WP 1

D1.3

Verification of the Multifactorial Fall Risk Model and Guidelines for its Adaption

Category: Deliverable

Author(s): Patrik Eklund (editor),
Milla Immonen, Jonas Jalminger, Lars-Åke Johansson, Antti Konttila, Heidi Similä

Verification: Carlos Garcia Gordillo, Tuula Petäkoski-Hult

Date: 5 April 2013

Status: Final version

Availability: Public

Contents

1 Introduction

Task T1.3 covers fall risk decreasing interventions aiming at behavioural changes of the older adults, as based on the multifactorial fall risk model. In effect this means that an intervention can aim at decreasing fall risk directly by setting up the care plan, implementing it, and ensuring that the older person actually complies with the suggested intervention. The intervention can be an instant event, basically without any duration, e.g. focusing on an environmental factor such as removing a loose rug or installing a grab rail in a bathtub, or more like a process with a progress and duration, where e.g. persuasive technology of various kind may be part of tools by which the older person's behavioural change is observable and leads to measurable effect with respect to fall and fall risk.

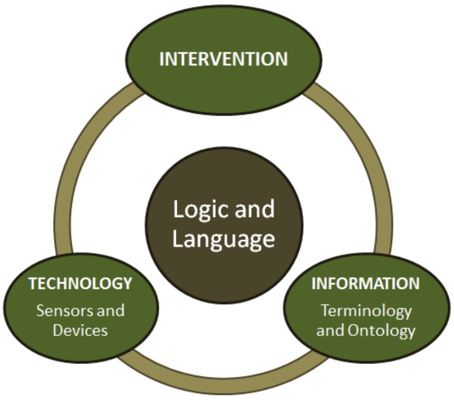


Fig. 1: The intertwining and cyclic nature of interventions, technology and information.

Verification is in this deliverables taken in the sense of T1.3, including device based verification of interventions, as utilizing the risk models presented in D1.1 and D1.2. The detailed and structured list of interventions, and the detailed specifications of devices and information enabled by respective devices, is yet to be provided. The guideline for adaption of the risk model is therefore a recommendation about how interventions and/or intervention models and processes are to be verified. In effect, this means that the fall risk model and the intervention model should blend into the same conceptual scope.

This deliverable also aims to be quite precise about the statistical and logic models underlying the verifications.

2 Some remarks on verification of fall risk factors

Fall risk is, on the one hand, a probability which is the outcome of an assessment of fall risk factors. On the other hand, fall risk is seen as a logical truth degree. The presence of a risk factor is similar, In ICF, the set of logical truth degrees are the following:

xxx.0 NO problem	(none, absent, negligible,…)	0-4 %
xxx.1 MILD problem	(slight, low,…)	5-24 %
xxx.2 MODERATE problem	(medium, fair,...)	25-49 %
xxx.3 SEVERE problem	(high, extreme, …)	50-95 %
xxx.4 COMPLETE problem	(total,…)	96-100 %
xxx.8 not specified		
xxx.9 not applicable		

This means e.g. that an environmental risk factor like ’obstructed walkway’ could use the ICF logical truth degrees in order to express presence of that risk factor e.g. in terms of ’mildly obstructed walkway’ or ’severly obstructed walkway’.

The degrees xxx.0 to xxx.4 can be seen as an ordered set of truth degrees including five points, where it is tempting to say that ’xxx.0’ is logically ’false’ and ’xxx.4’ is logically ’true’. However, this binding should not be done at a syntax level, but may be considered on a semantic level. Note that there is, from implementation point of view, an important distinction to be made between ’xxx.8 not specified’ and ’xxx.9 not applicable’, the former basically saying that a truth degree has yet not been provided, and the latter basically saying that the typing of the factor is not applicable. Note also that ’xxx.8 not specified’ is not split into the meanings of ”deliberately not specified” in the sense of ”possibly never to be specified (even if applicable)” and ”not yet specified” in the sense ”not yet, but most probably later”.

Note also that the coding of environmental factors is different as it considers ’facilitator’ and ’barrier’ in coding. Then ’problem’ in truth degrees become ’barriers’

xxx.0 NO barries	(none, absent, negligible,…)	0-4 %
xxx.1 MILD barries	(slight, low,…)	5-24 %
xxx.2 MODERATE barries	(medium, fair,...)	25-49 %
xxx.3 SEVERE barries	(high, extreme, …)	50-95 %
xxx.4 COMPLETE barries	(total,…)	96-100 %

and ’facilitator’ is represented by

xxx+0 NO facilitator	(none, absent, negligible,…)	0-4 %
xxx+1 MILD facilitator	(slight, low,…)	5-24 %
xxx+2 MODERATE facilitator	(medium, fair,...)	25-49 %
xxx+3 SEVERE facilitator	(high, extreme, …)	50-95 %
xxx+4 COMPLETE facilitator	(total,…)	96-100 %

As an example of providing terminology for muscle function related fall risk, we may use e.g. ICF’s neuromusculoskeletal and movement-related functions, including functions of the joints and bones (ICF b710-b729), *muscle functions* (ICF b730-b749), and movement functions (b750-b789). Muscle functions in turn subdivide in ICF e.g. into *muscle power functions* (b730), muscle tone functions (b735) and muscle endurance functions (b740). Muscle power functions subdivides further, e.g. with *power of muscles of all limbs* (b7304) being a specific muscle power function for which no further subdivision is provided within ICF. Power of muscles of all limbs related to *the force generated by the contraction of muscles and muscle groups of all four limbs*, and inclusions are impairments such as *tetraparesis* and *tetraplegia*.

In the D1.1, the risk factors related to muscle strength appearing in impaired postural stability is coarse granular and indicative only

- ✓ Muscle strength

but based on the ICF granularity could be enhanced to become

- ✓ Functions on the joints and bones (b710-b729)
- ✓ Muscle functions (b730-b749)
  - o Muscle power functions (b730)
    - ▪ Power of isolated muscles and muscle groups (b7300)
    - ▪ Power of muscles of one limb (b7301)
    - ▪ Power of muscles of one side of the body (b7302)

        - Power of muscles in lower half of the body (b7303)
        - Power of muscles of all limbs (b7304)
        - Power of muscles of the trunk (b7305)
        - Power of all muscles of the body (b7306)
        - Muscle power functions, other specified (b7308)
        - Muscle power functions, unspecified (b7309)
    - Muscle tone functions (b735)
    - Muscle endurance functions (b740)
- ✓ Movement functions
    - Muscle functions
        - Alzheimer’s disease

where ’muscle strength’ in D1.1 can be identified with ’muscle power functions (b730)’ in ICF.

The risk factors listed in D1.1 are all verified in the respective professional literature, and the main references have been provided in D1.1. In studies on effects of rehabilitation, the preciation of factors is not always unified, and comparing studies is sometimes like ’comparing apples and pears’. Furthermore, studies appear in different times, some before to 1980’s, some before 2000, and some mire recent than that. Underlying ontologies and terminologies, like the ICF, have emerged over time, but many studies almost ignore the existence of these terminologies.

The World Health Assembly officially endorsed the International Classification of Functioning, Disability and Health and the acronym ICF in May 2001. The predecessor of the ICF was the ICIDH (International Classification of Impairments, Disabilities and Handicaps) and was originally intended for "effects of chronic conditions such as arthritis and the long-term effects of rehabilitation". ICIDH was published by WHO in 1980 as a "manual of classification relating to the consequences of disease" and further as a "conceptual framework for information".

For many risk factors there is not only studies confirming the effect of a particular risk factor on increase risk of fall. In fact, for many well-known risk factors there are many studies, and often the studies confirm each other, which makes such risk factors particularly believable and accepted by the professions. However, there are also risk factors showing only weak evidence, or risk factors for which some studies do provide verification, but other studies have not been able to reproduce that evidence. In some of these case, the circumstances of the study is different and the targets are not comparable. Muscle strength may then serve as an example where different studies use their own meanings Furthermore, as pointed out in D1.2, the definition of fall is not all that accurate, and researchers often select their targets for falls that reflect the needs of particular studies. For instance, if it is desirable to analyze the effect of drugs for fall, studies may include targets with less cognitive decline and reasonbale good postural control, whereas studies on dementia related to fall may want to exclude other factors ”interferring” with analysis of factors in focus.

All this makes comparison of studies quite difficult, and the literature cannot point at ”canonical” results. It must also be said that statistical methods are only generally unified, and the interdependence e.g. of t-tests, z-tests, χ^2 tests and F-tests only follow standard statistical jargon.

It is often said that a main reason for non-comparability of studies is the selection of populations for respective studies. Little, however, is said about the typing of information. Sedatives may provide an example where saying ’no/yes’ for sedatives is not all that precise as some studies may include subsets of sedatives not comparable with subsets of sedatives used in other studies. The same remark is bascially valitd for almost all risk factors.

Hypothesis testing in general is not free from potential flaws appearing in comparison of analytics, e.g. as there are a number of mathematical justifications for the Gaussian distribution. Indeed it has to be said that the underlying assumption of various test in form of ”close to being normally distributed” is never questioned, but it is kind of taken as an axiom that in fact variation in data *is* normally distributed so that every uncertainty in the hypothesis testing is due the calculated overlap e.g. between positive true and positive false. Tests do not come attached with an estimation about how much the data deviates from being classifiable according to the that normal distribution. Furthermore, it’s all about the Central Limit Theorem which is theoretically quite in order, but speaks about what happens when things converge in the limits, and indeed when distribiutions are precisely normal. In reality they never are, and in practice we are never even remotely close to the limit (infinity!), so medical so called *evidence-based reasoning* is at most *modulo* this assumption. Every computional guideline related to complying to statistical power is therefore *modulo these assumptions*, for which in fact the truth degree of these assumptions is never aggregated with the statististical results.

Furthermore, hypothesis testing is based on measuring cardinality, i.e., counting elements in sets. This is also why statistics makes a logical assumption of being true-false in that an element is part of that set, or it isn’t. Downton’s scale may serve as an example in this respect. The eleven questions in the questionnaire are logical ande boolean in the sense of the answer to each question being true or false. This truth value is intuitively seen as a number being 0 or 1, and arithmetic with these ”numbers” is performed without any scruples.

Statistics speaks eloquently about typing of data but this typing has basically nothing to do with typing as recognized within signatures used in mathematical logic. Typing in statistics is informal, and often leads to ambiguities so that different studies may interpret that typing in different ways. A typical example is when tryuing to distinguish binary, nominal and ordinal data. Binary data is said to be e.g. the no/yes or male/female type of data, where we would say it is either or in a crisp way. Here no/yes is more clearly a false/true situation but in fact male/female is also a false/true situation since if not (male) is true then female is true, and wise versa. The logical meaning of two-valued data as used in statistics is two-valued truth values as used in establishing if a target belongs or does not belong to a certain set. As a typical example of nominal data the single/married/divorced/widowed is often mentioned, and ICF’s no/mild/moderate/sever/complete is usually called an ordinal scale. However, the naming is clearly misleading. A single person marries, and may become divorced or widowed, but may marry again so becomes married. The scale is then not purely nominal, since a person cannot become widowed without having been married. Further, saying married, does not per se inform about married from a single stage, or married from a divorced or widowed state. Different studies may provide different interpretations of ‘married’ and obviously then these studies are by definition not comparable. ICF’s scale is not actually ordinal but logically many-valued. Clearly, some sets of truth-values in many-valued logic are totally ordered, so they are “ordinal” in some sense, but this particular scale is more many-valued than ordinal, since e.g. “moderate” means in fact that a target is “moderately a member” of a particular set. A nominal scale like none/1/2/3/4/more on the other hand would more clearly seek for “how many” and expressing that ordinally in the true sense of the set-theoretic concept of ordinal. This brings us to the remark that we should never speak about “ordinal” but “cardinal”, because this what we do mathematically when we “count finite numbers”. Cardinal arithmetic is what we use for arithmetics, not ordinal arithmetics which is used when going beyond infinite and computing with “infinitely large numbers”.

3 On the formal ontology for risk factors

Statistical methods are well rooted in evidence-based medicine and other areas of medical, social and ntural sciences. Data analytics is indeed broadly based on statistics with bivariate methods, typically using hypothesis testing in various forms, and multivariate approaches, e.g. using principal component analysis, neural networks, or Bayesian techniques. Non of these are logical in nature, so when statistical findings are to be converted e.g. into logic based guidelines and decision-support, the underlying logical framework is missing and has to created. Proposing that logic language then has to be justified, and if such logic considerations haven't been made prior to statistical analysis, logical justifications become ad hoc and even suspicious. Therefore any logic consideration must be done already at data collection stage, where data is attributed to types and data operations, eventually becoming integrated as terms in sentences and further in rule bases, are anticipated at a very early stage. Thereby analytics and reasoning become appropriately intertwined.

The need and potential use of accurate typing of data and information, related to risk factors and as appearing in assessment scales, is a key success factor when aiming at combining the potential use of statistic results with their utility in rule bases as appearing in guidelines. Strictly speaking, an assessment scale is logically speaking an operator in the 'Gerontium signature'.

The Gerontium XML File implements the 'Gerontium signature', and this then also a justification for using XML File rather than XML Schema. The reason is that a schema compromises the underlying logic so that the typing would be decided by the built-in typing, e.g., of the underlying SQL Server. When using XML File we can formulate the whole file as a 'term' in the sense of produced by a formal term construction, which formally can based on the concept of signatures over monoidal closed categories[1]. Roughly speaking, the XML File is closer to the OAD logic, whereas the XML Schema would be closer to the SQL Server, and the desirable approach is that logic defines eventually the database structure, and not the other way around. This provides the desired flexibility.

4 Data from devices sensors and devices

Sensors and devices produce and deliver data in different formats and pre-processed in various ways. Some sensors provide more or less raw data and signals, without filtering the data in any way, and the device may not come with any API (Application programming Interface) supporting the developer to have encapsulated data. Other sensors come without sophisticated APIs and even SDKs (Software Development Kit) that support developers in management of sensor data.

The right-hand path of Fig. 2, from devices and sensors to end-user applications, is typically represented by various MEMS, where the programming support is more shallow, whereas the left-hand side is typical e.g. for Microsoft's Kinect.

Servers and database management appear in the system architecture and are treated as required by the customer and end-user. Sometimes servers suffice to manage data and information without database management, sometimes database management alone is used to replace and simplify many web services functions, but proper and sustainable system development pays attention to the complementary and overlap between utility of web services and databases.

[1] P. Eklund, M.A. Galán, R. Helgesson, J. Kortelainen, *Fuzzy terms*, Fuzzy Sets and Systems, accepted for publication.

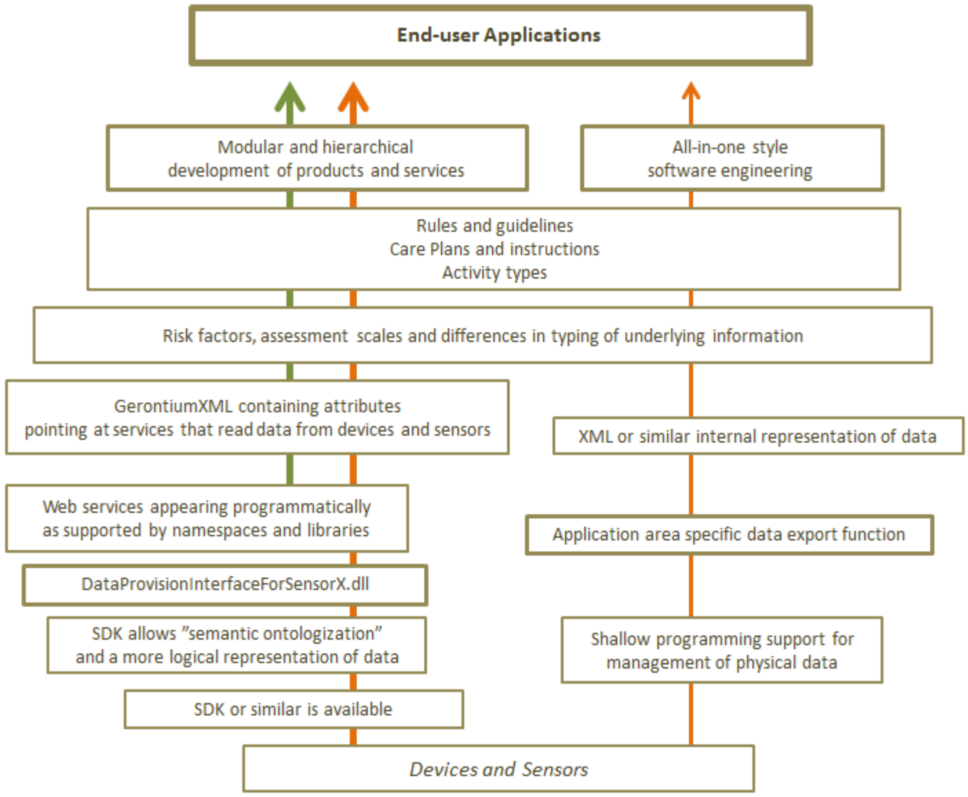


Fig. 2: From devices and sensors through middleware components in service-orientedness all the way to applications and user interfaces.

Shipping data and files back and forth between server and application without using web services in between can be achived by straighforward use e.g. of HTTP methods GET and POST methods, or using FileUpload for posting in ASP.NET. In such a case, web applications would be of style "all-in-one" engineering with a corresponding management of the GUI. This is usually quite quick-and-easy, and web service technology is typically not included. However, when we go for a broader spectrum of risk factors and assessment scales we start to have structure, and then straightforward and simple manipulation of numbers in data files cannot be recommended. We then need something more systematic, and web services come to rescue. Note also that web services allows for threading of executions, and we are able to scale up, when and as required. Scaling up usually means moving from data in files to data in databases. Note that for SQL we have a similar situation, namely, that SQL in a web application can be directly included in the code behind with DB connection strings (including usernames/passwords!) appearing in the web.config file (speaking in terms of IIS rather than Apache as HTTP server). This is yet another reason to hide and encapsulated the "SQL stuff" in special-purpose web services to handle this properly and securely. For prototyping purposes in AiB, lightweighted solutions may be adopted, but for more elaborate solution development, sophistication degrees increase.

JSON is a lighweight data-interchange format, and may be used for data files, e.g. in servlet based interfaces returns JSON format objects for the html GET requests. XML, on the other hand, is for more structured data, whereas JSON is more comparable with CSV. Thus JSON comes mostly with less structure, but is, on the other hand, fairly simple to parse, whereas CSV is typical for tabular data, and parsing is not needed.

Whatever the device or sensor, it is important to connect the data to types of data as required by risk factors, or as appearing as data within risk assessment scales. Here it is important to note that some risk factors may e.g. be found as diagnosis encoded by ICD-10, or within ICF (International Classification of Function), or similar standardizations. This means that terminologies and ontologies found and represented within these standards establish the common language by which data is understood and formatted.

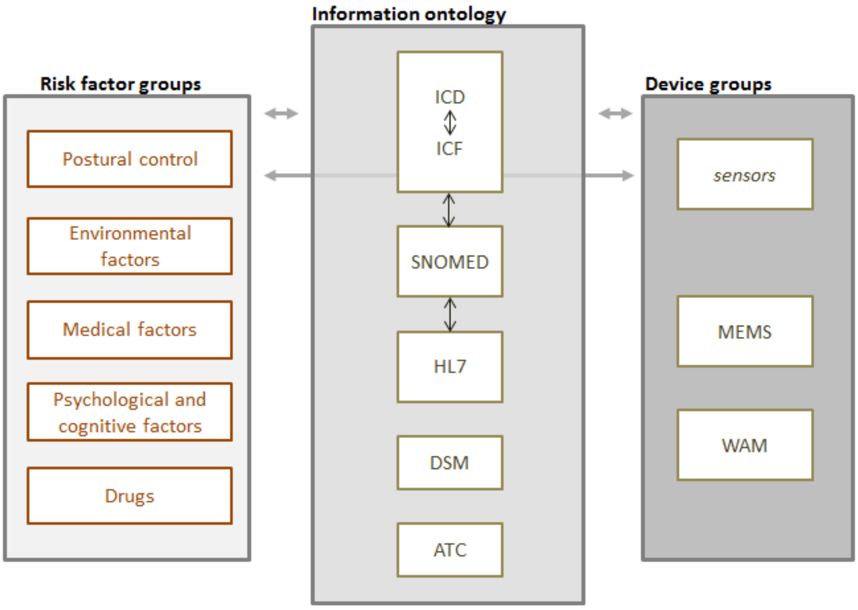


Fig. 3: From devices and sensors through middleware components in service-orientedness all the way to applications and user interfaces.

In the following we provide some examples of sensors and devices for which we require compliance with these terminological mappings.

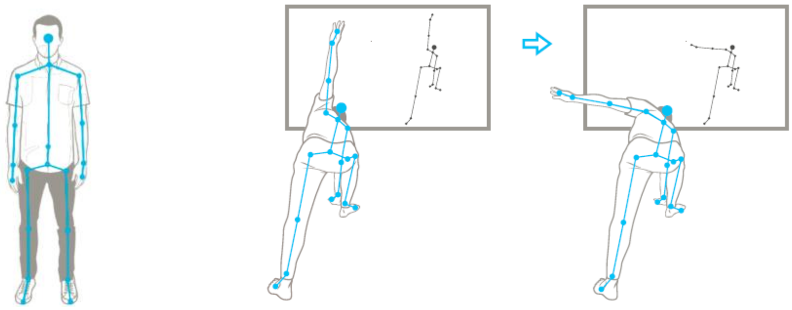
4.1 3D sensing

There are a number of 3D sensing devices on the market where *Kinect for Windows* (and Kinect for XBOX) is presently the most widely used. *Asus Xtion* is an alternative device, and is basically a Kinect clone. Kinect for Windows SDK support programming the Kinect sensor, where the OpenNI framework is an open source SDK used generally for development of 3D sensing applications and libraries.

Devices and Sensors

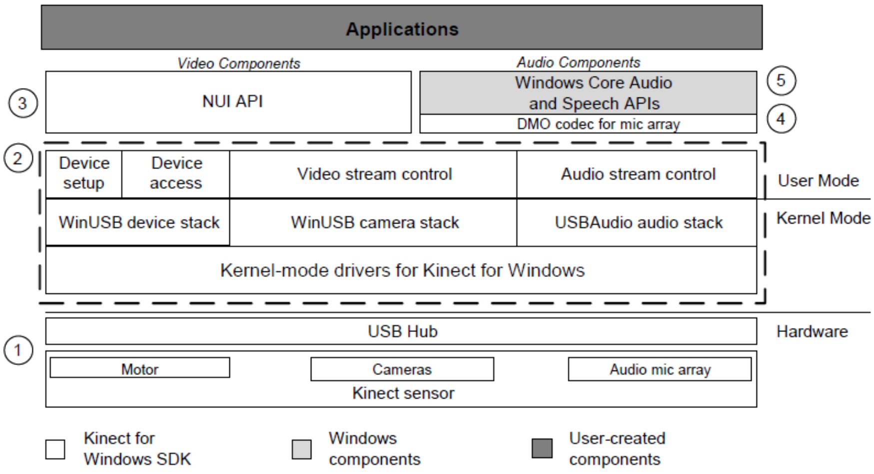
Kinect for windows

comes with both video as well as audio components. However, for AiB purposes, the video components and Kinect's Human Interface



are more important. The video stream control is supported by the NUI API, that is a set of libraries used in application development, e.g. using the Kinect for Windows SDK[2].

SDK or similar is available



SDK allows "semantic ontologization" and a more logical representation of data

Understanding the depth data stream and e.g. how to calculate distance is then prerequisite for a ontology based representation of data.

Working with human skeleton tracking involves the flow from raw depth data, through inferred body segments, to inferred joint proposals. A typical skeleton tracking to implement would be e.g.

- ✓ retrieving object from floor
- ✓ placing alternate foot on stool

in the Berg Balance Scale (BBS). *Retrieving objects from floor* should perhaps keep ankles and feet fixed, whith knees and the hip moving ownwards as the hand reaches for the object on the floor, or with knees and hip also remaining fixed as head and shoulders move down to hip level as the reaches the floor. *Placing alternate foot on stool* would be recognizing the knee joint to be lifted to the level of the hip, and the foot moving being more or less beneath the knee being lifted. Once the posture has found to rest, it would indicate a successful placing of foot on stool.

[2] A. Jana, *Kinect for Windows SDK Programming Guide*, PACKT, 2012.

Web services appearing programmatically as supported by namespaces and libraries

DataProvisionInterfaceForSensorX.dll

The following lines of example code (in VB) defines and sets a position, and defines a joint with that position, being a 'head', and being 'tracked', where the structure `Joint` is represented by JointType, Positions and TrackingState. Such code would typically appear as part of various libraries (DLL files) to be used by web services.

```
Dim thePosition As SkeletonPoint
thePosition.X = 1.1F
thePosition.Y = -1.1F
thePosition.Z = 1.8F

Dim myJoint As Joint
myJoint.Position = thePosition
myJoint.JointType = JointType.Head
myJoint.TrackingState = JointTrackingState.Tracked
```

Additionally, Kinect supports the RGBm YUV and Bayer colour image formats, where the image frames are a type of the `ColorImageFrame` class.

The Coding4Fun Kinect toolkit is an easy and quick way to get started with developing some first WPF application examples thereby providing insight into the Kinect namespace available after inclusion of the reference to the `Microsoft.Kinect` assembly .

4.2 MEMS

In Fig. 2, the difference in using e.g. accelerometers and Kinect is quite clear.

Application area specific data export function

The implementation of accelerometer data transfer can build upon existing modules and enables testing the software for determining what kind of changes/additions are needed for particular pilots.

XML or similar internal representation of data

The first version of the `AnnotatedObservation.xml` is the following:

```
<?xml version="1.0" encoding="utf-8" ?>
<AnnotatedObservation>
  <!-- personal identification -->
  <id personid=""></id>
  <!-- observed data targets a risk factor or variable in assessment scale -->
  <targetedTerm>
    <riskFactor></riskFactor>
    <AssessmentScale>
      <variable></variable>
    </AssessmentScale>
  </targetedTerm>
  <observer></observer>
  <date></date>
  <!-- Site of the observation -->
  <location>
```

```
    <observationSite>
      <id name=""/>
      <location>
        <name></name>
        <addr></addr>
      </location>
    </observationSite>
  </location>
  <reasonForObservation></reasonForObservation>
  <data>
    <value>
      <origin value="" unit=""/>
      <scale value="" unit=""/>
      <digits></digits>
    </value>
  </data>
  <annotations>
    <device></device>
    <model></model>
    <manufacturer></manufacturer>
  </annotations>
</AnnotatedObservation>
```

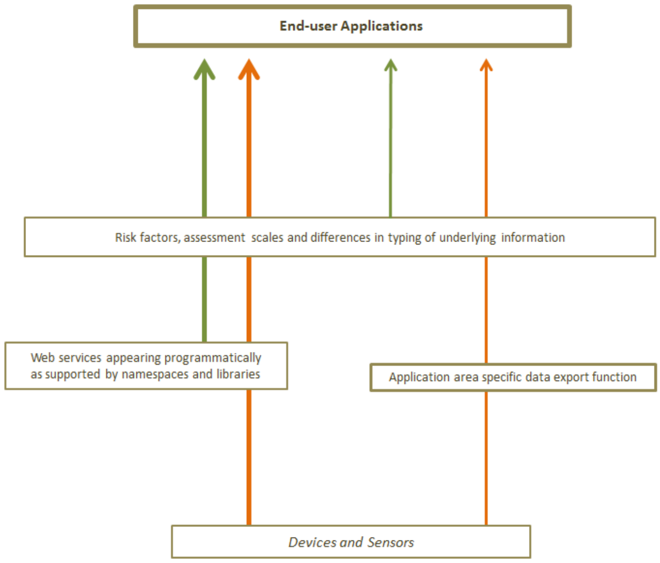
and can, as required, be amendment including mutliple channels) e.g. as follows:

```
<data>
  <channel1>
    <value>
      <origin value="" unit=""/>
      <scale value="" unit=""/>
      <digits></digits>
    </value>
  </channel1>
  <channel2>
    <value>
      <origin value="" unit=""/>
      <scale value="" unit=""/>
      <digits></digits>
    </value>
  </channel2>
</data>
```

4.3 Where and why is verification required?

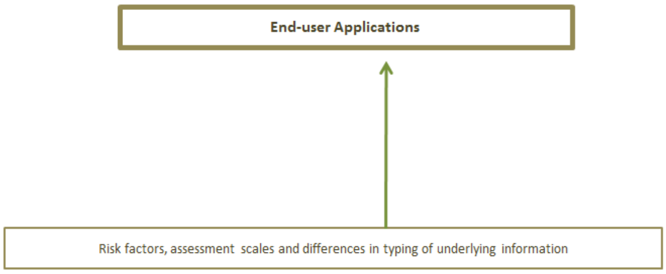
Verification intertwines with technology since specifications of devices and sensors involves both information ontologies as well as architectural considerations.

It is further important to understnad where the burden of verification exactly resides or appears as data and retrieval of it is arranged in various ways.



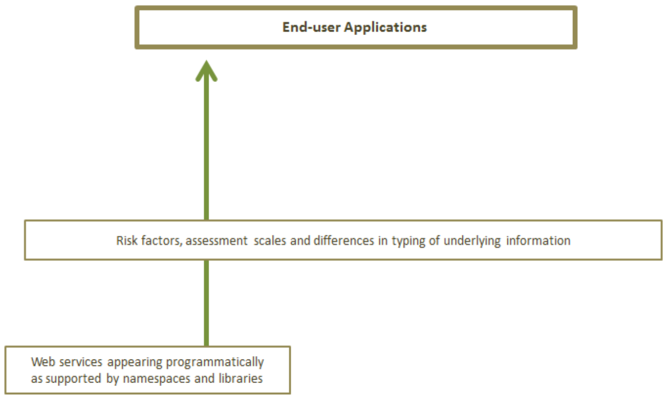
We will look at these four arrows, one by one.

The first one,



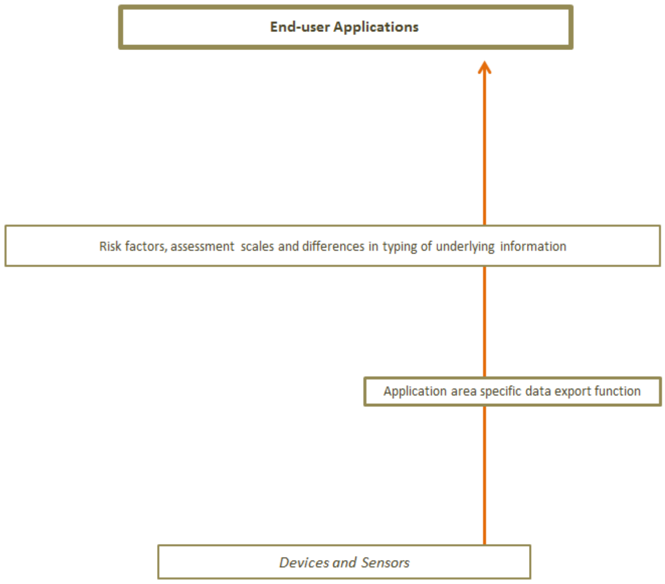
involves no additional need for verification as it relies entirely on verifications as provided by studies on respective risk factors.

The second one



is also exluding aspects of devices and sensors, and requires no additional verification, unless web services implementation introduces novelties not yet found and confirmed in exisiting studies. The web services may, on the other hand, include support for engaging in new studies and data analytic processes, but then verification comes as a result of these new studies, and is not a burden of the supporting web services themselves.

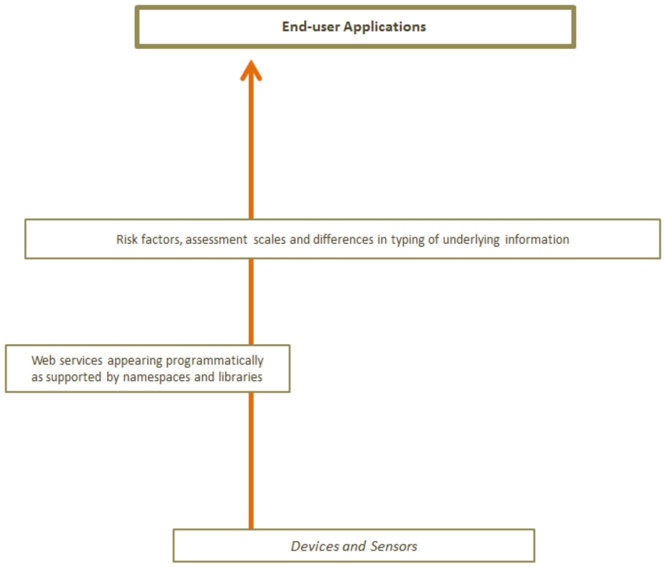
The third one



typically involves MEMS as sensors, and the verification burden arises in the mapping from sensor data to risk factors and information within assessment scales. This then is like a ”composed verification” where the verification of the mapping ”composes” with the exisiting verification of the risk factor. This then means that the mapping correlate more or less with the original way data was collected in the study for the particular risk factor in question.

Use of a particular sensor to ”invent” a new type of data representing a risk factor, i.e., in fact inventing entirely a new type of risk factor measured precisely by the use of that sensor, means that the proof burden rest entirely on this arrangement as a whole and is then producing a study ”from scratch”.

The fourth one



typically includes Kinect for Windows as sensor, and resembles the situation for the third one, but is less ”inventive” as raw sensor data is not used, and the verificationburden comes down to showing that the `Microsoft.Kinect` based implementation e.g. of the *placing alternate foot on stool* is one-to-one with the guideline for marking that criteria as 'true' in the Berg Balance Scale.

5 Verification of effect of interventions

An intervention may target fall risk in general by counting the occurence of falls after intervention. However, interventions typically related to specific fall risk assessment scales or specific risk factors, thereby implicitely aiming at reducing fall risk, where that fall risk is estimated in studies centred around those targeted assessment scales or specific risk factors.
Obviously, and intervention targeting a specific risk factor, e.g. a certain muscle power function, may positively affect other risk factors as well, like a training programme targeting muscle power also affects muscle endurance.

Interventions reducing fall risk can themselves be factors increasing fall risk, and in such cases removal of a risk factor to decrease risk may in fact increase fall risk. A simple example is antiparkinsonian drugs being both an intervention, in presence of Parkinson's disease, and a fall risk factor due to its side effects, so both the disease and its intervention are fall risk factors. In this case obviously drugs are used knowing that the side effects increase fall risk.