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XML Skeleton Definitions for Human Posture Assessments

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Abstract. In this paper, we show how the XML dialect SKAML (Skeletal Assessment Markup Language) can be used to use data from one or more Motion Capture systems to perform human posture assessments with multiple assessment methods. We show an implementation example using an inertial measuring suit and both OWAS and REBA assessment methods. SKAML makes it possible to implement classifiers for a Motion Capture system once and adapt the classifier *by-configuration* to various ergonomics assessment methods. We anticipate our work as help for researchers and developers that implement new assessment methods or motion capture systems.

Keywords. Skeleton markup, motion capture, posture assessment, posture classification, musculoskeletal disorders, SKAML, OWAS, REBA

1. Introduction

One of the primary causes of unfitness for work and early retirement for workers in physically demanding occupations are musculoskeletal disorders (MSD) [1]. Appropriate preventive measures may delay or even prevent the emergence of MSDs if the individual or workplace-related risk factors for MSDs are identified early [2].

A task that was -- and often still is -- performed using manual pen-and-paper assessment methods such as OWAS [3], REBA, EAWS, and others. Despite the practical usability of manual assessments, they have drawbacks and limitations: observer bias, limited view of human observers, non-repeatability, no automatic documentation and post-processing. As a result Motion Capture (MoCap) systems are increasingly used for ergonomics assessments, i.e., the determination of risk factors for occupational diseases, e.g., work-related musculoskeletal disorders (WMSD) [4]. Researchers that must implement a method for ergonomics assessment in software (to use it in conjunction with MoCap systems) define skeleton model as well as the rules of the assessment method in code, which is costly and error-prone. However, if the MoCap system is to be replaced by another system, e.g., by an inertial measurement system with less or more sensors, this provides another skeleton and probably does not provide spatial joint coordinates but relative limb orientations. For example, an optical MoCap system such as Kinect provides a predefined abstract Skeleton structure and updates the spatial joint coordinates accordingly. A computerized assessment method must be specifically adapted to this pre-defined skeleton to work properly. Here the description of an abstract skeleton structure that can be annotated to support multiple MoCap systems, as well as multiple assessment methods, is needed.

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The Skeletal Assessment Markup Language (SKAML) [5] used here has been developed to fill a need for a method to combine the input of different Motion Capture systems with the various available methods for assessing postures and motions.

2. State of the Art

There are various markup languages for several aspects of human behavior (e.g., HBML) to virtual avatars (e.g., HumanML), but to our knowledge, no markup language for the description of abstract skeleton representations in combination with motion capture and ergonomic assessments exists.

However, with the Unified Robot Description Format (URDF) [6], there is an XML markup language that allows robots to be modeled in their (possibly humanoid) structure as well as their movement capabilities. URDF starts at a relatively low level and allows, for example, the modeling of robot geometry from geometric primitives. The link with ergonomic assessment methods was apparently not considered.

The Motion Capture Markup Language (MCML) [7] aims for the integration of heterogenous MoCap file formats. The MCML is similar to SKAML with its approach to improve the usage of multiple MoCap systems with its different file formats. The language models the data close to the actual MoCap formats whereas SKAML tries to model the human skeleton on a more abstract level leaving details of the MoCap system to the implementor of a digitized assessment method.
Nevertheless, the authors of MCML recognize the importance of open and easy-to-implement formats and propose an XML-based markup language, too. MCML lacks the conjunction with assessment methods.

3. Concept

The Skeletal Assessment Markup Language proposed here fits into the gap of XML-based description languages between descriptions of human motion on an abstract level and descriptions of the human biomechanics. SKAML describes the skeletal system of a human body from a full-body motion capture observer perspective. It is not possible nor intended to describe details of the human biomechanics with SKAML. Implementors may refer to the XSD-specification[2].

3.1. General

On the technical side, SKAML allows the definition of simplified skeleton structures mainly consisting of joint and bone definitions. Root of an SKAML-document is the `<body>` tag, which has the direct child `<skeleton>`. A skeleton consists of a set of joints and bones. The `<joints>` tag contains one or more `<joint>` tags. Each joint may have one or more children so that the topology of joints (kinematic tree) can be described, e.g., a joint *hip* has two child joints *back_mid* and *femur_left* each having children as well:

[2] See http://www.skaml.org/SKAML.xsd

```
<joint id="hip">
    <joint id="back_mid"><joint id="neck"/></joint>
    <joint id="femur_left"> ... </joint>
</joint>
..
<bone id="arm_right" from="ellbow_right" to="hand_right"
length="0.279">
```

Bones of the skeleton can be defined using the bones tag followed by one or more bone tags. A bone is defined as a rigid connection between two joints.

3.2. Sensor Input

In a motion capture scenario using an inertial sensor suit, IMUs (Inertial Measurement Units) are placed on the limbs, in most cases around half the distance between two joints on the limb. One can model this using an abstract sensor definition and attach it to a bone definition, e.g.

```
<bone id="upper_spine" from="neck" to="back_mid">
    <sensor type="IMU" id="5" transformation="1 0 .. 0 1" />
</bone>
..
<joint id="ellbow_left">
    <sensor type="Kinect" id="ELLBOW_LEFT" />
</joint>
```

The transformation attribute is a 4x4 matrix that describes the translation and orientation of the sensor on the bone originating at the start joint if applicable.
It is also possible to attach a `sensor`-tag to a joint, which is useful if the motion capture system provides joint coordinates. This is the case for most optical MoCap systems, e.g., Kinect.The sensor type is not enforced by SKAML but application-specific.

3.3. Assessments

SKAML allows for the definition of various skeleton structures. Screening methods for posture or motion assessments consider only specific joint or bone combinations, in most cases different to the structure defined in SKAML. To address this, an assessment tag was introduced. The tag can be placed as child to a joint or bone, e.g.

```
<joint id="joint42">
    <assessment type="OWAS" joint="FOOT_RIGHT"/>
    <assessment type="REBA" joint="FootR"/>
</joint>
```

The attributes type and joint of the assessment tag refer to user-defined strings, i.e., identifying strings specific to the used assessment method and software.
With the assessment tags, the model skeleton on one side and the assessment method on the other side are loosely coupled.

4. Implementation

In this section we show how to use SKAML to implement a classifier for OWAS [3] assessment method using motion data coming from a Kinect sensor as well as IMU-based motion capture suit. The software for the classifiers is only implemented once, and the adaption for both Motion Capture systems is done using a SKAML document.

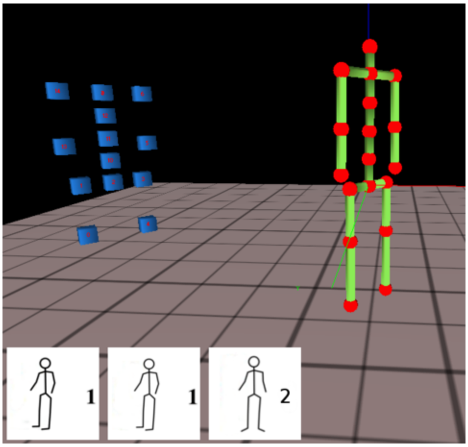

Figure 1: Skeleton visualization (center) based on SKAML description utilizing IMU-sensor data (blue cubes on the left) classified by an OWAS classifier (OWAS posture with code 112).

The software shown in Figure 1 was created for the SIRKA sensor suit [8]. The application can load recorded motion capture data from a file, both Kinect and SIRKA sensor suit. We created a SKAML configuration for each MoCap system for easier handling, although it would be possible to combine both configurations in one file. Once data and configuration are loaded, the classifier code can use some generic load functions to access the skeleton (C++ in our implementation):

```
Skeleton* skel = SKAMLLoader->loadFromFile(..);
..
// getGenericBone expects an assessment id (here: OWAS)
// and a bone id specific to this assessment method
Bone* bone_upperarm_l = skel->getGenericBone("OWAS", "ARM_LEFT");
..
bone_upperarm_l = skel->getGenericBone("REBA", "upper_arm_left");
..
// access bone properties
bone_upperarm_l->getOrientation();
bone_upperarm_l->getLength();
```

We have modeled classes for the SKAML entities Skeleton, Joint, and Bone, which provide methods for accessing both markup properties (e.g., length) and sensor-based properties (e.g., orientation matrix/quaternion for given timestamp). The assessment method classes are using the generic Bone and Joint objects as shown above, so one can change the underlying MoCap system without changing one line of code in the classifier.

5. Lessons Learned

An XML description language was introduced that allows the definition of abstract body skeletons that can be annotated for various MoCap systems and various ergonomic assessment methods.

We have shown that the description language can be easily integrated into software applications. SKAML makes it possible to increase the maintainability, reusability, and adaptability of the software. This reduces the development effort for new technologies and methods. Also, the formalization of the description avoids errors and enables automatic consistency checks using the XSD grammar. Additionally, SKAML may be used in conjunction with formally defined digitized assessment methods, e.g., formulated using Arden Syntax [9].

In subsequent additions, we plan to expand SKAML by modeling motion constraints, and we will provide an Open Source library (libskaml) as a convenience for developers and researchers.

6. Conflict of Interest

No potential conflict of interest was reported by the authors.

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