# Describing Movements for Motion Gestures

**Bashar Altakrouri**
Ambient Computing Group, Institute of Telematics
University of Luebeck, Luebeck, Germany
altakrouri@itm.uni-luebeck.de

**Andreas Schrader**
Ambient Computing Group, Institute of Telematics
University of Luebeck, Luebeck, Germany
schrader@itm.uni-luebeck.de

## ABSTRACT

Gestural interactions will continue to proliferate, enabling a wide range of possibilities to interact with mobile, pervasive, and ubiquitous environments. Particularly, motion gestures are getting an increasing attention amongst researchers. Likewise, a large adoption of motion gestures is noticeable on a commercial level. Motion gestures research strives to utilize the human body potential for interaction with interactive ecosystems. Despite the innovation and development in this field, we believe that describing motion gestures remains an unsolved challenge for the community to tackle and the effort in this direction is still limited. In our research, we focus on describing the human body movements for motion gestures based on movement description languages (particularly, Labanotation). In this paper, we argue that without adequate descriptions of gestural interactions, the engineering of interactive systems for large-scale dynamic runtime deployment of existing and future interaction techniques will be greatly challenged.

### Author Keywords

Natural User Interfaces (NUI); Gesture Interfaces; Motion Interfaces; HCI modeling; HCI documentation; Description Languages.

### ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g., HCI): Miscellaneous; H.5.2 Information interfaces and presentation (e.g., HCI): User Interfaces

## INTRODUCTION

Human Computer Interaction (HCI) research has continued to flourish, with an expanding world of interconnected devices and technologies driven by rich interaction capabilities. This innovation is fueled with increasing calls for HCI researchers to investigate new interaction possibilities. This has resulted into an increasing innovation in Gestural studies. Gestures in the HCI field have been closely related to human gesturing, which is extensively studied in different fields such as linguistics, anthropology, cognitive science, and psychology [20]. Principally, gestures describe situations where body movements are used as a means to communicate to either a machine or a human (revised from Mulder's definition of hand gestures [24]).

Gestures come in different forms such as motion gestures, facial expressions, and bodily expressions [24]. Moreover, they are often discussed, classified, and defined from various viewpoints and perspectives. The major part of human gesture classification research is focused on human discourse [31], but also extend to human/device dialog approach [29], input device properties and sensing technology [15], etc. This diversity has been reflected on the wide range and diverse gesture manipulation parameters, taxonomies, design spaces, and gesture to command mappings. Hence, the complexity to tackle many open questions regarding gestural interaction descriptions and languages is inevitably increased. Paradoxically, Scoditti et al. [30] pointed out that whilst sensor-based interaction research often presents highly satisfactory results, they often fail to support designers' decisions and researchers analysis. Bailly et al. [6] proposed a set of guidelines for gesture-aware remote controllers based on a series of studies and five novel interaction techniques, but the scope of their guidelines remains limited and is not scalable to other application domains or interaction techniques. Moreover, researchers have pointed out that Gestural research still lacks a well defined and clear design space for multitouch gestures [31] and motion gestures [29]. Furthermore, the bodily presence in HCI remains limited due to the subtlety and complexity of of human movement, leaving an open space for further investigations [23].

Principally, gestures are described and disseminated in various forms including written material, visual clues, animated clues, and formal description models and languages. In their work about formal descriptions for multitouch interactions, Hamon et al. [11] analyzed the expressiveness of various user interface description languages (an extension to [26]). Principally, modeling includes mainly data description, state representation, event representation, timing, concurrent behavior, and dynamic instantiation. Despite the existence of various approaches to describe touch-based interactions, the literature lacks a similar coverage for motion gestures. An extensive review on those approaches is out of the scope of this paper. Herein, we target our effort to describe the movement aspects of motion-based gestures, which we believe is not a well exploited research direction by the HCI community.

EGMI 2014, 1st International Workshop on Engineering Gestures for Multimodal Interfaces, June 17 2014, Rome, Italy.

http://ceur-ws.org/Vol-1190/.

Gesture description languages are relevant for the correct execution of interactions by end users, the preservation of technique by designers, the accumulation of knowledge for the community, and the engineering of interactive systems. Moreover, we argue that languages for describing various movement aspects of gestures are very important resources of context information about the gestures, which can be utilized by interactive systems for various reasons. For instance, filtering and selecting adequate gestural interactions could be based on the user's physical context. Recently, we have proposed a shift towards completely dynamic on-the-fly ensembles of interaction techniques at runtime [4]. The Interaction Ensembles approach is defined as "Multiple interaction modalities (i.e. interaction plugins) are tailored at runtime to adapt the available interaction resources and possibilities to the user's physical abilities, needs, and context" [4]. Engineering an interactive system of this kind imposes new dissemination (especially interaction description and modeling), deployment, and adaptation requirements and challenges to consider.

In this paper, we discuss the use of movement description languages for describing motion gestures and we present our approach of choice to tackle this problem.

## BACKGROUND AND RELATED WORK

Research on utilizing movements for interaction is spread over a wide research landscape. For instance, computer vision studies different approaches to visually analyze and recognize human motion on multiple levels (i.e. body parts, whole body, and high level human activities) [22]. Other research projects involve affective computing to study expressive movements as in the EMOTE model [9] and EyesWeb [8], movements visual analysis [1], and representation of movements [5]. The literature is also rich with examples on utilizing movements for interactions. Rekimoto [28] presented one of the earliest work on mapping motion (e.g., tilting) to navigate menus, interact with scroll bars, pan, zoom, and to perform manipulate actions on 3D objects. The research effort on tilting was then followed, especially in the mobile interaction area by Harrison et al. [12] and Bartlett [7]. Meanwhile, Hinckley et al.'s [16] idea of using tilting for controlling the mobile screen orientation is one of the most widely adopted techniques implemented in many mobile phones currently sold on the market.

In their work on movement-based interactions, Loke et al. [22] presented an interesting analysis on the design of movement-based interactions from four different frameworks and perspectives: Suchman's framework for covering the communicative resources for interacting humans and machines; Benford et al.'s framework (based on Expected, Sensed and Desired movements) for designing sensing-based Interactions; Bellotti et al.'s framework (Address, Attention, Action, Alignment, Accident) for sensor-based systems; and Labanotation as one of the most popular systems of analyzing and recording movement. In Benford et al.'s framework "Expected" movements are the natural movements that users do, "Sensed" movements those which can be sensed by an interactive system, "Desired" movements are those which assemble commands for a particular applications. In Bellotti et al.'s framework "Address" refers to the communication with an interactive system, "Attention" indicates whether the system is attending to the user, "Action" defines the interaction goal for the system, "Alignment" refers to monitoring the system response, and finally "Accident" refers to errors avoidance and recovery.

The richness of human body movements makes human movement an overwhelming subject for designing and engineering interactions. The hand and its movements, for instance, provide an open list of interaction possibilities. In his work, Mulder [24] listed just a subset of hand movements that reflects interaction possibilities, which included: Accusation (index pointing); moving objects; touching objects; manipulating objects; waving and saluting; pointing to real and abstract objects; and positioning objects. Moreover, he described and categorized hand movements into goal directed manipulation, empty-handed gestures, and haptic exploration. This classification reveals the potential of one individual part of human body. The goal directed manipulation category includes movement for changing position (e.g., lift and move), changing orientation (e.g., revolve, twist), changing shape (e.g., squeeze and pinch), contact with the object (e.g., snatch and clutch), joining objects (e.g., tie and sew), and indirect manipulation (e.g., set and strop). The empty-handed gestures category included examples such as twiddle and wave. Finally, the haptic exploration category included touch, stroke, strum, thrum, and twang. In the same work, he also indicated that there are other types of categorization base on communication aspects for example. Yet, this potential grows greatly when considering the rich nature of natural interaction techniques, as in whole body interactions and motion-based interactions for instance.

The notion of movement qualities is another well studied and applied topic in different fields, especially in dance and choreography. Despite the importance of movement for interaction, the HCI field does not yet explore this notion on the same scale. In fact, some argue that the primary foundations of movement qualities are very poorly discussed in the HCI literature [2], despite some recent research contributions as James et al. (interactions technique based on dance performance) [18], Moen (applying Laban effort dance theory for designing of movement-based interaction) [23], Alaoui et al. (movement qualities as interaction modalities) [2], and Hashim et al. (Laban's movement analysis for graceful interaction) [13]. The discussed work in this paper contributes to this area of research.

To our best knowledge, universal design guidelines for motion-based interactions are not easily found in the literature. Nonetheless, efforts to investigate and outline such guidelines are recently reported for specific application domains. For instance, Gerling et al. [10] proposed seven guidelines for whole body interactions created based on gaming scenarios and focused on elderly population.

Principally, one of the foundations of the work presented in this paper is to relay on human body movements as the central focal point in designing, sharing and executing motion gestures. This position puts human body movement at the core of our approach to describe gestures and our implementation of what we call movement profiles.

## DESCRIBING MOVEMENTS FOR MOTION GESTURES

Loke et al. [21] have presented an analysis of people's movements when playing two computer games, which utilize players' free body movements as input sensed by a basic computer vision. Their analysis included various ways to describe movement, ranging from the mechanics of the moving body in space and time, the expressive qualities of movement, the paths of movement, the rhythm and timing, and the moving body involved in acts of perception as part of human action and activity. Kahol et al. [19] proposed an intuitive method to understand the creation and performance of gestures by modeling gestures as a sequence of activity events in body segments and joints. Once captured, the sequences can be annotated by several different choreographers, based on their own interpretations and styles.

HCI researchers tend to preserve and describe the movement aspects of newly developed gestures using direct personal transmissions, written textual records, still visual records (e.g., images, sketches, drawings), and animated visual records (e.g., videos). Nevertheless, the aforementioned methods suffer from different drawbacks, which negatively affect the description quality, e.g., textual records are often too ambiguous, inaccurate, or too complex to comprehend; still visual records fail to convey timing and movement dynamics; and animated visual records are affected greatly by the capturing quality.

Previously in [3], we have argued that describing movement as an interaction element for ubiquitous and pervasive environments is a more challenging task because of the heterogeneity of users' needs and abilities, heterogeneity of environment context, and media renderers availability. We have also argued that the current documentation practices are not fully suitable for motion gestures because of the lack of standardized and agreed upon description methods for motion gestures. Current practices are too static and fixed to a particular media type, which may easily limit the target users of the interaction technique; current methods such as direct personal transmissions fail to scale with a massive user population; and current practices fail to clearly reveal the required physical abilities to perform the interactions.

To demonstrate one of the many issues regarding current documentation practices, Figure 1 and Figure 2 show two different drawings of the same interaction technique. The technique presented in the drawings is a simple arm swiping gesture. This gesture requires the user to position the left arm to the front parallel position to the ground (as a starting position), and move it to the left side to do a left swipe (for interaction). The two drawings depict the interaction differently using different drawing styles, angles, and ways to depict sequencing. Both drawings can be easily differently interpreted by users as well as peer-designers. This causes great variations in interaction understanding and execution. Moreover, this style of interaction description is not machine readable,

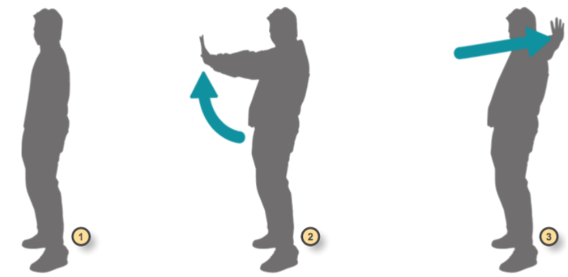


**Figure 1. Designer drawing 1: Documenting an arm swipe interaction by drawing**

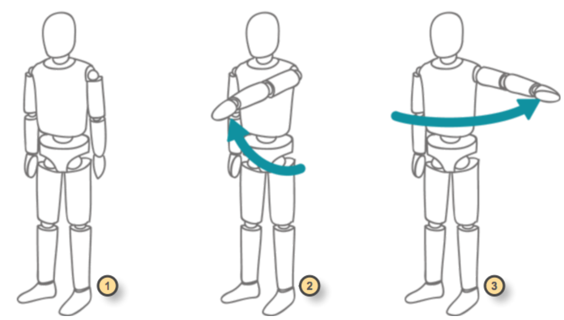


**Figure 2. Designer drawing 2: Documenting an arm swipe interaction by drawing**

hence challenging the design and engineering of interactive systems that utilize gestural interaction techniques.

Formal description models and languages are also used to describe or disseminate the developed interaction. In their work, Hamon et al. [11] analyzed the expressiveness of various multitouch user interface description languages. They argued that modeling should include data description, state representation, event representation, timing, concurrent behavior, and dynamic instantiation. Nonetheless, modeling and describing the movement aspects of motion-based gestures, the focus of this paper, is not well investigated.

Proper description of movements in motion gestures should therefore ensure a standardized machine readable and parsable language; generation of documentation learning and presentation material (e.g., visual records, and audio records) based on the context of the user and his environment; and methods for observing users' interactions in order to provide suitable feedback and adaptation to depict clearly the required interaction movements and physical abilities [3].

Labanotation is adopted for our approach due to its flexible expressive power and holistic power to capture movements in terms of movement structural description, analysis of patterns (shapes), and qualities of movement (efforts). Labanotation is a system of analyzing and recording movement, originally devised by Rudolf Laban in the 1920's. It is then further developed by Hutchinson and others at the Dance Notation Bureau [17]. Labanotation is used in fields traditionally associated with the physical body, such as dance choreography, physical therapy, drama, early childhood development, and athletics. Additionally, Labanotation fosters great flexibility that em-

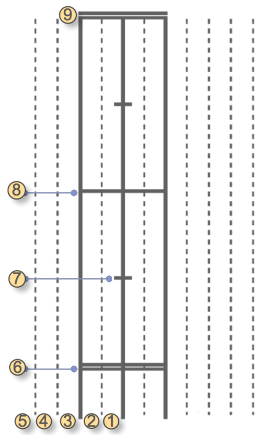


**Figure 3. Labanotation visual notations (staff)**

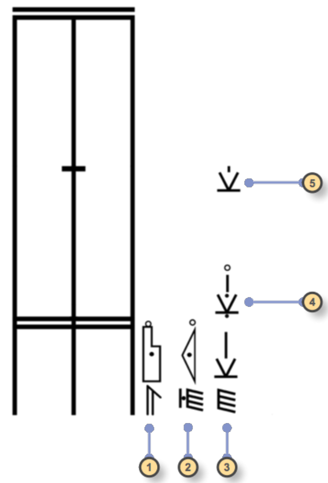


**Figure 4. Using Labanotation to document 3Gear pinch interaction technique (right hand)**

powers designers to describe all or any part of movements as required. In this paper, we particularly aim at the structural aspects of the movement.

In its current form, Labanotation is a visual notation system where symbols for body movements are written on a vertical "body" staff. Each element in the notation has a dedicated Labanotation symbol, which is used to present and document various movement qualities. Figure 3 illustrates the Labanotation staff. The staff is used as the layout for all involved movements. Each column, from inside out, presents a different body part. Column (1) presents the support (i.e., the distribution of body weight on the ground). Columns (2) to (4) present leg, body, and arm movements respectively. Column (5) and additional columns can be defined by the designers as required. The most right column is defined for head movements. The designer is still able to change this order as required by redefining any columns except (1) and (2). The staff is split into different sections. The symbols before the double lines, indicated by (6), present the start position. Moreover, the movements components appear after the position lines in terms of measures (horizontal lines as in (8)) and beats (horizontal short lines as in (7)). The measures and beats define the timing of the movements. The right side and the left sides of the staff correspond to the two sides of the body involved.

In Figure 4, a simple 3Gear[1] pinching gesture for the right hand is modeled in Labanotation and its corresponding XML representation is presented in Listing 5. The Figure 4 is read as follows: (1) The right arm starts at a 90-degree angle to the rest of the body pointing forward. (2) The palm of the hand points to the left and should remain so during the interaction. (3) The right hand is naturally curved. (4) The right hand is curved and the fingers tips touch each other. The position of the fingers should be held for short time. (5) The hand returns to the natural curve quickly with the fingers naturally spread.

The visual notation aims at a human readable approach for describing and reading movements, but is not adequately machine readable. Therefore, we have designed a compliant XML scheme that is both machine and human readable.

[1]http://www.threegear.com, accessed on 03.04.2014

There have been a few previous research attempts to provide XML presentation of Labanotation such as MovementXML [14] and LabanXML [25] in the area of dance representation. Nonetheless, the efforts were neither aimed at describing gestural interactions nor have they been widely adopted.

This scheme allows translating the notation to a machine readable representation of the motion gesture description. Clearly, the representation illustrated in Figure 4 is not targeted at end users due to its speciality. The representation (in its visual and XML code) provides an exact description of the movement that can be only correctly interpreted by interaction designers and developers, as well as interactive systems. Nonetheless, user friendly readable descriptions for end users are possible to be generated automatically based on the XML code by interactive systems (a detailed discussion in this direction is out of the scope of this paper).

Generally, increasing the description details will result into a fine preservation and execution of movements details. Nonetheless, this inevitably causes a large movement profile that results into an increasing complexity of reading and interpretation. On contrary, reduced details result into a simple movement description that is easy to read and interpret. Nonetheless, this leads to losing the details of movements.

## LABANOTATION XML SCHEME

Our approach based on Labanotation aims at a robust and standardized description of movements in motion gestures, whereby the transmission and preservation of motion gestures become possible. Nonetheless, the modeling of Labanotation is challenging due to the extensibility of the notation, size, and variations of symbols.

In the scope of this work, a subset of Labanotation is considered. Nonetheless, the extensibility of this scheme is still possible. The current scheme mainly targets the following structural elements: direction symbols, pins and contact hooks, space measurement signs, turn symbols, vibration symbols, body hold sign, back-to-normal sign, release-

```
<laban:movement>
 <laban:column>4</laban:column>
 <laban:measure>0</laban:measure>
 <laban:beat>0.0</laban:beat>
 <laban:duration>1.0</laban:duration>
 <laban:preSign>
 <laban:bodyPart>
   <laban:surface>
    <laban:limb>
     <laban:custom>
     <laban:extremity>
       <laban:joint>
        <laban:joint>hand</laban:joint>
      </laban:joint>
     </laban:extremity>
     </laban:custom>
    </laban:limb>
    <laban:side>inner</laban:side>
   </laban:surface>
   <laban:side>right</laban:side>
 </laban:bodyPart>
 </laban:preSign>
 <laban:hold>false</laban:hold>
 <laban:direction>
  <laban:vertical>middle</laban:vertical>
  <laban:horizontal>left</laban:horizontal>
 </laban:direction>
</laban:movement>
```

**Figure 5. Movement profile: 3Gear right pinch interaction technique (excerpt)**

contact sign, path signs, relationship bows, room-direction pins, joint signs, area signs, limb signs, surface signs, a universal object pre-sign, dynamic signs, and accent signs.

Figure 6 (left) illustrates an overview over the movement profile XML scheme. The original Labanotation naming is preserved to insure compatibility and readability of the scheme. As shown in the figure, the staff is defined in terms of timing information (measures and timing) and the body parts involved (by defining the columns), and movement components are defined in the movements element. The movements element contains a collection of elements to define the individual movements, path, the movement directions, relationships, and phrasing (connecting individual movements together).

Figure 6 (right) illustrates a close overview on the movement element. In this element, a single individual movement is fully described. The information modeled includes placement in the score (defined by the column element), timing information (beats, measures, and execution duration), the body part(s) involved (defined by the preSign), and movement quality such as direction, space, turn, and vibration. The number and detailed level of movements modeled depend on the designer. The design should model just enough information for ideal execution of the movement.

## DISCUSSION

Describing movements for motion gestures is a challenging process and imposes a number of open issues (only some are discussed in this paper):

- **Support of dynamic interactive systems**: The lack of adequate interaction documentation and dissemination leads inevitably to challenge the design and engineering of interactive systems. Documentation can be used to extract information about the type of movements involved in the interaction, involved body parts, adequate interaction execution, etc. The absence of such information will necessarily lead to burden the deployment of interaction techniques in automated interactive systems, especially processes such as context acquisition, reasoning, interaction filtering, etc. are greatly hindered. Good record-keeping of motion gestures should guarantee to preserve and transfer the technique to users and other peer designers without endangering the originality and vital aspects of the technique.

- **The tension between formal and empirical movement descriptions**: Formal interface description languages support interaction at the development as well as the operation phase, while conventional empirical or semiformal techniques lack to provide adequate and sufficient insights about the interaction (e.g., comparing two design options with respect to the reliability of the human-system cooperation) [26]. Those techniques are more susceptible to losing parts of the movements, overly complicated descriptions, losing timing information, etc. Nonetheless, a wide adoption of formalized languages amongst motion interaction designers is challenged by the potential complexity of language learning and movements description.

- **Meeting future challenges**: New interactive systems are targeted to achieve ad-hoc composition of multiple interaction techniques; de-couple the close binding between devices, interaction techniques, and applications; and address user physical needs and preferences [4] [27]. This shift imposes new requirements and challenges the current practices for describing motion gestures. To meet those challenges, gestures should by transparent to reflect their internal functionality and physical requirements for intelligent interactive systems.

- **Limited research effort**: We argue that this area of research requires a lot of attention for the community including: a better understanding of gestures and their requirements; guidelines for describing gestures; new authoring and design tools for motion gestures; and better understanding of the users' learning habits and practices for learning motion gesture.

## CONCLUSION

In this paper, we have argued that adequate movements description of motion gestures is very relevant to the correct execution of interactions by end users, the preservation of technique by designers, the accumulation of knowledge for the community, and most importantly for the process of designing and engineering interactive systems. Moreover, languages for describing the movement aspects of gestures are very important resource of context information about the gestures, which can be utilized by interactive systems for interaction filtering, adaptation, and dynamic on-the-fly deployment at runtime. Herein, Labanotation as a flexible and extensible movement documentation system is adopted for describing the movements aspects of gestural interactions.

## FUTURE WORK

We continue our work on an authoring tool called Interaction Editor [3], which aims to ease the workflow for describing the movement aspects of gestural interactions for gesture developers and designers. Moreover, one of our active areas

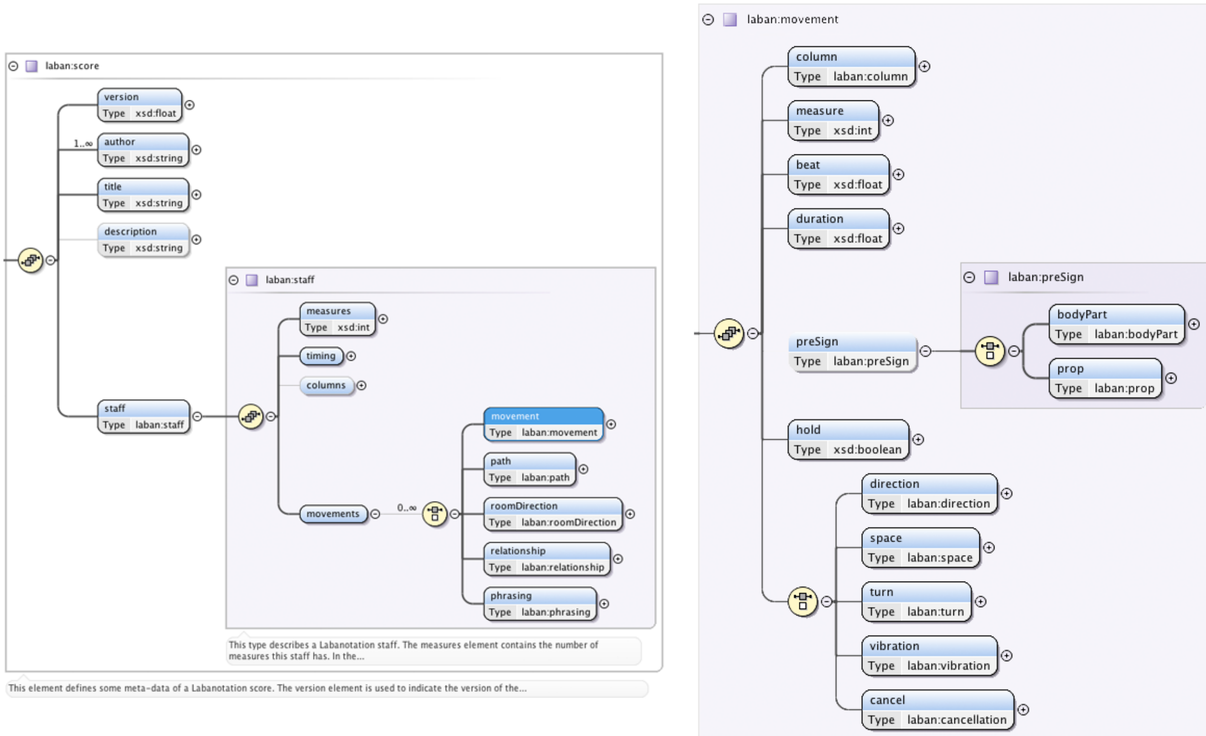


**Figure 6. Movement profile scheme - movement element (high-level overview)**

of research continues to investigate the real practices for describing gestural interactions applied by the HCI community.

## ACKNOWLEDGEMENT

This work was partially supported by the Graduate School for Computing in Medicine and Life Sciences funded by Germany's Excellence Initiative [DFG GSC 235/1] and by vffr (Verein zur Förderung der Rehabilitations- Forschung in Hamburg, Mecklenburg-Vorpommern und Schleswig-Holstein e.V.) We also thank Michal Janiszewski for drawing the design sketches in Figure 1 and Figure 2.

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