# An Approach Towards Artistic Visualizations of Human Motion in Static Media Inspired by the Visual Arts

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*Abstract—* **The visualization of 3D human motion on a 2D canvas or display is employed by a wide spectrum of disciplines to abstract and provide insight on the motion of human subjects that is depicted by the 2D medium. Painters, illustrators and directors use motion lines, contrast, superimposition as well as juxtaposition of visual frames for a better conveyance of motion. The proliferation of digital cameras, motion sensors, combined with computer vision has enabled the 3D recording of human motion in a wide range of conditions. At the same time, applications of human motion visualization, such as illustrated safety or assembly instructions, still have a wide use in conventional depictions of human motion, namely 2D static depictions, whether these are presented on screen or on paper. Inspired by the depiction of human motion in the visual arts, we transfer pertinent visual approaches to the domain of human motion visualization. Our goal is to utilise these visualization techniques and create insightful visualizations of human motion recordings on static 2D media. To that end, we propose the MotiVo system that dynamically integrates multiple tools for the visualization of human motion. Based on these tools, we study basic approaches of human motion visualization and abstraction.**

*Keywords-Motion visualization; Artistic Visualization; Motion capture; Image processing;Computer Vision.*

## I. INTRODUCTION

In visual arts, human motion and activity are often conveyed through still depictions or sculptures. Depiction of motion is an important part of artistic expression. Over the years, artists have depicted both motion (e.g., Claude Monet, En Plein Air, 1886) and lack of motion, (e.g., Johannes Vermeer's Woman Holding a Balance, 1664) as a way to stimulate interest [1]. We call *visual abstraction*, a drawing that encapsulates events lasting more than one moment and possibly occurring in more than one location. In essence, a visual abstraction is a manipulation of realistic imaging aiming to convey an understanding of the events occurring within a time-space interval. Motion is effectively conveyed in static media using superimposed and juxtaposed images. Pertinent techniques are based on the cognitive capability of the observer to "fill-in" missing information. In this way, the depiction encodes an event, taking place during a time interval rather than a photographic recording of a single moment. Superimposed

forms are employed in the visual arts to summarize motion within a short time interval, taking place at a location (Figure 1).
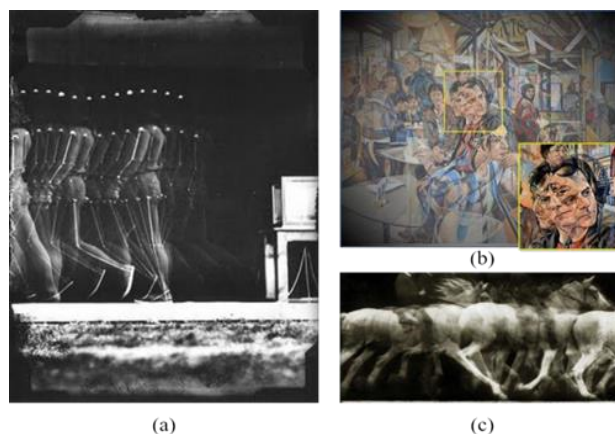


Figure 1. (a) *Man walking*, Marey 1891 (b) *Calder's Ascension*, Head 2017 (c) *Cheval blanc monté*, Marey 1886.

Juxtaposed illustrations are used in comics [2] and illustrated instructions to convey motion. Visualizing motion, as a sequence of juxtaposed key pose [3] depictions, provides a clear understanding of the illustrated motion. Annotations, such as motion lines, provide visual cues to motion and facilitate understanding (Figure 2).



Figure 2. Juxtaposed illustrations encoding motion.

Representation of motion and activity in longer time intervals or scenes has been treated in art by manipulating time in the depiction, so that multiple time instances are seamlessly summarized, or "gracefully superimposed" without affecting the realism of depiction. For example, in Figure 3, it is the characteristic activity of each person depicted by each form in the painting rather than a photographic depiction of a moment. If the depiction would be literally considered, the depicted behaviours would probably not occur simultaneously. Instead, the painting

summarizes the behavior of each character during the depicted event. The painter guides the observer to examine each form sequentially. The dominant stroke of light creates a salient visual path in the painting. Then, the attention [4] is guided by contrast changes in an elaborate visual path that visits the depicted characters and reveals the interaction among them.
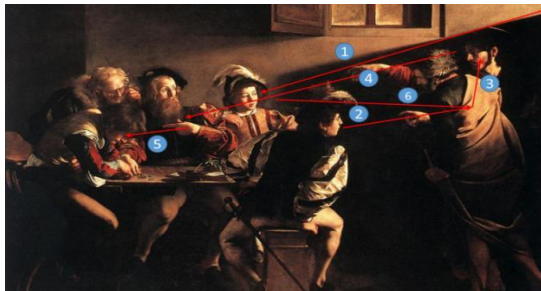


Figure 3. *The Calling of St. Matthew*, Caravaggio 1599-1600.

Juxtaposition is also used in illustrated instructions (e.g., manuals) as an ordered representation of images combined with written information and graphical annotations, to direct the reader (Figure 4).
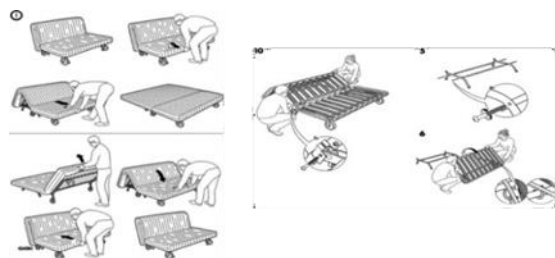


Figure 4. Motion and action visualization in instruction manuals.

Although this was conventionally a manual task for illustrators, nowadays technology is offering a plethora of tools for digital creativity. It is common for graphic designers and illustrators to use image-processing software in order to simplify authoring and enhance visualization. Though these tools are a commodity, they still require insight and art skills from the illustrator. The efficiency of communication and the abstraction of form is also noted as another inspirational aspect of story-telling visuals. Le Corbusier in a letter, he describes his project through suggestive drawings. The style reminds of the so-called "ligne claire" (clear line) [5], whose precursor is now recognized in Rodolphe Töpffer [6]. The technique is explained in: *"Le Corbusier obsessively draws "after" photographs as in an attempt to remove anything superfluous"*. The overlaps with Töpffer were particularly vivid in Le Corbusier's sketches of human body actions, creating figures with a dynamism and liveliness (Figure 5).

Le Corbusier's trademark line style transformed his architecrural representations to a graphic narrative communication tool.
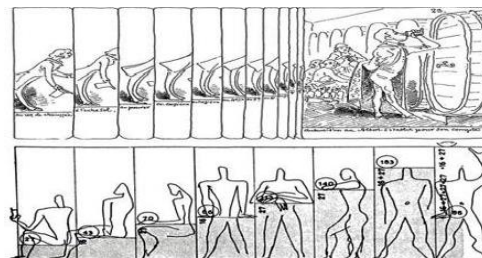


Figure 5. Reduction of complex photographs into drawings.

The goal of this research is to build over centuries of experience in the domains of the visual arts and implement a system that transfers artistic concepts in the digital world. Although there are techniques that offer a wide range of motion visualization tools, some of them focusing on Motion Capture (MoCap) whereas others work exclusively on motion visualizations, there is still need for an interactive and simple to use editor. Existing works are mostly targeted to one specific motion visualization technique that fits their work subject, nevertheless, there have not yet been presented works for general purposes. In this context, we present MotiVo, an interactive system that simplifies this process by offering a number of visualization tools and provides insightful and visually pleasant results requiring minimum expertise and knowledge from the user side. Using these tools, motion is visualized by parameters, such as the blending of key poses retrieved from an activity, the visualization of motion trajectories, the application of image filters to visualizations and their 3D and 2D combinations for hybrid depictions of motion.

The rest of the paper is structured as follows. In Section II, we summarize the related work. In Section III, we present system's input data and also give a brief description of how we acquired them. In Section IV, the *MotiVo* user interface and its tools are described. In Section V, there are presented some experimental results as well as we give some guidelines for a better experience according to an expert-based evaluation with the tools. Finally, we present our future work and draw some conclusions (Section VI).

## II.    RELATED WORK

A large number of existing studies in the broader literature have examined motion visualization techniques. Digital artists, such as T. Gremmler, use technology to produce artistic visualizations of motion. Gremmler has rendered a sequence of animations that illustrate the disciplined and defined movements of Kung Fu practice in the form of shapes, geometries, and abstract shapes. Human figures are reduced to a minimum of a simple sequence of lines, lines, and points, which adopt postures and pose throughout the video [7].

In this context, technical state-of-the-art is offering a number of alternative ways to digitize human motion, such as MoCap and Computer vision technologies [2][8]-[10].

These technologies provide accurate digitized representation of movement in 3D [11][12]. At the same time, in the domain of computer graphics, a wide range of visualization tools are available that allow the simplification of the production of 2D and 3D visualizations.

Key Probe is a key-frame extraction technique, relied on an algorithm appropriate for rigid-body and soft-body animations that converts a skeleton based motion or animated mesh to a key frame-based representation [13]. To select a representative moment from a performance, they introduce "Action Snapshot", a method based on information theory that automates the process of generating meaningful snapshots, by taking as input dynamic scenes as input and producing a narrative image as output [14].

3D visualization has also been proven valuable in the demonstration of Motion Capture (MoCap) data. Such an example is ToolY, a 3D authoring platform for demonstration of simple tool operations in 3D environments [15]. In sports, human motion visualization is used to display 3D models of swimmers by digitizing their motions and creating personalized virtual representations [16]. Lucent Vision is a visualization system developed for tennis. It uses real-time video analysis to extract motion trajectories and provides a variety of visualization options [17].

Action summarization is prevalent in the human motion visualization community, as it can produce motion effects in still image frames. "Action Synopsis" takes as input human movements, encoded either as MoCap animations or videos and presents motion in still images [18]. The work [19] creates compact narratives from videos, by composing foreground and background scene regions into a single interactive image, using a series of spatiotemporal masks.

Depth information of animations assists summarization of 3D animations in a single image. A method that extracts important frames from the animation sequence based on the importance of each frame is proposed, based on its contribution to overall motion-gradient [20].

Similar work has also been developed for the artistic motion visualization. In [21], simulates thick, dominant brush strokes, to place emphasis on important line features of an image. M.G Choi proposed an interface, where the user browses overall motion visualized by a unified medium in the form of 2D stick figure images [19].

All these proposals offer a wide range of motion visualization techniques but they lack in terms of intuition, interaction and ease of use. In this work, we identify a gap between motion digitisation and insightful, artistic motion visualization. We propose a bridging of these dimensions in a single workflow. To realise this approach, we implemented MotiVo, a 2D visualization editor. In this editor, two tools are presented for the production of motion visualizations. The first is based on video key frames. The second visualizes 2D motion trajectories computed by visual tracking. To further assist users, we include post-processing tools that enable the application of image filters to input visual assets and manual annotation of upon these assets. Finally, we propose a method to use 3D information about human and object motion to enrich the produced visualizations. Our editor does not only focus on motion visualization effects, but also facilitates users to extend the tools through their combination in order to generate unique representations of motion visuals.

## III. ACQUIRING VISUALIZATION SOURCES DATA FROM IMAGE, VIDEO AND HUMAN MOTION

For the purposes of this research work, two types of potential digital input are of interest. The first type is still images and image frames acquired from video and the second type is MoCap data. In order to collect data for our case study, we use the following methodology. Initially, we recorded in a video format of a person performing typical activities, such as waving. The video stream was segmented to video frames and frames of interest were then extracted from the video stream to produce a summarization in frames of movements. Furthermore, the video stream was used as a source for the Open Pose Computer Vision library [22]. Using the Open Pose output in this research work, we isolated specific joints of the skeleton in order to produce the trajectories path for our visualization algorithm.

## IV. THE MOTIVO APPROACH

### A. MotiVo tools

#### 1) Motion Blender

Motion blender creates a directional motion effect by overlapping key poses into a united content. Specifically, as a dataset, each user is able to import multiple strong key pose images, they consider as the main motions of an activity. This dataset differs for every user. The combination of all the frames summarizes the overall action. Besides the visualization of motion direction, the user can emphasize on each frame with varying contrast and color intensity volumes. The contrast intensity of each key pose is determined by a value selected by each user via the tool's User Interface (UI) sliders. The value range is between zero and one hundred, with zero to be the lowest contrast value whereas one hundred the maximum intensity.

Depending on the nature of activity, the emphasis on the each image frame may be differentiated. In many cases the most significant action is the initial, middle or the last one. For example, on hammering a nail, the dominant action could be the last key pose, which indicates exactly how to hit the top of the nail, therefore this key frame is highlighted the most. In contrast to the previous scenario, in dance choreographies the motion sequence can be evenly defined as important, thus the relative intensity of each key pose is uniformly visualized. Users on runtime can view the resultant image. The output is a single image that can be also saved as an asset in the current project and then be loaded by another MotiVo tool for further processing. A color image $I$ at coordinates $x, y$ has pixel value $c = I(x, y)$ where $c$ has values {R, G, B}. We do not treat monochromatic (grayscale) differently. If such input is given, the monochromatic

channel is replicated in all the RGB (Red Green Blue) bands and the image is treated as a color image.

Let *n* be the number of key frames selected by the user. We denote by $I_i$ the corresponding images, where *i* is in *[1, n]*. In case of even distribution between contrast and volume of the image frames, for each $I_i$ we average the corresponding pixel RBG values from the color arrays of each selected image (1). This can be achieved in case of all the number values are set evenly. The combined result is a visualization of all the images demonstrating a motion sequence (Figure 6).

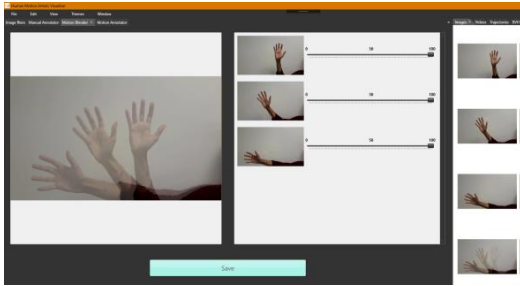$$I_s = \sum_{i=1}^{n} \frac{I_i(x,y)}{n} \qquad (1)$$



Figure 6. Averaged Motion visualization.

An extended approach of the previous scenario is the weighted visualization of human motions. In this version, users alter the UI slider values thus setting different weight value $w_i$ for each image frame to denote the contrast intensity depicted in the final result (2). For lower weight values, the frames have low opacity volume in contrast to high weights values where the RGB values are greater. The effect of fading and overlapping motion allows the human eye to perceive easily the chronological order of the action (Figure 7).

$$I_s = \frac{\sum_{i=1}^{n} w_i * I_i(x,y)}{\sum_{i=1}^{n} w_i} \qquad (2)$$
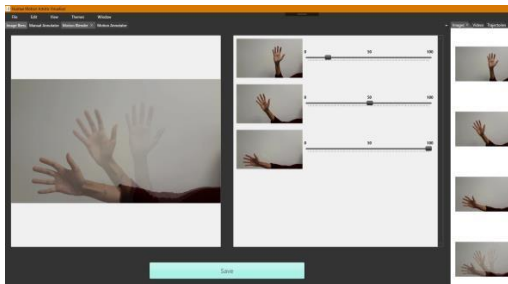


Figure 7. Weighted motion visualization.

Average and weighted visualization of Motion Blender were implemented using the Windows Presentation Foundation (WPF). In order to rectify the problem of CPU overhead in pixel operations, the algorithms, we developed, were optimized using parallel loops and direct memory access.

### 2) Motion Annotator

The second tool of MotiVo editor is Motion Annotator. This tool takes as an input, an image frame depicting a human action, (e.g., the produced image from Motion Blender) as well as a trajectory file containing the specific joints of the skeleton body as *(x, y)* coordinates in 2D space. The trajectory files are generated by the OpenPose output for a specific joint of interest, thus isolating the movement of this joint for visualization purposes. These *(x, y)* coordinates are visualized on the canvas of the loaded input image. The algorithm we have developed, highlights with artistic designs the specific coordinates provided by the 2D trajectory file. There are multiple ways of hi-fidelity artistic representations that can be depicted based on the trajectories (i.e., bullets, simple lines, comic style lines). The annotated points on the image frame denote the direction of the motion. For example, in the case of hand waving, by annotating the image with the retrieved points, it highlights the human hand trajectory during the activity (Figure 8).
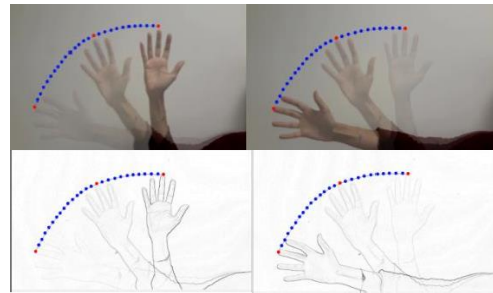


Figure 8. Motion annotations using Motion Blender (top) and Motion Annotator with trajectories extracted by Open Pose (bottom).

To smooth the visualized trajectories, we used composite Bézier curves. In computer graphics, a composite Bézier curve is a piecewise Bézier curve that is at least continuous. In other words, a composite Bézier curve is a series of Bézier curves joined end to end where the last point of one curve coincides with the starting point of the next curve [23].

### 3) Manual motion enhancer

In some cases, there is need for manual annotation of motion, especially where the context information is to be added to the visualization. To that end, we exploit the techniques used to create juxtaposed illustrations in comics. The manual motion enhancer is an editing component that allows users to load an existing image result from the project assets and manually enhance it by attaching ready to use concepts and icon sets (i.e., arrows, lines, etc.), such as those in comics (Figure 9).

### 4) Image filters

This tool receives as input an image file and provides a list of image filters that can be used image similar to the ones

used in popular image processing software [10][24]. Currently a wide array image transformations, color operations and artistic transformations are available. An example of edge detection is presented in Figure 10.
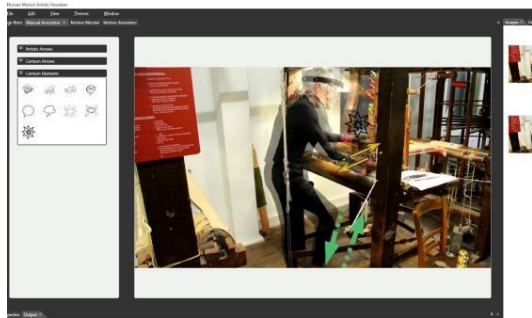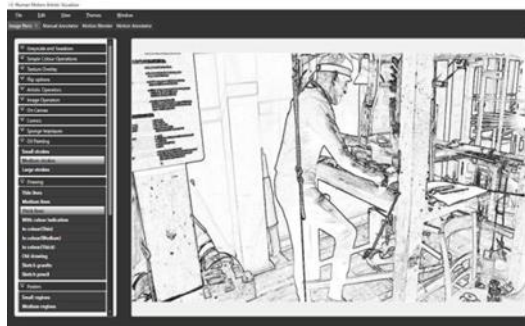


Figure 9. Motion frames enhancement using icon sets



Figure 10. Edge detection filter.

### 5) Scene composer

The scene composer was inspired by the depictions of crafts in art and photography (Figure 11). Its goal is to abstract human motion and tools to the minimum ingredients.



Figure 11. Depiction of tools grip and usage in the visual arts (left, middle) and moment of interest for Scene Composer (right).

As a result, scene composer is capable of depicting the essential parts of the craft so as to assist human perception and understanding and improve the development of captivating visualization for information and education.

Scene Composer is a tool that takes as input an overview of the scene from a static moment in the course of a craft action, (e.g., passing the shuttle through a loom). This static motion frame is then used by a computer vision tracker, capable of tracking the position and orientation of hands and

objects. An example of such a moment where both the hand posture and the tool orientation can be extracted (Figure 11).

In both cases, we march from the hypothesis that the tracker has already the geometry and texture of the object to be tracked, (e.g., a generic model of a hand or a 3D model of the tool to be tracked). In both cases, the tracker is estimating the Rotation and Translation and Scale of the object tracked (i.e., hand, or tool) and overlays the model on top of the given frame for abstraction and emphasis on the spatial arrangement of the critical actors in the scene. Scene composer is inspired by visualization in robotics, where they are used to create a human-comprehensible illustration of the model of that the robot has built for its environment. In Figure 12, an example of such a visualization is shown for the case where a robotic manipulator grips objects upon a table top. The visualization illustrates the location and poses that the robot has estimated regarding the objects on the table top (blue) and its own manipulator (red).
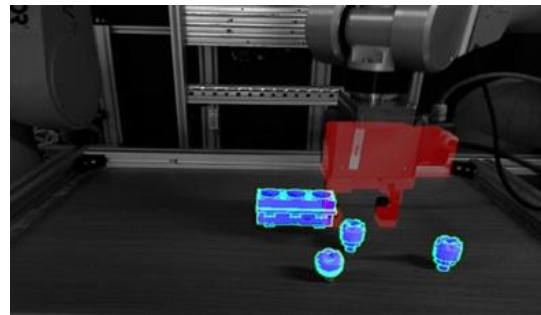


Figure 12. Illustration of object and robotic manipulator localization.

In Figure 13, the process of integrating information in static frames using the scene composer tool is illustrated. In the illustrations, on the right is the 3D model of the tool that is tracked and on the right the inference of the position of the tool at the imaged moment.



Figure 13. Visualization of tool usage.

### B. Extendable UI architecture

The main requirement of the system-UI architecture of MotiVo was to use a plug-in based software development pattern where there is a distinction between the main system and visualization tools. This distinction was important so as to develop an extendable motion visualization system where new components are added as new visualization tools arise. In such a context, it was decided that the main system should support the creation of project files and the assignment of assets to these projects (images, videos, Biovision Hierarchy (BVH) files, image trajectories, etc.). All tools should be then loaded as window components and should be drag-drop

enabled. Taking into consideration this main requirement, a dockable UI container architecture was selected, based on the one followed by Integrated Development Environments. In this architecture, components can be loaded and unloaded on the fly and new components can be loaded as plugins by integrating a new dockable window to the main window manager. Furthermore, this was considered a good option as one of the target groups of this tools are technical people with expertise on using dockable layouts. The only limitation is that typically such UIs may have a longer learning curve that simpler ones with the added value of extensibility and extensibility in the future. For the purposes presented above it was decided to structure the UI of MotiVo on top of the DevZest WPF Docking library [25].

## V.   EXPERIMENTS AND GUIDELINES

A formative evaluation was conducted in the context of the Mingei Innovation Action under the Horizon 2020 Programme of the European Commission [26]. The evaluation was based on images and videos of craft practitioner recordings in the context of the Mingei project. Based on these datasets, an expert-based evaluation was performed and several experiments were conducted with practitioners to assess our motion visualization strategies by using all the MotiVo tools. The outcome of those experiments formed a set of preliminary guidelines to address the needs of each individual tool.

### Guidelines

In order the users to use MotiVo editor efficiently, we propose some guidelines based on an expert-based evaluation.

*1)   Motion Blender*

After experimenting with weight values, we concluded that imaging settings play a significant role in the outcome.

Guideline 1: Prefer image sequences acquired through static camera.

Guideline 2: When working with a moving camera select a frame of reference where the camera is static and another one with multiple changes happening in the initial scene. This will improve the blending quality.

*2)   Motion Annotator*

Guideline 1: The use of 2D trajectories can be sometimes be non-representative. The total number of Points *(x,y)* should be sufficient for the trajectory visualization to be precise. Despite the fact that we use Bezier splines to design curves, the input files content should be a good starting point for the Motion Annotator.

*3)   Manual motion enhancer*

Guideline 1: Depending on the nature and style of the annotated image, users should choose graphic elements of similar style so as to fit the context.

Guideline 2: For comic style images, annotations should be comic styled or even multicolored whereas in the case of simple and minimal images, artistic arrows or other elements are the appropriate ones.

Guideline 3: Due to the fact that we are trying to visualize motion in 2D space, users are advised to adjust the projection on the annotation stickers so as to indicate the depth and direction of motion.

*4)   Image Filters*

Guideline 1: Motion filters may be a powerful tool for post and pre-processing results. Experiment with motion filters to have an overview of the potential outcomes.

Guideline 2: When a motion blending fails you can facilitate motion filters to simplify the input of motion blender and thus get better Visualization results.

*5)   Scene Composer*

Guideline 1: Make sure that source frames have sufficient information regarding the visualized-tracked object or hand (i.e., it is clearly visible).

Guideline 2: Avoid using frames where the position of the object can only be inferred through the position of the hand (non-occluded hand but occluded object).

*6)   Combined usage of tools*

Guideline 1: Create richer motion Visualization by combining several MotiVo tools in the same Visualization project (Figure 14).
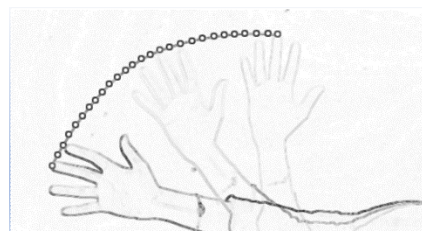


Figure 14. Visualization of tool usage through the estimation of hand and 3D model pose within the static motion frame

## VI.   CONCLUSION AND FUTURE WORK

This paper has presented an approach towards the visualization of data stemming from video recordings and visual tracking of human movement. Until now such visualizations were mainly targeted to the actual reproduction of motion in 3D or 2D space, such as for example the preview of MoCap output or the visualization of 2D pose estimations on top of the video or image sources.

Inspired by motion visualization in art, cinema and design we marched into implementing MotiVo, a motion visualization editor that is comprised of four distinct tools built on top of a plugin-based architecture capable of being extended and enriched in the future.

Based on the experience gained in this research work and the experiments performed in the context of implementing the visualization tools, it can be safely concluded that artistic visualization of human motion in 2D is technically feasible and can produce aesthetically pleasant results. Of course, human intervention is needed to orchestrate the appropriate selection of tools. This paper reports not only on the implementation of these tools, but

also through the experience during implementation and experimentation provides a set of best practice guidelines so as to get the most
[2] out of these tools.

The authors plan to enhance their approach by exploring the advances on style transfer algorithms to provide even better visualizations. Furthermore, the integration of 3D information to the static motion frames will enable the use of 3D data, in favor of motion analytics and visualization. Finally, video visualizations would be easily produced and even the isolation of the actors in a movement sequence would be facilitated, in order to reproduce them in another context, for example, in Virtual Reality (VR) training.

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