtual Financial Assets Bill[9]) deal with distributed ledger technologies, smart contracts, and ICOs, with the ambition of making Malta a forward-looking haven capable of attracting corporate initiative willing to experiment with financial innovation tools like ICOs using crypto currencies.

A few days later, in the same month of November 2018, a comprehensive analysis and guideline for the phenomenon of crowd-funding based on ICOs was published by the French Authorité des Marchés Financiers (AMF)[10].

ICOs – they state – is a recent phenomenon, which appears to be a method of fundraising still in its infancy, but beginning to take shape, allowing the emergence and the financing of new businesses in innovative technology sectors. “At the global level, ICO financing remains marginal, but a recent form of professionalisation and concentration can be observed. Analysis of French ICO projects, with the help of an original database, demonstrates the growing interest in this type of fundraising by certain project initiators, who seem to welcome the opportunity to call on a community of international investors and introduce this method along with other, more traditional methods of financing”[11].

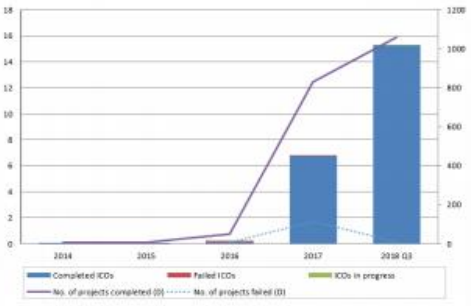
[7] http://justiceservices.gov.mt/DownloadDocument.aspx?app=lp&itemid=29080&l=1
[8] http://justiceservices.gov.mt/DownloadDocument.aspx?app=lp&itemid=29078&l=1
[9] https://parlament.mt/media/95198/act-xxx-virtual-financial-assets-act.pdf.
[10] Caroline Le Moigne, *French ICOs - A New Method of Financing?*, November 2018, amf-france.org.
[11] *French ICOs*, cit., p. 20-21.

Figure 1: Amounts raised by ICO
(in billions of dollars (G) and number of projects (D))



Source: AMF[19]

Figure 2: Amounts raised by ICO including ICOs that failed
(in billions of dollars (G) and number of projects (D))

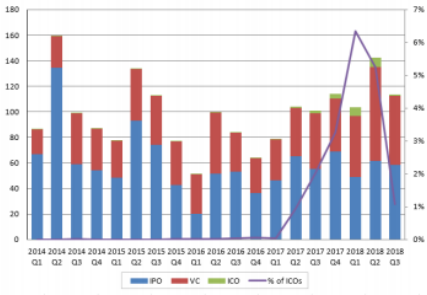


Source: AMF[20]

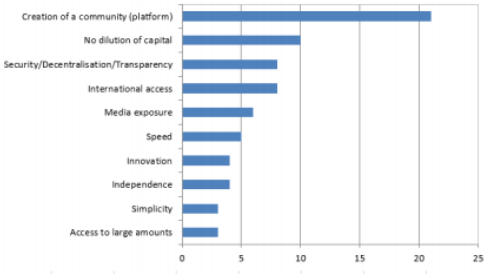
12

In Europe, Switzerland and the United Kingdom are the preferred countries for ICOs (5% and 9% of projects respectively, and 1.7 billion and 1.1 billion dollars raised), along with Estonia (5% of projects, 594 million dollars raised). The location of the ICO also relates partly to the legal environment of the country, and the AMF remarks that "there is an over-representation of small countries where the regulation, or the lack of it, is favourable to ICOs".

The following two figures show the amounts raised by ICOs compared with equity financing, globally (in billions of dollars) and the reasons given by project initiators for launching an ICO (in number of projects)[13].



Source: Bloomberg, Eikon, AMF.



Source: AMF.

AMF has shown an appreciation of the tokenomics phenomenon, positing that the "Initial Coin Offerings can be defined as fundraising transactions, realised via distributed register technology and resulting in an issue of tokens. These tokens can then either be used to obtain products or services, be traded on a platform (secondary market) and/or earn an income"[14].

However, they also remark that "this new form of financing, which is in some respects similar to more traditional channels (public offer, venture capital, crowdfunding), does present some specific characteristics of its own; for example, it benefits from the network effects and the potential liquidity resulting from the token being traded on a secondary market. Consequently, this hybrid nature of the tokens makes them difficult to qualify from a legal perspective"[15].

There are, in fact, some benefits specific to ICOs and to the network system on which they are based. Firstly, unlike other means of financing, "an ICO is realised with no sale platform or third-party intermediary

[12] Cit., p. 8.
[13] Cit, p. 9 and 12.
[14] Cit., p. 2.
[15] Ibid.

(banks, auditors, payment circuits, etc.), which means that the cost of the fundraising transaction is lower and allows investors and contributors to the network to be directly recompensed, thus financing the development of new decentralised networks. The model put forward by Li and Mann (2018)[16] also shows that an ICO can aggregate dispersed information and thus resolve the coordination required to assess the value of a project. Moreover, they propose that an ICO makes sense if the project benefits from network externalities, i.e. if the surplus resulting from an additional user benefits the rest of the network, which is the case for most ICO projects"[17].

AMF also remarked that the ICOs "represent a successful use case for blockchain technology on a large scale. The creation of smart contracts by the Ethereum blockchain has made it possible, and easy, to create, transfer and manage other crypto-assets, without an intermediary. Smart contracts are IT programmes that automatically execute conditions defined in advance in the blockchain, such as contractual clauses, for example, that are registered and can be viewed publicly. In the case of ICOs, they can provide specific guarantees, e.g. a guarantee that the funds will be returned to the investor if the ICO does not achieve its minimum subscription objective"[18].

In order to protect consumers, who may be exposed to the risks of fraud, asymmetry of information or volatility of their investments, the AMF is looking at "the qualification of this hybrid method of financing and the best way to prevent abuse with regulation"[19].

France – they say – "has chosen to propose optional regulation of these fundraising projects, in order to allow the identification of trustworthy, non-fraudulent projects in France, and to ensure the appropriate balance between the protection of investors and support for innovation"[20]. This is why the AMF study also presents the French proposal for an optional ICO visa, which is the new system of optional approval for offers of tokens defined in article 26 of the draft *Pacte* law. This provides that issuers of tokens may request a visa from the AMF (this is optional) as long as they do not fall within the scope of existing regulation such as that applicable to transferable securities, and the issuer is constituted as a legal entity established or registered in France.

The AMF verifies "whether the proposed offer provides certain minimum guarantees ensuring the protection of investors, in particular the quality of the information document intended for the investors, as well as the existence of a system in place to monitor and safeguard the funds collected, and the nature of the promotional material and advertising, etc."[21]

On completion of the offer, the issuer will be bound to inform investors of the amounts raised and the existence of a secondary market, if applicable. Furthermore, issuers of tokens applying for an AMF visa will be subject to requirements relating to the fight against money laundering and terrorist financing. Issuers with a visa will appear on a "white list", which the AMF will communicate to the general public. This list will identify issuers that comply with regulations and will provide potential subscribers with important evidence of respectability.

Following this comprehensive approach defined by the French Authorité des Marchés Financiers, a European regulatory framework is more likely to take shape. The European Securities and Markets

[16] Jiasun Li and William Mann, "Initial Coin Offerings and Platform Building", George Mason University and U CLA Anderson School of Management, October 1, 2018, 2018 WFA, 2019 AFA. Available at SSRN: https://ssrn.com/abstract=3088726 or http://dx.doi.org/10.2139/ssrn.3088726.
[17] Cit., p. 5.
[18] Cit. p. 4.
[19] Cit., p. 23.
[20] Ibid.
[21] Ibid.

Authority (ESMA) is expected to issue a specific report on ICOs[22], after the Vice-President of the EU, Vladis Dombrovskis, stated that the European Commission will have to conclude on a regulatory assessment for the governance of digital assets because they are "here to stay"[23].

It is clear that any strategic choice, in relation to WhoLoDancE/WholoMove crowdfunding plans, will necessarily be depending on this European forthcoming regulatory framework.

13. Conclusion

The reasoning followed in this report has endeavoured to highlight how WhoLoDancE overall exceeded its technical objectives, delivering innovative modules and solutions well beyond the initial scope. While most of them are elements of a larger potential platform to which they provide incremental effectiveness and outreach, other (like the blending engine machine by Motek Entertainment and the motion similarity search engine and mobile interface by Peachnote) can have some commercialisation paths ahead of them also as stand-alone tools.

The whole WhoLoDancE platform, now still in a prototypical stage and needing further integration, is itself approaching a readiness stage where a process of commercialisation can be initiated, starting from consolidation of its architecture and user workflows and the selection of a smaller set of functionalities based on the intended use case, in cooperation hopefully with Balletto di Roma.

Further steps, also in view of the larger strategic ambition of WholoMove, will be taken after the definition of a sustainable implementation plan with the support of Lazio Innova, the financial agency for innovation supporting Balletto di Roma.

Such a plan will take in close consideration the possibility of using digital tokens for adding a substantial crowd-funding layer to sustain both the implementation and growth phases of the deployments. The latter focusing especially on the acquisition and curation of targeted motion capture content, in order to significantly enrich the amount of quality data, and the number of covered genres, available on the WhoLoDancE Movement Library.

For this, the incipient ICO regulatory framework needs to have reached a sufficient matureness also at the Europen level.

Other funding mechanisms will be at the same time considered, including regional, national and European grants.

Digital technologies for dance, being a relatively limited market segment, limit our ability to effectively reach out to private investors in this phase, beyond what has been highlighted above.

[22] https://cryptonewsreview.com/european-union-set-to-address-ico-regulation-question-in-2019/
[23] https://xbt.net/blog/european-commission-vice-president-praises-cryptocurrencies-and-ico-funding-model/

1. Appendix 1: Una piattaforma di e-learning per Balletto di Roma sulla base dei risultati tecnologici conseguiti da WhoLoDancE (Dicembre 2018)

1. L'obiettivo di una piattaforma di e-learning per la danza

Il progetto WhoLoDancE (Whole-Body Interaction Learning for Dance Education, Grant # 688865, www.wholodance.eu), finanziato nell'ambito del programma dell'Unione Europea H2020, giunge ora al suo termine programmato per la fine di dicembre 2018.

Nei tre anni di durata del progetto, WhoLoDancE ha mostrato la capacità di registrare, ricostruire e preservare la rappresentazione e il patrimonio di inestimabili modalità espressive di movimento, originate nel mondo della danza e primariamente dedicate alla sua approfondita analisi e conoscenza, tramite lo sviluppo di tecnologie digitali di avanguardia.

L'innovativa strumentazione digitale messa a punto da WhoLoDancE comporta già allo stato attuale un'incipiente piattaforma in grado di utilizzare registrazioni di *motion capture* e strumenti di raffronto con modalità di basso costo e di estrema semplicità d'uso di movimenti autoprodotti in contesti di *e-learning*, che si avvalgano sia di molteplici rappresentazioni con avatar dei dettagli del movimenti, sia di un'accresciuta percezione della qualità dei medesimi in termini di *sonification* autogenerata, nonché della possibilità di raffigurarli in termini di realtà virtuale con Hololens, con inoltre l'aggiunta di funzionalità di *similarity search* e di *blending engine* utilizzabili anche per la creazione coreografica.

Tutto ciò, che sarà analiticamente descritto nella sezione 2, può consentire a una crescente comunità di utenti di essere in grado di sperimentare nuove modalità di apprendimento e di insegnamento, così come di progettare nuovi movimenti e coreografie anatomicamente corretti.

Questa intera strumentazione può essere ora posta a disposizione del Balletto di Roma per fungere da componente di base di una specifica piattaforma di *e-learning* che potrà costituire la prima realizzazione di questo tipo nel panorama non solo italiano, ma anche internazionale.

1.1. In attesa della *final review* di WhoLoDancE

Già in occasione della prima *periodic review* della Commissione Europea, tenutasi in Lussemburgo nell'autunno 2017, dove erano stati presentati i risultati dei primi 18 mesi di attività, i valutatori della Commissione avevano ritenuto che il progetto WhoLoDancE fosse "promettente per lo sviluppo e l'implementazione di nuove tecnologie nella danza e nella coreografia ... e ... per la creazione di nuovi strumenti sia per uso professionale sia amatoriale, con specifiche potenzialità per la conservazione del patrimonio non tangibile". Inoltre, essi avevano affermato, "vi è la possibilità che il lavoro svolto nell'ambito del progetto possa costituire una risorsa per promuovere nuove forme di insegnamento della danza e determinare un nuovo impulso alla ricerca neurologica dedicata al movimento e alla sua rappresentazione" [...] "I risultati e il lavoro svolto hanno un potenziale di attrazione sociale [...] non solo all'interno della comunità della danza, ma anche in altri campi correlati al movimento (ad es. sport, medicina), e a nuove tecnologie di realtà virtuale ".

Questa valutazione tecnica complessiva venne accolta come significativo elemento di incoraggiamento dai partner di WhoLoDancE, nel promuovere ulteriormente l'integrazione e il progresso del loro progetto. Tale valutazione ha anche spinto ad affidare a Lynkeus, in qualità di coordinatore del progetto, l'ambiziosa esplorazione delle opportunità di sfruttamento e utilizzazione collettiva dei risultati ottenuti da WhoLoDancE, ispirandosi al concetto di "multi-sided platform (MSP)" sviluppato dal premio Nobel per l'economia del 2014 Jean Tirole.

È in questo spirito che Lynkeus, nell'attesa di far completare alla Commissione Europea la valutazione complessiva di WhoLoDancE al termine della *final review* prevista per il 14 febbraio 2019, sottopone a Balletto di Roma la presente proposta di collaborazione come modalità di ulteriore *exploitation* e di *deployment* dei risultati raggiunti.

1.2. "An ICO for WholoMove" (una ICO a partire da WhoLoDancE)

I partner di WhoLoDancE hanno concorso ad alimentare le premesse di una piattaforma integrata basata su Web e Unity, sfruttando gli sviluppi tecnici già realizzati e facendo ricorso a Unity come motore multipiattaforma prescelto.

Volendo consentire un uso più ampio di dispositivi di fascia bassa poco costosi, ci si è orientati a optare per un approccio multilivello di licenze software, con l'implementazione di una politica di accesso generale di tipo *freemium*, che consenta in forma gratuita sia la navigazione sia l'accesso limitato alla piattaforma, offrendo invece a pagamento l'accesso a tutte le funzionalità di della piattaforma.

Il proposito perseguito è quello di innescare un meccanismo di *feedback*, così da promuovere ulteriori acquisizioni di movimenti (*motion capture*) con cui ampliare i contenuti del database e garantirne la sostenibilità, fornendo al contempo, attraverso *blockchain* e *smart contract*[24], un ritorno economico non solo a beneficio degli sviluppatori della tecnologia in uso, ma anche degli artisti che contribuiscono ad alimentare la raccolta dei dati tramite le sessioni di *motion capture*.

Il principale strumento di finanziamento attualmente allo studio per l'attuazione di questo piano di sviluppo è l'emissione di *token* digitali, tramite il lancio di un'*offerta iniziale di moneta* (*Initial Coin Offering*, ICO).

Lo scopo è quello di avvalersi della tendenza per cui le ICO stanno diventando il fondamento finanziario prescelto per molte piattaforme, dove i partecipanti scambiano servizi utili pagandoli attraverso monete elettroniche (*token)* appositamente emesse, legate a uno scopo specifico. L'assunto di base è che la diffusione dell'emissione di valuta diffonda anche la creazione di valore.

I *token* forniscono infatti uno strumento specifico di scambio e mediazione in grado di incentivare la domanda e l'offerta di nuovi beni digitali, implementando, con forme di concertazione basate su *blockchain*, una precisa tracciabilità di tutte le transazioni, e assicurando così l'attribuzione e la proprietà sia del *token* che del bene transato. Ciò a sua volta rende la piattaforma scalabile e sicura, attirando la raccolta di ulteriori dati, alimentando la domanda e riducendo i costi di distribuzione.

In tal modo, un sistema di *tokenomics* ben progettato non solo realizza di *default* una piena trasparenza, ma consente anche che si allineino gli incentivi destinati agli svariati "attori" operanti sulla piattaforma, contribuendo coralmente alla sua crescita.

Negli ultimi due anni, molteplici ICO sono state promosse con successo da un numero significativo di imprese innovative in diverse aree economiche e geografiche, riuscendo a far leva su due principali fattori economici. Da un lato, le ICO hanno fornito alle start-up un meccanismo di finanziamento collettivo (*crowd-funding*) per raccogliere capitali in modo molto più celere rispetto a modalità tradizionali di raccolta di investimenti privati o istituzionali. La rapidità di accesso alla liquidità ha a sua volta consentito un'accelerazione dei piani di sviluppo, aumentando le possibilità di successo. Allo stesso tempo, le ICO hanno anche dato innesco a comunità di *stakeholders* che hanno poi costituito l'iniziale aggregazione della domanda e dell'offerta nei rispettivi mercati di riferimento.

L'iniziativa ICO, che intende muovere dall'esperienza di WhoLoDancE, mira a sfruttare entrambi gli effetti. Gli investitori iniziali che vi aderiranno saranno in grado di contribuire direttamente alla roadmap di sviluppo di una piattaforma già funzionale, che verrà ulteriormente ampliata, integrata e predisposta a sostenere una progressiva crescita di dimensione.

Il capitale raccolto attraverso l'offerta pubblica di *token* sosterrà l'ulteriore sviluppo della piattaforma, sula base di piani d'azione pubblicamente condivisi, cui la comunità degli *stakeholder* sarà in grado di far pervenire richieste di accresciute funzionalità. L'obiettivo è quello di investire il capitale raccolto in servizi di *motion capture* mirati a soddisfare la domanda relativa alle tipologie di movimenti più richiesti da specifiche comunità di utenti.

1.3. Possibili estensioni ad altre aree

In base ai risultati tecnologici che si potranno conseguire, passando da un prototipo *proof-of-concept* a una vera e propria piattaforma operativa, testata per l'e-learning della danza (che è probabilmente una delle forme più

[24] Un sistema *blockchain* (selezionato sulla base dell'esperienza maturata in parallelo nell'ambito del progetto MyHealthMyData - www.myhealthmydata.eu, sempre finanziato con H2020 dall'UE) verrà utilizzato come registro di riferimento per la transazione dei servizi WholoMove e l'esecuzione degli *Smart Contract*. Attraverso questi ultimi, i creatori di contenuti definiranno termini e condizioni in base ai quali il loro lavoro potrà essere acquistato, utilizzato e distribuito, mentre *fingerprint*, *timestamp* e altre tecnologie di protezione dei dati garantiranno l'uso corretto e legale dei file e dei contenuti.

complesse di attività corporee), si possono ipotizzare ulteriori sviluppi e utilizzi delle premesse realizzate da WhoLoDancE.

È lecito presupporre che un approccio analogo possa essere esteso anche ad altri generi di danza (così come alle danze sociali) e ad ambiti affini, come il *wellbeing*, lo sport, le arti marziali, l'artigianato e l'ergonomia del lavoro, i movimenti del corpo per la riabilitazione e persino la robotica.

In particolare, l'estensione di applicazioni digitali per effetti speciali nel settore dello sport e del benessere sta rapidamente crescendo e comprende attualmente funzionalità avanzate come *screening* e valutazione, miglioramento delle prestazioni, allenamento funzionale e nuove piattaforme sportive *social*.

In generale, si stima che la domanda di soluzioni basate su *motion capture* sia particolarmente elevata e cresca di un 20% -30% all'anno, raggiungendo addirittura il 40% nell'area delle attività sportive. Il business degli effetti speciali digitali viene ulteriormente stimolato dal numero in rapida crescita di fornitori di *hardware* e *software* (VR, AR e MR correlati) che offrono modalità di cattura e manipolazione dei dati di movimento, con importanti attori internazionali come Facebook (Oculus) HTC (Vive) Sony, Microsoft, Autodesk, Vicon, Magic Jump, Industrial Light & Magic, Pixar, Disney, Namco e altri.

I budget per la produzione di tali dispositivi digitali risentono di una marcata pressione al ribasso dei prezzi per l'arrivo di hardware più economico e veloce, e gli operatori del settore (specialmente quelli con budget più modesti) sono alla ricerca di nuovi e convenienti fattori di differenziazione.

Tutte le attività basate sul movimento richiedono l'analisi del movimento. Questo vale soprattutto per l'atletica amatoriale, dove troppo spesso movimenti scorretti possono comportare prestazioni non ottimali o addirittura lesioni.

Utilizzando tecnologie avanzate di analisi del movimento, la biomeccanica, i movimenti, lo spostamento, le forze d'impatto, la velocità e l'accelerazione degli atleti possono essere analizzate in modo appropriato e i dati relativi a movimenti atletici complessi possono essere ridotti a semplici visualizzazioni per raccomandare miglioramenti, tecniche più efficaci, e consapevolezza nella prevenzione degli infortuni.

Valutare i modelli di movimento degli atleti è fondamentale per ottenere un funzionamento ottimale ed essere competitivi. Attraverso lo *screening* di tali modelli tramite tecnologie informatiche avanzate che consentano di misurare il movimento, l'attività muscolare, la produzione di forza e il consumo di ossigeno, i limiti funzionali e le asimmetrie degli atleti o dei professionisti del benessere possono essere agevolmente identificati e conseguentemente si possono determinare in modo preciso e personalizzato gli esercizi più utili e le modifiche consigliate nelle modalità di movimento per raggiungere o ripristinare la mobilità corretta e il rafforzamento necessario.

Una delle ulteriori aree di sviluppo su cui WholoMove potrà concentrarsi saranno programmi di allenamento individuale e di gruppo e di benessere che utilizzano innovativi metodi di VR, AR e MR per massimizzare, migliorare e ottimizzare le prestazioni fisiche, consentendo agli atleti e ai professionisti di raggiungere il loro massimo potenziale in un modo responsabile, interattivo e biomeccanicamente informato. Prestazioni sportive / prevenzione degli infortuni / allenamento nelle attività di *wellbeing* potranno beneficiare di database in crescita, tra cui:

1) *Optical motion capture data* (Dati ottici di acquisizione del movimento)
2) Test cinematico 3-D con e senza valutazione della pressione plantare (piastre di forza / pedane mobili)
3) Analisi Video
4) Analisi dei dispendi energetici
5) Superficie dinamica ed Elettromiografia.

L'obiettivo sarà quello di conseguire un database completo di registrazioni *motion capture* per la valutazione, tanto funzionale che sotto il profilo del benessere, e per la disponibilità di un software di supporto per l'allenamento, per qualsiasi sport o attività prescelta. Ciò implicherà forme di *feedback training*, utilizzando i dati registrati in *motion capture*, con l'apporto di sensori di attivazione muscolare e altre tecnologie di analisi del movimento, per assistere chiunque pratichi attività connesse al movimento e intenda migliorare le proprie prestazioni, aumentando l'agilità e l'appropriatezza dei movimenti, rinforzando la flessibilità corporea complessiva e la forza muscolare, la potenza e la velocità, riducendo al minimo i fattori di rischio biomeccanici correlati a potenziali lesioni.

Tutto questo può essere completato con programmi di riabilitazione specifici per il paziente o di allenamento per il ritorno allo sport o al *wellness*, colmando il divario tra lesione e partecipazione ottimale all'attività. Attualmente la riabilitazione sportiva e di *wellness* comporta una valutazione biomeccanica completa con una valutazione completa del fisioterapista e un programma di allenamento personalizzato. Poter contare su database di movimento personalizzati con *software* finalizzati a specifici compiti di riabilitazione può sostituire parzialmente l'approccio tradizionale o rafforzare l'efficacia del trattamento, attirando potenziali utenti (oltre agli atleti e professionisti direttamente interessati) tra gli allenatori sportivi e gli esperti di medicina, come chirurghi ortopedici, medici di medicina sportiva, fisioterapisti sportivi, istruttori atletici certificati, biomeccanici, kinesiologi, specialisti certificati di resistenza e condizionamento, nutrizionisti sportivi, ecc.

Ulteriori applicazioni possono essere pensate per l'ergonomia, così come per la robotica che si proponga di stabilire modalità di agevole interazione con i movimenti umani.

1.4. L'ambizione di lungo termine: WholoMove

L'ambizione di lungo termine è in sintesi quella di stabilire la prima piattaforma, passibile di forte crescita in termini di economie di scala (*scalable*), basata sulla raccolta di *file* digitali di *motion capture* con annotazioni, insieme a strumenti per modificare, miscelare, vendere e distribuire le registrazioni e ricostruzioni di movimenti corporei reali e gli strumenti per avvalersene in un mercato algoritmico, confidando che questa piattaforma digitale consenta ad artisti, artigiani, atleti, o chiunque altro, di eseguire movimenti di alta qualità e precisione per catturare le proprie prestazioni in ambienti decentralizzati di *motion capture*, caricare *on line* tali contenuti in un contesto integrato e con un vaglio di qualità, e di condividerli con un pubblico globale.

Si è pensato di chiamare **WholoMove** questa più ampia piattaforma multi-progetto, evidenziando con ciò la volontà di andare ben oltre il solo mondo della danza.

WholoMove avrà l'ambizione di poter costituire presumibilmente la prima modalità di sfruttamento dinamico, sotto forma di ICO, di un progetto finanziato dall'Unione Europea nell'ambito di H2020. Potrà avvalersi in ciò dell'attrattiva finanziaria che è in grado di esplicare un risultato di successo di un progetto europeo, caratterizzato com'è, fin dall'origine, da un *background* scientifico e imprenditoriale che è frutto di un processo di selezione altamente competitivo quale quello dell'UE, e che WhoLoDancE ha attraversato, per essere in primo luogo finanziato e valutato in tutto il suo svolgimento.

WholoMove mirerà a stabilire per la prima volta un *marketplace* per condividere file di acquisizione dei movimenti (*motion capture*) in contesti creativi e scientifici, e allo stesso tempo promuovere la formazione di nuovi contenuti fornendo agli utenti strumenti per cercare, confrontare, selezionare e infine fondere i movimenti del corpo umano in nuove sequenze dinamiche.

La creazione di nuovi movimenti e di forme anatomicamente precise attiverà a sua volta un effetto rete in termini di contenuti atti ad accrescere il valore dell'esperienza dell'utente. Le strutture dei vincoli muscoloscheletrici, codificate nel *blending-engine* di WhoLoDancE, consentono la creazione di accurate dinamiche corporee che gli utenti possono sperimentare con la massima flessibilità creativa arricchendo, nel processo, la piattaforma di nuovi contenuti.

2. Gli strumenti già sviluppati da WhoLoDancE

Nello specifico, WhoLoDancE ha sviluppato 13 strumenti, già disponibili per un inziale impiego nell'insegnamento della danza e nella coreografia, in grado di ispirare, incentivare, supportare gli artisti – ballerini e coreografi – ma anche tutti coloro che sono interessati a effettuare movimenti in modo accurato e creativo.

2.1. Libreria di movimenti e annotazioni - Movement Library and Annotator (partner tecnologico: Athena RC)

Lo strumento Libreria di movimenti e annotazioni è un sistema basato sul *web* che consente di navigare, cercare e annotare le registrazioni multimodali sincronizzate (sia *motion capture* sia video), che sono state effettuate durante le sessioni di registrazione di *motion capture* di WhoLoDancE tenutesi ad Amsterdam e Genova. È costituito da un'interfaccia *web*, da dati, metadati, *back-end* di gestione delle annotazioni, e da un sistema di gestione degli utenti. Gli utenti possono accedere, registrarsi e accedere allo strumento tramite un *link* per:

a) Sfogliare e cercare le registrazioni usando le parole chiave correlate ai metadati, così come le annotazioni

b) Visionare le registrazioni con una visualizzazione sincronizzata in cui video e *motion capture* sono mostrati uno accanto all'altro, attraverso un lettore con tutte le funzionalità standard
c) Creare le proprie *playlist* in cui si possono aggiungere specifiche registrazioni di particolare interesse
d) Annotare le registrazioni, usando sia il testo libero che i vocabolari controllati sulla base del *framework* concettuale di WhoLoDancE, e modificarle successivamente
e) Vedere le proprie annotazioni in due modalità, una tabulare e una cronologica.

Il sistema integra una semplice visualizzazione delle registrazioni con un *avatar* rappresentatnte una figura stilizzata. Inoltre, è disponibile un altro visualizzatore, il visualizzatore di Choreomorphy, sviluppato in Unity e integrato tramite WebGL, che consente di rappresentare la medesima registrazione con molteplici avatar, così da poter agevolmente scegliere quello che risulta essere il più adatto nella circostanza data.

2.2. Segmentazione - Segmentation (partner tecnologico: Politecnico di Milano)

Lo strumento di segmentazione è stato progettato per consentire la segmentazione manuale delle sequenze di movimento, registrate in *motion capture*, in segmenti di movimento molto più brevi e più semplici. I dati risultanti - insieme alla relativa annotazione - costituiscono la conoscenza di base utilizzabile per lo sviluppo e la valutazione degli algoritmi in grado di determinare la segmentazione automatica. Lo strumento di segmentazione è un servizio *web* atto a raccogliere annotazioni manuali; le tecniche di segmentazione si basano su algoritmi automatici che si avvalgono di tali annotazioni. Lo strumento può essere utilizzato per ispezionare e correggere manualmente il risultato di una segmentazione automatica, contribuendo al progressivo perfezionamento dell'algoritmo. Lo strumento è attualmente un'applicazione *web-based*, alla quale gli utenti possono accedere da qualsiasi luogo.

2.3. Libreria di software per l'Analisi del movimento - Movement Analysis Software Library (partner tecnologico: Università di Genova)

Sono disponibili una serie di moduli *software* per l'estrazione in tempo reale delle qualità del movimento, idonei a soddisfare diversi obiettivi: dall'annotazione automatica (*off-line*) dei segmenti di danza memorizzati nel *data base*, alle esigenze in tempo reale di un ballerino o di un professionista, per supportare la visualizzazione interattiva della sonificazione e l'improvvisazione.

La libreria include un ampio *set* di moduli software per analizzare le qualità del movimento che vanno dalle caratteristiche di livello più basso (*low end*) legate alla cinematica (per esempio, velocità delle articolazioni, accelerazioni) a qualità di livello superiore (*high end*), come per esempio, energia, leggerezza, simmetria, origine del movimento.

È disponibile come libreria *software* per la piattaforma EyesWeb, oltre che come libreria *software* separata, in entrambi i casi integrata con Unity e gli altri moduli WhoLoDancE.

I moduli di analisi sviluppati sono progettati per essere integrati con vari strumenti: i moduli in tempo reale vengono utilizzati nel *Movement Sketching Tool* (Strumento per delineare il movimento), e le strategie di raccordo del movimento alla sonificazione interattiva e alle visualizzazioni. I moduli possono essere integrati con applicazioni Unity e altri ambienti (cioè, ambienti di sonificazione).

I moduli *off-line* offrono la possibilità di analizzare sequenze di danza registrate per ulteriori analisi e visualizzazioni. I moduli possono ricevere flussi di dati da applicazioni UNITY, *streaming live* da dispositivi o leggere file FBX di registrazioni (dal *data base* o appena registrate dagli utenti).

L'*output* dei moduli può essere trasmesso a UNITY per la visualizzazione in tempo reale o immesso nel *Similarity Search Engine* (motore di ricerca di similarità) per l'esercitazione (*training*) o per la ricerca di sequenze simili.

2.4. Estrazione tramite dati delle qualità del movimento - Data-driven extraction of movement qualities (partner tecnologico: Politecnico di Milano)

Le metodologie basate sui dati implicano l'uso di segmenti annotati manualmente per far sì che le tecniche di apprendimento automatico diventino in grado di comprendere la relazione tra la rappresentazione di livello inferiore del movimento e la sua descrizione di alto livello. Questo implica la raccolta di annotazioni manuali degli esperti di danza relative alle qualità del movimento delle performance e l'uso di tecniche per l'estrazione e la selezione delle caratteristiche, algoritmi di apprendimento automatico e metriche di valutazione.

La raccolta delle annotazioni degli esperti di danza ha costituito l'insieme di dati di base per l'implementazione e la formazione di algoritmi fondati sull'apprendimento automatico. Questa procedura ha presentato una difficoltà tecnica primaria, poiché vari esperti, provenienti da diverse specialità di danza, mostravano una diversa percezione soggettiva e culturale delle qualità del movimento, come la fluidità o la pesantezza, che rendeva difficile raggiungere quel consenso nei valori necessario per ottenere un algoritmo efficace. Per bilanciare questo limite pregiudiziale (*bias*) derivante dalla soggettività, il passaggio successivo è stato quello di riprogettare e semplificare lo strumento di annotazione, prima di sottoporlo a una più ampia comunità di esperti di danza e dilettanti (amatori) sul *web*.

2.5. Motore di ricerca e di similarità – Search and similarity engine (partner tecnologico: Peachnote)

Il motore di ricerca e similarità implementa una serie di metodi per misurare la somiglianza tra le *performance* di danza modellate utilizzando diversi formati di dati.

È stata sviluppata un'interfaccia basata sul *web* che consente di identificare sequenze di movimento simili a qualsiasi sequenza indicizzata dal motore di ricerca e di riprodurre contemporaneamente sia la domanda presentata (*query)* sia le sequenze identificate.

La piattaforma di ricerca e similarità supporta l'invio automatico di registrazioni e dati di serie temporali da parte di utenti autorizzati. Supporta scenari di *query* flessibili, in cui gli utenti possono specificare da soli le funzionalità da utilizzare per la ricerca e i relativi pesi. La funzionalità è esposta tramite un'API REST che consuma e produce dati in formato JSON. L'API è documentata e facilmente utilizzabile in una varietà di ambienti. Viene utilizzato un semplice schema di autenticazione. Più istanze di implementazione del motore sono disponibili per i partner tecnici per sperimentare, con l'API, le funzionalità di basso, medio e alto livello che possono generare e inviare al motore di ricerca per conto proprio e i modelli ponderati personalizzati senza interferire con altri partner o l'implementazione della produzione. Le implementazioni sono facilmente aggiornabili per supportare cicli di sviluppo e distribuzione brevi.

Il motore di ricerca e similarità è implementato come applicazione Java autonoma con la quale interagire tramite un'API REST. L'API implementa una definizione API Swagger, da cui è possibile generare automaticamente l'implementazione *client* in più lingue.

Per le applicazioni in tempo reale, le connessioni WebSocket possono essere utilizzate per il *motion streaming* HLF sul motore di ricerca e per ricevere un flusso di puntatori riferiti ai risultati della ricerca. Le connessioni WebSocket sono supportate sia per Unity sia per *web-based client*.

L'applicazione ospita la propria documentazione disponibile presso l'*endpoint* principale dell'API, http://search.wholodance.peachnote.com. La documentazione descrive tutti gli *endpoint* REST disponibili e le strutture dati utilizzate e restituite dall'API.

2.6. Motore di miscelazione – Blending engine (partner tecnologico: Motek Entertainment)

Il blending engine di WhoLoDancE è uno strumento interattivo di miscelazione e composizione dei dati di acquisizione del movimento che sono già disponibili nella Libreria di movimento. Le sequenze possono essere assemblate in una configurazione lineare o utilizzate per la miscelazione parallela, in cui i segmenti consecutivi sono una sovrapposizione di segmenti dalla Libreria.

Gli utenti possono assemblare coreografie o combinazioni di sequenze e salvarle come nuovi file FBX. Questi file possono essere letti e visualizzati all'interno del motore UNITY utilizzando uno qualsiasi degli avatar creati (Choreomorphy).

2.7. Strumento di software per il disegno del movimento - Movement Sketching Software Tool (partner tecnologico: Università di Genova)

Il *Movement Sketching Tool* consente agli utenti di accedere, sfogliare e interrogare il repository di Wholodance tramite le qualità del movimento. Ad esempio, un utente può eseguire un movimento "fluido" e "aperto" con un arto, e il sistema estrae queste qualità espressive del movimento per recuperare movimenti simili usando il *Similarity Search Tool*.

Lo strumento è scalabile: funziona sia con i sistemi di *motion capture* sia con i sistemi a basso costo come IMU (ad esempio, xOSC, sensori Notch), per consentire, a chi esercita attività di danza, di catturare la sequenza di movimento di un ballerino, analizzarla in termini di qualità desiderate e ricercare movimenti simili attraverso il motore di Similarity

Search. In questo modo, lo strumento confronta i movimenti dell'utente con quelli dei ballerini professionisti presenti nella Libreria, e i risultati dell'interrogazione possono essere visualizzati con dispositivi di realtà virtuale e standard. Inoltre, possono essere utilizzate tecniche di sonificazione per generare una sonificazione dei movimenti eseguiti e registrati.

Lo strumento può ricevere flussi di dati da applicazioni UNITY, *streaming live* da dispositivi o leggere file FBX di registrazioni (dal *data base* o appena registrate dagli utenti). L'*output* dello strumento può essere trasmesso all'UNITY per la visualizzazione in tempo reale.

2.8. Realtà virtuale di fascia bassa – Low-End VR (partner tecnologico: Politecnico di Milano)

La piattaforma VR di fascia bassa consente all'utente di visualizzare l'acquisizione del movimento di una *performance* di danza come un'esperienza VR immersiva utilizzando un supporto VR a basso costo, come Google Cardboard (10 €) e uno *smartphone* di uso quotidiano.

La piattaforma supporta il tracciamento (*tracking*) dell'orientamento della testa, quindi quando gli utenti si guardano attorno, la visualizzazione dell'ambiente virtuale 3D muta di conseguenza.

2.9. L'applicazione di ricerca di movimenti in tempo reale su dispositivo portatile – Real-time mobile movement search application (partner tecnologico: Peachnote)

Tale applicazione consente a chiunque disponga di un dispositivo mobile e di un secondo schermo di trovare i movimenti acquisiti all'interno della Libreria di movimento, nonché con registrazioni video effettuate con videocamera esterna.

L'obiettivo del sistema è l'accessibilità (qualsiasi telefono cellulare con una telecamera e una connessione cellulare può essere utilizzato come dispositivo di acquisizione), semplicità e assenza di interferenze (*non-disruptiveness*) nell'applicazione (la ricerca viene eseguita in *streaming*, fornendo continuamente risultati in base al movimento catturato dalla fotocamera). Poiché non è necessario alcun *hardware* o *software* speciale oltre il *browser*, il sistema non richiede alcuna competenza tecnica per essere utilizzato e un tempo di installazione molto breve.

Nella configurazione minima, l'utente che acquisisce un movimento punta un telefono cellulare o un *tablet* verso una persona in movimento e riceve sul proprio schermo un flusso di immagini registrate che sono state indicizzate dal motore di ricerca e che corrispondono a posizioni simili al movimento catturato in tempo reale. La latenza del sistema è di circa un secondo in condizioni normali. L'utente può in qualsiasi momento decidere di interrompere la ricerca e passare a uno dei risultati di ricerca, riproducendo l'*offset* identificato.

In una configurazione più ampia, i risultati della ricerca possono essere proiettati su una parete utilizzando un proiettore, in modo che la persona catturata possa anche vedere i risultati della ricerca in tempo reale modificare e orientare i propri movimenti in base a tale risultati.

Un'impostazione ancora più ampia include il ballerino che indossa un dispositivo Hololens e vede i risultati della ricerca trasmessi in 3d nello spazio circostante. Questo è possibile per le registrazioni che sono state precedentemente catturate in 3d, quali quelle della libreria di movimenti di WhoLoDancE.

Il sistema è costruito modularmente e consta di diverse componenti: un servizio di *streaming* video per l'importazione dei flussi video del *client*, un servizio per l'estrazione di informazioni di movimento scheletrico dai flussi video grezzi utilizzando GPU, il motore di ricerca che indicizza il *data base* di dati o video dei movimenti acquisiti e trova sequenze simili, dato il flusso in tempo reale del movimento scheletrico fornito tramite i passaggi precedenti, e il livello di presentazione che visualizza i risultati della ricerca degli utenti.

Il sistema può funzionare con flussi sia bidimensionali che tridimensionali (*motion capture* e sorgenti video e *query*), mescolandoli come richiesto nel contesto dello specifico caso d'uso. Ad esempio, uno *smartphone* che fornisce uno *streaming* video a bassa risoluzione può essere utilizzato per richiedere dati 3D di *motion capture* di elevata precisione che possono essere proiettati su in 2D o trasmessi in *streaming* in 3d in un'applicazione VR. Viceversa, i flussi di dati provenienti da apparecchiature *motion capture* possono essere utilizzati per trovare video contenenti gesti simili o altri movimenti acquisiti in 3D.

2.10. Choreomorphy (partner tecnologico: Athena RC)

Choreomorphy è un'applicazione, basata su Unity, cui è possibile accedere attraverso varie modalità di interazione:

d. *Choreomorphy whole-body experience* (esperienza corporea integrale)
e. *Choreomorphy HoloLens experience* (esperienza tramite HoloLens)
f. *Choreomorphy desktop app* (applicazione desktop).

L'idea guida muove dal presupposto che differenti avatar e visualizzazioni del movimento pongono in risalto aspetti diversi che determinano l'innesco di differenti qualità e modelli di movimento, on effetti significativi sia dal punto di vista pedagogico sia da quello estetico e creativo.

In altre parole, Choreomprphy consente all'utente di modificare e personalizzare facilmente la propria visione del movimento.

Più nello specifico:

i. L'esperienza di interazione di tutto il corpo di Choreomorphy consente agli artisti/performers di vedere sè stessi in avatar, visualizzazioni e ambienti diversi mentre si muovono in tempo reale indossando una tuta inerziale di *motion capture*, quindi può essere utilizzato come strumento per autoriflessione e improvvisazione nella danza.
ii. La versione HoloLens di Choreomorphy estende le stesse funzionalità in AR. Usando i dispositivi HoloLens gli utenti possono vedere il movimento preregistrato in avatar tridimensionali che si muovono nello spazio fisico, in modo da poter seguire il movimento nello spazio fisico.
iii. L'applicazione desktop di Choreomorphy è un'applicazione scaricabile integrata in Unity, che è attivabile sia su MAC OS sia su Windows, e che consente di vedere le registrazioni in una varietà di avatar, visualizzazioni, effetti e ambienti.
iv. Il visualizzatore di Choreomorphy, sviluppato in Unity e integrato tramite WebGL, consente di vedere esattamente la stessa registrazione in diversi avatar.

2.11. Hololens UNITY (partner tecnologico: Motek Entertainment)

L'ambiente personalizzato UNITY è la base per l'integrazione di tutti gli altri strumenti dei partner. Serve come risultato chiave del progetto, cioè, consentire a uno studente di danza di essere all'interno o di fronte a una proiezione olografica di un avatar guidato da dati di acquisizione di movimento di un maestro di danza.

Questo ambiente UNITY offre anche una capacità multiuso, quindi un insegnante / coreografo può anche vedere il vero studente di ballo immerso nell'avatar. L'ambiente UNITY offre pure *feedback* per parte del corpo allo studente, informandolo quando le rispettive parti del corpo sono al di fuori del volume dell'avatar.

2.12. Strumenti di Analisi musicale – Tools for Music Analysis (technological partner: PoliMi)

Nell'ambito di WhoLoDancE, è stato sviluppato anche un insieme di algoritmi per l'analisi della musica, con l'obiettivo di estrarre automaticamente funzioni di basso livello, come caratteristiche spettrali e di forme d'onda, e funzioni di medio livello, come ritmi di musica e accordi.

Dato l'insieme di brani musicali, gli algoritmi estraggono un ampio insieme di caratteristiche. La procedura di estrazione delle caratteristiche è integrata sia con *web-based framework* sia con Unity attraverso lo scambio di dati *client-server*.

2.13. Piattaforma educativa ed esercizi su Kinect – Educational Platform and Kinect-based exercises (partner tecnologico: Athena RC)

La piattaforma educativa è un'applicazione basata sul *web* che mette in mostra i vari strumenti e scenari WhoLoDancE secondo una prospettiva pedagogica. Completa la libreria di movimento e amplia il quadro concettuale di WhoLoDancE.

La piattaforma educativa alimenta scenari specifici per progettare corsi e attività di apprendimento per un particolare genere di danza (contemporaneo, balletto, flamenco, folk greco), obiettivo (principi del movimento, qualità, azioni), contesto (creatività, passi e forme di apprendimento, improvvisazione, ecc.), e strumenti (Sonificazione, Choreomorphy, Annotatore, *Movement Sketching*, attività basate su Kinect ecc.).

Le attività di apprendimento descritte nella piattaforma educativa richiedono un *hardware* particolare a seconda dello strumento. Come *proof of concept*, sono stati costruiti esempi specifici di scenari pedagogici per dispositivi di fascia bassa come Kinect, in particolare per esercizi interattivi relativi all'allineamento e alla direzionalità.

3. WhoLoDancE per Balletto di Roma: nuove possibilità di didattica della danza

I 13 strumenti di base sviluppati nell'ambito di WhoLoDancE trovano il loro campo di applicazione elettivo nella didattica per la danza e la coreografia, consentendo sia al docente sia all'allievo di conoscere e visualizzare correlazioni e combinazioni provenienti da generi diversi (*Movement library* e *Similarity search*, *Blending engine*), di sperimentare nuove forme creative (Choreomorphy, *Real-time mobile Sketching tool*), di utilizzare strumenti in grado di fornire maggiore consapevolezza e precisione ai movimenti effettuati, che possono essere utilizzati sia durante una lezione collettiva di danza sia per l'esercizio autonomo o a distanza, anche in modo personalizzato (Hololens Unity).

In particolare, grazie allo sviluppo della piattaforma di *e-learning*, sarà possibile per un docente costruire, secondo le specifiche esigenze di insegnamento, un percorso didattico che, combinando fra loro diversi strumenti di WhoLoDancE, guidi l'allievo anche dell'apprendimento e allenamento a distanza, consentendo di monitorare e sviluppare esercizi e coreografie specifici, in grado di tenere conto anche di particolari qualità del movimento o annotazioni.

L'apporto innovativo di queste possibilità di insegnamento sembra particolarmente adatto a un contesto didattico come quello del Balletto di Roma, un'istituzione d'eccellenza nel mondo della danza classica e contemporanea italiana e internazionale, che sin dalla sua fondazione, negli anni '60, ha fatto della sperimentazione e della commistione e superamento fra generi il tratto distintivo della propria ricerca.

Da sempre attenta al rinnovo delle attività didattiche e a "proiettarsi nel futuro a fianco delle nuove generazioni di ballerini", la scuola offre un percorso accademico professionale ampio e completo, dall'imprescindibile base di studio costituita dalla danza classica ai nuovi linguaggi della danza contemporanea, da corsi dedicati ai più giovani alle possibilità di interagire in laboratori pratici e incontri teorici con partner europei e ospiti internazionali, fino alla creazione coreografica supportata da un vasto repertorio.

I corsi, dedicati ad allievi da 8 a 17 anni, fino a raggiungere un livello professionale, sono attualmente organizzati in classi a numero chiuso, fino a un massimo 18 componenti, sulla base di criteri che potranno un domani trovare motivi di eventuale riconfigurazione sulla base delle possibilità di ulteriore apprendimento e allenamento dall'utilizzazione degli strumenti messi a punto da WhoLodancE, e da altri ancora che potranno concorrere a caratterizzare la piattaforma di *e-learning*.

Se attivata, la collaborazione fra Lynkeus e Balletto di Roma consentirà non solo di mettere a disposizione gli strumenti WhoLoDancE di studio, esercizio, e creazione del movimento sopra descritti per l'attività didattica in classe o di esercizio individuale, ma anche di dare avvio a un primo corso sperimentale a distanza, in cui dall'iniziale lavoro sulla qualità dei movimenti e sui diversi generi sarà persino possibile arrivare alla creazione o all'apprendimento di una specifica coreografia.

L'auspicata ulteriore interazione con Lazio Innova, l'Agenzia finanziaria di supporto all'innovazione della Regione Lazio, potrà costituire un importante elemento di sostegno nel perseguire l'ambiziosa strategia di WholoMove delineata in questa nota.

2. Appendix 2: e-mail exchanges with Balletto di Roma

Da: Francesca Magnini <francescamagnini@gmail.com>
Inviato: 27 December 2018 21:53
A: Edwin Morley-Fletcher <emf@lynkeus.com>
Cc: Luciano Carratoni <carratoni@gmail.com>; Ludovica Durst <l.durst@lynkeus.com>
Oggetto: Re: I: Una piattaforma di e-learning per Balletto di Roma sulla base dei risultati tecnologici conseguiti da WhoLoDancE

Caro Edwin,

spero abbia trascorso un sereno Natale e che anche i giorni a venire siano volti all'insegna del tempo da trascorrere con un pò più di calma del solito insieme alle persone care.

Avendo ritrovato anche io un pò di tempo ho letto con attenzione l'allegato inviato e confermo di essere molto colpita dalla complessa articolazione del progetto e dal fatto che tocca tanti temi a me molto cari.

Per quanto riguarda la proposta specifica rivolta al Balletto di Roma, mi sembra mirata soprattutto al lato didattico della nostra struttura, vale a dire la nostra **Scuola**, volta alla formazione delle giovani leve. Trovo molto utile espandere/creare strumenti in grado di fornire maggiore consapevolezza e precisione ai movimenti effettuati, che possono essere utilizzati sia durante una lezione collettiva di danza sia per l'esercizio autonomo o a distanza, anche in modo personalizzato. Per questo posso darle la nostra adesione ad eventuali operazioni condivise volte a consentire da un lato al docente e all'allievo di conoscere e visualizzare correlazioni e combinazioni provenienti da generi diversi, dall'altro di sperimentare nuove forme creative. Sottolineo tuttavia la nostra disponibilità a discutere anche ulteriori strumenti rivolti alla **Compagnia** e quindi al nostro lato creativo/produttivo, per espanderne orizzonti di senso e modalità operative.

In sincerità gli aspetti che più mi affascinano di questa ricerca, e che osservo sempre in relazione alle possibilità di sviluppo di nuovi ambiti di lavoro per BDR, sono WholoMove e l'area del wellbeing (che noi abbiamo chiamato Benessere e che ancora si è faticato ad espandere), insieme all''indagine su funzionalità avanzate come screening e valutazione, miglioramento delle prestazioni, allenamento funzionale e nuove piattaforme sportive social.

Resto quindi a disposizione per un confronto in merito, finchè posso rispondo senza problemi sia a mail che al telefono

Un caro saluto e buona continuazione,

Francesca

Il giorno ven 21 dic 2018 alle ore 16:23 <emf@lynkeus.com> ha scritto:

Cara Francesca,

grazie per la tua tempestiva risposta. Sei stata tanto più ammirevole perché in procinto di partorire!

Auguri vivissimi per tutto, e un abbraccio,

Edwin

Da: Francesca Magnini <francescamagnini@gmail.com>
Inviato: 20 December 2018 15:19
A: Edwin Morley-Fletcher <emf@lynkeus.com>
Cc: Luciano Carratoni <carratoni@gmail.com>
Oggetto: Re: I: Una piattaforma di e-learning per Balletto di Roma sulla base dei risultati tecnologici conseguiti da WhoLoDancE

Carissimo Edwin,

grazie per la mail e per la proposta inviata, la leggerò con attenzione e la condividerò con Carratoni quanto prima.

Ricambio intanto gli auguri di un sereno Natale (per la cronaca non ho ancora partorito ma ci siamo quasi!).

Un caro saluto,

Francesca

Francesca Magnini

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Piazza S. G. Battista De La Salle 3/5, 00165 Roma
formazione@ballettodiroma.com

Da: emf@lynkeus.com <emf@lynkeus.com>
Inviato: 20 December 2018 11:50
A: 'carratoni@ballettodiroma.com' <carratoni@ballettodiroma.com>
Cc: 'magnini@ballettodiroma.com' <magnini@ballettodiroma.com>; Ludovica Durst (l.durst@lynkeus.com) <l.durst@lynkeus.com>
Oggetto: Una piattaforma di e-learning per Balletto di Roma sulla base dei risultati tecnologici conseguiti da WhoLoDancE

Caro Direttore Generale,

mi dispiace che il susseguirsi di impegni ha fatto tardare il nostro dar seguito in forma scritta alle intese di massima cui eravamo approdati nell'incontro avuto a fine ottobre insieme con Francesca Magnini.

Ecco una prima formulazione in italiano della nostra proposta, cui saremo lieti di lavorare ulteriormente, se utile, in base alle vostre esigenze.

Con i migliori auguri per un felice Natale e un buon anno nuovo (specie per Francesca, che immagino avrà già partorito), restiamo in attesa di un vostro cortese riscontro.

A presto,

Edwin

_____
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