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Telecommunication security

The telebiometric multimodal model – A framework for the specification of security and safety aspects of telebiometrics

ITU-T Recommendation X.1081

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ITU-T Recommendation X.1081

The telebiometric multimodal model – A framework for the specification of security and safety aspects of telebiometrics

Summary

This Recommendation defines a telebiometric multimodal model that can be used as a framework for identifying and specifying safety aspects of telebiometrics, and for classifying biometric technologies used for identification (security aspects).

The telebiometric multimodal model has been developed from two main sources that provide the solid foundation for the model. The first relates to theoretical work on systems, scale propinquity, hierarchies and modalities of interaction between a human being and the environment. The second is the specification in ISO 31 and in IEC 60027-1 of quantities and units for all known forms of measurement of the magnitude of physical interactions between a person and its environment.

The telebiometric multimodal model is not limited to consideration of purely physical interactions, but also recognizes behavioural interactions. Such interactions are currently not quantified by standard units.

The model itself consists of a specification of a number of dimensions related to interactions in a set of specified modalities, in both directions, at various intensities, using the complete range of quantities and units specified in ISO 31 and IEC 60027-1. This provides a taxonomy of all possible interactions, which contains more than 1600 combinations of measurement units, modalities and fields of study.

Source

ITU-T Recommendation X.1081 was approved on 29 April 2004 by ITU-T Study Group 17 (2001-2004) under the ITU-T Recommendation A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Introduction

This Recommendation provides a multimodal model to assist in the standardization of the telecommunication domain referred to as "telebiometrics".

This telebiometric multimodal model provides a framework for the identification of safety aspects of biometric devices, and for the specification of limits related to their safety, by analysing and categorizing the interactions between a person and its environment. It also provides a framework for the identification of new biometric approaches to security based on the same analysis and categorization of the interactions between a person and its environment (it can be sensed, measured, and hence potentially identified). Thus, this Recommendation provides a common framework for the specification of both security applications and safety aspects of telebiometrics.

Telebiometric data is recorded by a measurement instrument recording some bio-phenomenon. A taxonomy is presented of the interactions that can occur at the multimodal layer where the human body meets electronic or photonic or chemical or material devices capturing biometric parameters, or impacting on that body. Authentication of a human being, with preservation of his privacy and safety, can be specified in terms of interactions between devices and the personal privacy sphere, which models and encapsulates the interactions of a human being with its environment, making discussion of such interactions explicit and engineerable.

This Recommendation provides a structure for categorizing the interaction of human beings with telecommunication terminals based on scale propinquity, using the International System of Units as it appears in ISO 31 and IEC 60027-1, with standardized descriptors for units of physical phenomena (such as the bel, candela, and becquerel units for sound, light, and the intensity of radio-activity).

The telebiometric multimodal model specified in this Recommendation can:

a) assist with the derivation of safe limits for the operation of telecommunication systems and biometric devices;

b) provide a framework for developing a taxonomy of biometric devices; and

c) facilitate the development of authentication mechanisms, based on both static (for example finger-prints) and dynamic (for example gait, or signature pressure variation) attributes of a human being.

Many issues of safe levels in telecommunication systems in debate today (for example, privacy, biometric authentication and radiation protection) can be resolved using tables based on the model developed in this Recommendation, and applying the best current scientific knowledge. Telecommunication equipment manufacturers require solid foundations for their specifications, accepting liabilities only to the levels of the best of current knowledge. The telebiometric multimodal model defined here can be used to provide specifications related to:

– safety issues;

– security issues;

– biometric authentication issues; and

– privacy issues.

Appendix I, "ISO 31 specification of SI units", contains a copy of a table from ISO 31 for convenience, as it is fundamental to the use of the telebiometric multimodal model.

Appendix II, "Use of the telebiometric multimodal model", addresses in more detail the areas in which the model may be useful.

Appendix III, "Theory of organizations and levels", summarizes some of the theoretical work that underpins the telebiometric multimodal model. This is supplemented by the extensive Bibliography that references most of the major papers in this area for those requiring further background.

Appendix IV, "Tables illustrating scale hierarchy", provides illustrations of scale hierarchy with respect to time.

ITU-T Recommendation X.1081

The telebiometric multimodal model – A framework for the specification of security and safety aspects of telebiometrics

1 Scope

1.1 This Recommendation defines a telebiometric multimodal model that provides a common framework for the specification of four interconnected security issues: Privacy, Authentication, Safety and Security with, for example "Acceptable Biometric Authentication Schema" (see Appendix II).

1.2 This telebiometric multimodal model covers all the possibilities for safe and secure multimodal man-machine interactions, and is derived in part from ISO 31 and IEC 60027-1. The cognitive, perceptual and behavioural modalities of a human being are also relevant in the field of telecommunication, and are likely to be used by a biometric sensor or effector in the future, for authentication purposes. These are also covered by this telebiometric multimodal model.

1.3 This Recommendation includes specification of the personal privacy sphere, categorization of modalities of interaction across that sphere, base and derived units for measuring and specifying (in a quantitative manner) such interactions, and a scale hierarchy for relative propinquity. It also includes some discussion of the differences between particle and wave interactions.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[1] ITU-T Recommendation X.810 (1995)|ISO/IEC 10181-1:1996, *Information technology – Open Systems Interconnection – Security frameworks for open systems: Overview*.

[2] ISO 31:1992, *Quantities and units* (14 parts).

[3] IEC 60027-1:1992, *Letter symbols to be used in electrical technology – Part 1: General*.

NOTE – ISO 31 and IEC 60027-1 are currently being merged to provide a Harmonized Standard to be published as ISO/IEC 80000. It is not expected that this will require revision to this Recommendation, other than to update this References clause.

3 Definitions

3.1 This Recommendation uses the following terms defined in ISO 31-0:

a) base quantity;

b) derived quantity.

3.2 This Recommendation defines the following terms:

3.2.1 base unit: A unit that cannot be expressed in terms of any other base unit.

NOTE 1 – Base units are used in the specification of derived units.

NOTE 2 – Examples of base units are metre, kilogram, second, candela, etc. (see ISO 31 and IEC 60027-1).

3.2.2 biometric: Pertaining to the field of biometrics.

NOTE – "biometric" should never be used as a noun.

3.2.3 biometrics: Automated recognition of living persons based on observation of behavioural and biological (anatomical and physiological) characteristics.

3.2.4 biosphere: A 1 m radius sphere surrounding a person. When associated with multimodal security and safety measures, it is called the Personal Privacy Sphere, and may have human means to protect its privacy and ensure its safety.

3.2.5 black box: A system observed to produce output in response to input whose inner workings are not known.

3.2.6 derived unit: A unit that is defined in terms of one or more base units.

NOTE – Examples of derived units are coulombs, hertz, watts, etc. (see ISO 31 and IEC 60027-1).

3.2.7 interaction modality: A distinct form of interaction across a biosphere, each of which may have subcategories.

NOTE – Examples of interaction modality across the biosphere are chemo-in (smell), audio-in, audio-out, etc. Music and speech are subcategories of audio. Gesture and facial expression are subcategories of video-out.

3.2.8 legal metrology: The entirety of the legislative, administrative and technical procedures established by, or by reference to, public authorities, and implemented on their behalf in order to specify and to ensure, in a regulatory or contractual manner, the appropriate quality and credibility of measurements related to official controls.

3.2.9 modality ideal-type: A classification of interactions across the personal privacy sphere based on the direction of the interaction and on whether it contains security-related information (see clause 7).

3.2.10 personal privacy sphere: The biosphere and the individual means to protect its privacy and ensure its safety.

3.2.11 scale: A relative ranking based on spatiotemporal size and scope of influence, often reflected in the duration in time of phenomena (longer for higher-scale entities) or of periods between events (longer for events coming out of processes at a higher scale).

3.2.12 scale hierarchy: An ordered set of derived units that are related by successive units being a power-of-ten multiple of the preceding unit.

3.2.13 semio-anthropology: The study of the use of signs and symbols in human communication.

3.2.14 telebiometrics: The application of biometrics to telecommunications.

3.2.15 telebiometrology: The study of the use of measurement, the measurement process, the classification of Standards and the SI system of units, applied to telebiometrics (see also legal metrology).

3.2.16 telebiometronomy: The study of the use of automatic measurement and transmission of data from remote sources related to life-science measurements.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

PPS Personal Privacy Sphere

SI INternational System of Units

TS Telecommunication System

5 Overview of the telebiometric multimodal model

5.1 In the telebiometric multimodal model, a human being is considered in terms of the possible interactions between that human being and its environment across the biosphere (see clause 6). The internal processes of the human being that produce or react to such interactions are not modelled. Thus the biosphere is essentially a black box representing a human being.

NOTE – The term biosphere derives from a drawing by Leonardo da Vinci (see Figure 1) in which he considered the region reachable by outstretched arms and legs as the important privacy area for a human being. The Leonardo drawing is often used in discussions and presentations on the biosphere and the personal privacy sphere.

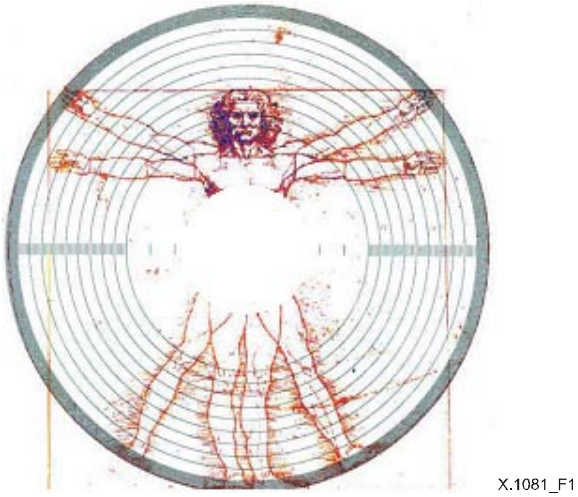


Figure 1/X.1081 – Drawing by Leonardo da Vinci

5.2 When constraints act upon the interactions that can take place across the biosphere, we refer instead to the personal privacy sphere. It is beyond the scope of this Recommendation to categorize these constraints, but it provides a framework within which they can be expressed in a quantitative manner.

5.3 Interactions across the biosphere are classified into ten modalities (see clause 7), representing interactions arising from the five human senses (seeing, hearing, touching, tasting and smelling), but generalized to all known categories of interactions. The five become ten, because effects of the environment on the human being (e.g., Video-in, bright lights, or flashing lights) are modelled as distinct modalities from the effect of a human being on the environment or a sensor (e.g., Video-out, gestures or facial expressions).

5.4 There are a number of possible subcategories of modalities that are identified in the model, but these are not considered exhaustive in this version of the model.

5.5 For the model to be useful, especially for safety discussions, it is important to be able to quantify the interactions in the different modalities. The system of units specified in ISO 31 and IEC 60027-1 is incorporated into the telebiometric multimodal model (by reference) in clause 9, for this purpose.

5.6 In almost all cases, the intensity of an interaction, and hence its safety aspects or its usefulness for sensing and identifying the human being, will depend on propinquity; the nearness of the source of an interaction or a sensing device to the biosphere. In general, many orders of magnitude are needed to specify the various forms of interaction and propinquity, and clause 10 introduces the concept of the scale hierarchy for this purpose. Clause 10 also discusses some issues related to particle versus wave aspects of interactions.

5.7 Clause 11 develops the concept of a three-layer model, following the work described in [18], incorporating a scientific layer identifying areas of academic study, a sensory layer identifying an interaction modality, and a metric layer identifying a unit of measurement. This clause includes the definition of a 20 dimensional vector that identifies the components of the model, and can be used to index taxonomies and specifications related to it.

6 The biosphere and the personal privacy sphere

6.1 This is the fundamental starting point for the abstraction of a human being. A human being, as a living organism, is modelled as a black box that interacts with its environment at the boundaries of the personal privacy sphere (at some level of hierarchical scaling, see clause 10).

6.2 The multimodal perfect man (the black box), is illustrated by the "Leonardo" diagram (Figure 1), placed within a scale hierarchy framework (see clause 10), illustrating the multilevel and multimodal approach of telebiometrics. Multimodality encompasses perceptual, conceptual and behavioural modalities of communication (see clause 7).

6.3 The "Leonardo" diagram shows the concentric spheres of propinquity from the biosphere of a telecommunication systems' user. These concentric spheres are given a code name (derived from the names for the power-of-ten multiples listed in ISO 31 and IEC 60027-1 (see clause 9)) and are considered as sectors to be specified by attributes giving upper and lower thresholds for innocuous (safe) interactions with terminals, as well as in the present ongoing large security standardization process. The diagram may be fine-tuned for complete satisfaction of security issues, including division into further scalar sectors within the natural electronic system that we currently name the person.

6.4 This self-organizing biosphere is a self-mobile topological sphere (1 m radius), but is subject to scaling (see clause 10) in which dwells a world citizen with a will to use telecommunication services and devices. We call these unique Einsteinian coordinates the Personal privacy sphere (PPS). A purposeful and fully secured user of telecommunication networks will release unique biometric signs to a highly-secure detector that are then transcribed into a unique identifier transmissible through appropriate authentication protocols, with a location (perhaps obtained through a global positioning system), an identification and a time stamp, as well as such other unique identifiers as may be needed for any desired security level.

6.5 At whatever scale level and in whatever field an observer may focus, a clear and measurable set of upper and lower thresholds can be defined to guarantee the integrity and sustainability of the personal privacy sphere. Ten subdivisions of the modalities of the personal privacy sphere provide a generic multimodal model (see clause 7) to be used in the lowermost level of the bio field interacting with open telecommunication systems, securely and safely.

6.6 The personal privacy sphere uses the SI unit categorizations (see clause 9) to provide a scale for the model of the Personal Privacy Sphere (PPS). Signals enter and leave the biosphere: the guiding principle is harmlessness in the set of signals going inward from telecommunication devices and full accessibility and authenticability in the set of signals going outward from the personal privacy sphere. Multimodality (see clause 7) is modelled within a scale hierarchy framework constructed with the relevant units and prefixes of ISO 31 and IEC 60027-1. Four security issues, apparently very different, have a single coherent treatment within this model, spanning:

a) privacy;

b) biometric authentication;

c) safety; and

d) security.

6.7 Summary of this component of the model

This component of the telebiometric multimodal model is the fundamental starting point for the abstraction of a human being. A human being, as a living entity, is modelled as a black box that interacts with its environment at the boundaries of the personal privacy sphere (at some level of hierarchical scaling and propinquity). It:

a) generates detectable interactions with its environment that can be used for biometric identification and authentication;

b) can receive and can potentially be damaged by incoming interactions from its environment;

c) has rights and privileges related to both the nature of incoming interactions and the use made of outgoing interactions.

7 Modalities of interactions

7.1 The interactions that take place across the personal privacy sphere can be categorized into five broad categories based on the human senses and on ionizing radiation that can both be produced by the human body and can damage it (but cannot be directly sensed). These broad categories are called the basic interaction modalities.

7.2 These five basic interaction modalities occur in one of two interaction modality ideal-types:

– the behavioural modality ideal-type represents interactions from the human being to the environment (five outgoing interaction modalities). The five behavioural modality ideal-types can be used to classify what kind of biometric signals and what type of measurements are going to be opted for by users, according to their cultural and personal preferences;

– the perceptual modality ideal-type represents interactions from the environment to the human being (five incoming interaction modalities).

7.3 A third interaction modality ideal-type, the conceptual modality ideal-type represents interactions from the human being that presents things that it knows to the environment (see 7.8). This information can be transmitted using any of the five basic interaction modalities of the behavioural modality ideal-type.

7.4 The ten (two-way) perceptual and behavioural modalities are:

– Video in (I see it);

– Video out (it sees me);

– Audio in (I hear it);

– Audio out (it hears me);

– Tango in (I touch it);

– Tango out (it touches me);

– Chemo in (I smell it or I taste it);

– Chemo out (it smells me or it tastes me);

– Radio in (I am irradiated);

– Radio out (I emit radiation).

7.5 Voluntarily emitted biometrically unique signs are thus of five basic interaction modalities in the behavioural modality ideal-types, and are the "out" bullets of 7.4. They are multimodal generic descriptors of what we are and what we manifest towards sensing devices such as a charge-coupled device, a microphone, a keyboard, or a Geiger-counter.

7.6 Voluntarily received biometrically unique signs are of five modalities in the perceptual modality ideal-types, and are the "in" bullets of 7.4. They are multimodal generic descriptors of what we are and what we manifest towards emitting devices that simulate these human senses.

7.7 Voluntarily emitted biometrically unique signs produced using any of the interaction modalities in the behavioural modality ideal-type may also be of the conceptual modality ideal-type: "What we know". Examples are passwords, PIN codes, maiden name of mother, birth-date.

7.8 The telebiometric multimodal model incorporates the concept of signs emitted from the human body, as defined in the study of semio-anthropology. These signs are conveyed by either the video or the audio behavioural modality ideal-type. Semio-anthropology says that only four kinds of signs are emitted by the human body:

– postural (including postural variations);
– gestural;
– facial;
– vocal or verbal.

7.9 Combined signs are used for redundancy purposes, and are excellent for disambiguation of meaningful information. They are adequate in a security policy for protecting users and telecommunication operators and service providers by voluntarily emitted signs for authentication purposes.

7.10 Summary of the component of the model

This component of the telebiometric multimodal model provides three overlapping classifications of the interactions that occur across the personal privacy sphere.

7.10.1 The first classification is into the basic interaction modalities of:

– Video basic interaction modality;
– Audio basic interaction modality;
– Tango basic interaction modality;
– Chemo basic interaction modality;
– Radio basic interaction modality.

All interactions in the model are modelled as one of these interaction modalities.

7.10.2 The second classification is into modality ideal-types of:

– behavioural modality ideal-type;
– perceptual modality ideal-type;
– conceptual modality ideal-type.

Behavioural and perceptual ideal-types contain interactions in all the basic interaction modalities, and define the direction of the interaction. The conceptual ideal-type is a subset of the interactions in the behavioural ideal-type that convey specific knowledge-related information relevant to security.

7.10.3 The third classification is into signs (and not-a-sign). The classification is:

– postural signs;
– gestural signs;
– facial signs;
– verbal signs;
– demeanoral signs;
– not-a-sign interactions.

This classification applies only to a subset of the interactions in the behavioural ideal type.

7.11 Relation to biometric device standardization

Currently, the market recognizes a number of biometric types, and standardization of biometric data block formats for a number of those biometric types, with others likely to be added in the future. Projected standardization work recognizes the biometric types in column 1 of the table below. Column 2 gives the interaction modality (or modalities) in which each biometric type operates:

Biometric types	Interaction modality
Face Image, Finger minutiae, Iris, Retina, Hand Geometry, Vein Pattern, Finger Image	Video in (input of artificial light is usually needed) and Video out
Lip Movement, Thermal Face Image, Thermal Hand Image, Ear Shape, Finger Geometry	Video out
Voice	Audio out
Signature Dynamics, Keystroke Dynamics, Foot Print	Tango out
Gait	Postural
Body Odor, DNA	Chemo out
Finger minutiae, Palm Print, Finger Pattern	Depends on the technology used, Video out or Tango out

8 Fields of study

8.1 In the telebiometric multimodal model it is recognized that interactions across the personal privacy sphere can be studied using the concepts and approaches of a number of different disciplines. Each discipline contributes to the specification of threshold values for damage, means of identification and so on, for particular interaction modalities, and a combination of the requirements of the different disciplines is usually appropriate in any use of this telebiometric multimodal model.

8.2 The basic categorization of disciplines recognizes the following areas as relevant for the telebiometric multimodal model (disciplines such as astronomy are not currently considered relevant to the model), as they provide measurement techniques, methodologies, and/or constraints and obligations that are relevant to the model:

– physics;
– chemistry;
– biology;
– cultural or social;
– psychology.

It will often be appropriate to examine a particular interaction against more than one of these disciplines. For example, display of a video image might cause damage under the physics discipline because the light is too intense, or under the cultural or social or psychology disciplines because of the offensive and perhaps damaging nature of the image.

8.3 Disciplines such as biochemistry that combine aspects of two or more basic disciplines are well known. Other combinations are less common, such as psychophysics, but may arise in the future. A detailed list of currently recognized combinations of the basic disciplines is beyond the scope of this Recommendation.

8.4 Summary of this component of the model

The model requires interactions to be examined from the point of view of each of the relevant disciplines or their combinations.

9 Measurable entities

9.1 Units employed in measurements, calculations and threshold specifications

9.1.1 In the telebiometric multimodal model it is recognized that both biometric authentication and specification of thresholds for safe and secure operation of telecommunication systems is dependent on the measurement of an interaction using some physical unit or units.

9.1.2 In ISO 31 and IEC 60027-1 quantities and units (SI units) are specified (see Appendix I), thus providing a top-level taxonomy of measures that can be used in biometrics or in determining safety and security. This is fundamental to the telebiometric multimodal model defined in this Recommendation.

9.1.3 In ISO 31, a table of names (to be used for various power-of-ten multiples and sub-multiples of the SI units) is also specified. Some of these names are widely known and in widespread use (e.g., micro, kilo, mega). Others are less well known (e.g., zetta and yocto).

NOTE – This table is not included in this Recommendation, but see ISO 31-0.

9.1.4 Summary of this component of the model

The model requires the use of appropriate SI units for measurement and for the specification of threshold values.

9.2 Specification of thresholds for security and safety

The specification of these thresholds is outside the scope of this Recommendation. However, the following template is provided as an illustration of the use of this Recommendation for the specification of permissible sound levels.

Further studies are necessary to define the appropriate thresholds for the units listed here.

Audio IN				
Unit		Values		Source
name	symbol	min	max	
Metre	m			
Second	s			
Kilogram	kg			
Ampere	A			
Kelvin	K			
Mole	mol			
Candela	cd			
Square metre	m^2			
Cubic metre	m^3			
Metre per second	$m \cdot s^{-1}$			
Metre per second squared	$m \cdot s^{-2}$			
Kilogram per cubic metre	$kg \cdot m^{-3}$			
Ampere per square metre	$A \cdot m^{-2}$			
Ampere per metre	$A \cdot m^{-1}$			
Mole per cubic metre	$mol \cdot m^{-3}$			
Candela per square metre	$cd \cdot m^{-2}$			
Hertz	Hz			
Newton	N			
Pascal	Pa			
Joule	J			
Watt	W			
Coulomb	C			
Volt	V			
Farad	F			
Ohm	Ω			
Siemens	S			
Weber	Wb			
Tesla	T			
Henry	H			
Becquerel	Bq			
Radian	rad			
Steradian	sr			
Lumen	lm			
Lux	lx			
Gray	Gy			
Katal	kat			
Sievert	Sv			

10 Scale hierarchies and particle and wave interactions

10.1 The concepts of scalar and specification hierarchy are incorporated in this telebiometric multimodal model (see bibliography).

10.2 For any given interaction, there are scales associated with many aspects of the interaction. There are also scales associated with the part of the human being that is affected by the interaction. For most interaction modalities, the scales of the various units used to describe an interaction can vary by many orders of magnitude. Appendix IV contains illustrations of the extremes of time-scale that can arise.

10.3 [20] notes the following in relation to any sender and receiver of a signal, but goes on to apply it to the reception of (and possible damage to) a part of a human being receiving a signal from some source:

> "Any embedded receiver will be of a given scale (even if, as with a human being, it has modalities at more than one scale), and so will be limited in its range of effectiveness.

Subnormal signals, at a great distance from source, will be subliminal and ignored. Supernormal signals, too close to source, can damage the receiver."

10.4 [20] also recognizes the distinction between impact by particles at a microscopic scale and the effect of waves at a more macroscopic scale and concludes:

"The (human) organism has modalities receiving at more than one scale. Wave reception occurs macroscopically, while particle reception is mostly microscopic (photons, and chemicals, as well as particle agitation recording temperature), although receiving a blow from an object would be macroscopic.

It can be noted that multiple modalities at multiple scales allows the organism to test the robustness of the information recorded at a given interaction modality. If we hear a sound, we search to see or touch or smell its source. Finding no corroboration, we ignore the noise, connecting it to no event. In this regard, the different scales within the modalities are important. Sound and pressure simultaneously are very close in kind, and hardly distinguishable if the pressure is great enough. But if we also see a flash of light at the same time, from an entirely different scale, then we are reassured of the actuality of a noisy event.

Here we see the importance of the fact that dynamics at different scales are non-transitive. Sound waves will not get entangled with streams of photons, and so audio and video are truly different sources of information. Of course, once the respective sense organs have been activated, both kinds of information traverse scales together, merging finally together as a macroscopic perception in the central nervous system."

10.5 In the chemo basic interaction modality we can get similar scale effects. Particles in (for example) a decaying paint may have no effect at normal particle sizes, but when provided at nano-sizes they can penetrate deeper into the skin and may (or may not) then have adverse effects.

10.6 In biometric sensing, there is a large-scale difference between finger and face geometry and finger minutiae (finger-print recognition), and sensing of gait and gestures and general behaviour (surreptitious, bold, furtive) is again a larger scale measurement.

10.7 Summary of this component of the model

In this area, the model simple draws attention to the need to consider phenomena and interactions at a variety of scales. Suitability of a behavioural modality ideal-type for use in biometric authentication, or safety of a perceptual modality ideal-type can be affected by issues of scale in the interaction (for example, wavelength, particle size), not just the scale for the intensity of the interaction.

11 The telebiometric multimodal model: a three-layer model

11.1 This clause specifies the telebiometric multimodal model, which provides a taxonomy of some of its elements, drawing on work described in [18] (see a Morphological Model for Telebiometrics). There is not a perfect fit between this work described in the reference and the telebiometric multimodal model presented in this Recommendation, but they share many commonalities. A practical realization of the telebiometric multimodal model comprises the 20 dimensional framework described below as an example of how a formal taxonomy can be produced from the telebiometric multimodal model.

11.2 The telebiometric multimodal model is a three-layer model:

– the scientific layer;

– the sensory layer;

– the metric layer.

11.3 The scientific layer applies different disciplines to the study of the interactions across the personal privacy sphere. The following disciplines are identified:

– physics;

– chemistry;

– biology;

– culturology;

– psychology.

These are very close to the disciplines identified in clause 8.

11.4 The sensory layer identifies interactions as belonging to four of the basic modalities that are presented in clause 7, namely:

– Video;

– Audio;

– Tango;

– Chemo;

with each interaction having both an IN and an OUT state, corresponding to the behavioural and perceptual modality ideal-types of clause 7.

11.5 The metric layer specifies the quantities used in measurement, and references the seven SI base units given in ISO 31 and IEC 60027-1, listed in the table in Appendix I.

11.6 This Recommendation makes use of proposals given in [18] to assign a numerical labelling for all elements of the model, recognizing all possible combinations of the five disciplines, of the ten in/out modalities, and of the seven SI base units.

11.7 The scientific layer (combination of disciplines being considered) is represented by a five dimensional binary vector (five values that are all either zero or one, one representing consideration of that particular discipline). Thus the vector (0,1,1,0,0) would identify consideration of aspects of the interaction related to biochemistry.

11.8 The sensory layer (combinations of basic in-out modalities) is represented by an eight dimensional (the radio interaction modality is not present in model described in [18]) binary vector (eight values that are all either zero or one, one representing the presence of an interaction of that in or out modality). Thus the vector (0, 0, 1, 1, 0, 1, 0, 1) would represent an interaction with Tango In, Chemo In, Audio Out, Chemo Out. This is clearly a complex interaction, and combinations such as this are unlikely to arise in the real world.

11.9 The labelling for the metric layer (combinations of the seven base units), is a little more complex. Many measurable quantities (for example speed) are not just combinations of the seven basic units, but involve both positive and negative powers of the base units. (The unit of speed is $m^1 s^{-1}$.) A particular unit is therefore represented by a seven dimensional vector with (positive and negative) integer values for each dimension. Thus speed is represented by (1, 0, –1, 0, 0, 0, 0), and the Weber (a derived unit that is $m^2 kg^1 s^{-2} A^{-1}$) is represented by (2, 1, –2, –1, 0, 0, 0).

11.10 Thus the telebiometric multimodal model provides a 20 dimensional vector space that can identify all combinations of discipline, of interaction modality, and use of a single base or derived unit. This can be useful for both labelling and for exhaustive computer enumerations of elements of the model.

11.11 Summary of this component of the model

The model described in [18] provides a labelling of many (but not all) of the elements (see 11.8) of the telebiometric multimodal model, and is recommended for use where such labelling is needed.

Appendix I

ISO 31 specification of SI units

This table is fundamental to the approach taken by the telebiometric multimodal model, and is copied from ISO 31 for the convenience of users of this Recommendation. The normative specification is in ISO 31.

Unit Name	Quantity	Symbol	Special symbol
SI base Units			
Metre	Length	m	-
Kilogram	Mass	kg	-
Second	Time	s	-
Ampere	Electric current	A	-
Kelvin	Thermodynamic temperature	K	-
Mole	Amount of substance	mol	-
Candela	Luminous intensity	cd	-
Examples of SI derived units			
Square metre	Area	m^2	-
Cubic metre	Volume	m^3	-
Metre per second	Speed	$m \cdot s^{-1}$	-
Metre per second squared	Acceleration	$m \cdot s^{-2}$	-
Kilogram per cubic metre	Mass density	$kg \cdot m^{-3}$	-
Ampere per square metre	Current density	$A \cdot m^{-2}$	-
Ampere per metre	Magnetic field	$A \cdot m^{-1}$	-
Mole per cubic metre	Substance concentration	$mol \cdot m^{-3}$	-
Candela per square metre	Luminance	$cd \cdot m^{-2}$	-
SI derived units with special names			
Hertz	Frequency	s^{-1}	Hz
Newton	Force	$m \cdot kg \cdot s^{-2}$	N
Pascal	Pressure	$N \cdot m^{-2}$	Pa
Joule	Energy	N·m	J
Watt	Power	$J \cdot s^{-1}$	W
Coulomb	Electric charge	s·A	C
Volt	Electric potential	$W \cdot A^{-1}$	V
Farad	Capacitance	$C \cdot V^{-1}$	F
Ohm	Electric resistance	$V \cdot A^{-1}$	Ω
Siemens	Electric conductance	$A \cdot V^{-1}$	S
Weber	Magnetic flux	V·s	Wb
Tesla	Magnetic flux density	$Wb \cdot m^{-2}$	T
Henry	Inductance	$Wb \cdot A^{-1}$	H
Becquerel	Activity	s^{-1}	Bq
Radian	Plane angle	1	rad
Steradian	Solid angle	1	sr
Lumen	Luminous flux	cd·sr	lm
Lux	Illuminance	$lm \cdot m^{-2}$	lx
Gray	Absorbed dose	$J \cdot kg^{-1}$	Gy
Katal	Catalytic activity	$mol \cdot s^{-1}$	kat
Sievert	Dose equivalent	$J \cdot kg^{-1}$	Sv

Appendix II

Use of the telebiometric multimodal model

The telebiometric multimodal model can be applied in the areas of privacy, biometric authentication, ecological liability, and acceptable biometric authentication schema. These are described below.

II.1 Privacy

Every human user of Telecommunication Services (TS) is entitled to be safe and secure while using telecommunications terminals. Meaningful information, delivered at the right time, within an appropriate context, to an attentive human user, "makes a difference that makes a difference" (G. Bateson) and this is the added value of Telecommunication Services (TS). Privacy of a human user may be, in a minimalist approach, based on a one-metre radius sphere from his or her navel in all spherical directions (this is illustrated in the Leonardo diagram in Figure 1). This Personal Privacy Sphere (PPS) has a natural mean duration as a biological phenomenon of 3 000 000 000 s (approximately 95 years). Perceptual, cognitive and motor components of human intelligence are brought into a relationship with similar components of another human being through telecommunication technologies.

II.2 Biometric authentication

Recording a measurement obtained from a human being which can then be used for authentication purposes, proof of identity, etc.

II.3 Ecological liability

Ecological liability arises in the domain of antennas and human liability in the domain of terminals, devices held or kept within the personal privacy sphere.

II.4 Acceptable biometric authentication schema

A technologically neutral standards approach is introduced here, as telebiometric terminals of very many kinds are going to enter the market. A precise multimodal taxonomy is introduced, optimized for computability. Every technology involving body-inserts of telecommunication capabilities, as well as DNA bar-coded business cards should remain as an option to be used by the customer of telecommunication services. Accessibility and human factors are thus taken care of, and are ethno-politically correct!

Appendix III

Theory of organizations and levels

This appendix is a set of notes giving a summary of some of the academic work that underlies the personal privacy sphere discussions. It may be of use to users of this Recommendation as background material, but is not essential to an understanding or to use of this Recommendation. The interested reader can consult the extensive bibliography.

III.1 Introduction

An axiomatic system is proposed to improve the identification, description, and analysis of complex ecological systems. Such systems are assumed to be organized and to have structure. Organization is the complex of interactions and properties of a structure that make the perpetuation of that structure possible. An entity of a structure is assumed to be composed of other entities. The term

entity is adopted as a "primitive term". The concept of *minimum interactive structure* is introduced as an epistemological constraint on the structural infinity of real systems. Other terms are defined as either relations between entities of structure, derived properties resulting from combining such entities into entities of higher order, or conditions necessary for their assembly. Organization is a composite term and consists of complementarity, coordination, integration, and hierarchy. Evaluation of the overall organization of an ecological entity appears theoretically possible through parameterization and quantification of these components of organization.

III.2 Theory of organizations

III.2.1 Kolasa (see [10]) states: "Addressing the problem of ecological units requires a theory of self-maintaining units, or a theory of organization", and proceeds with the following reasoning:

Definition 1: Entity is a primitive term. Its meaning is intuitively understood.

Axiom 1: Each ecological entity has structure consisting of other entities.

Definition 2: Structure of an entity is an internal complex of other entities and their static connections to each other.

Axiom 2: Every structure results from the properties and interactions of low-level entities within a higher-level entity.

Axiom 3: The structure of an entity changes.

Definition 3: Organization is the mode of dynamic perpetuation of structure. Organization includes the interactions and connections among structural elements that allow the static structure to persist.

III.2.2 From these, Kolasa makes the following derived statements:

Theorem 1: Structure is hierarchical.

Definition 4: Hierarchy is a condition of being composed of subunits.

Theorem 2: Lower-level entities change with higher frequencies than higher-level entities. Change requires deletion, addition and replacement of lower-order entities.

MIS: Minimum Interactive Structure. The entities are allowed to have a hierarchical structure open downward and to aggregate upward without apparent limit.

NOTE – Recognizing MIS requires that at one level we see the structure as an entity, while on the next lower level we see the first-order structure of this entity, i.e., a complex of sub-entities. At an even lower level, the structure of the subunits appears. Isomorphism of a MIS of an entity between successive times is thus a sufficient criterion for the determination of its identity, for example, for biometric authentication.

Definition 5: Function is that part of the interactions of a component of MIS that contributes to the persistence of the higher-level entities.

Axiom 4. Components of minimum interactive structure are complementary.

Definition 6: Complementarity is the capacity of entities to remain components of the minimum interactive structure of an entity by acting as functional supplements to one another, or being functionally dependent upon each another.

Theorem 3: For entities that persist, changes of structure are constrained in such a way that minimum interactive structure is preserved.

Definition 7: Coordination is an action of one element of minimum interactive structure in response to the behaviour of another (others) such that they remain complementary.

Definition 8: Only a specific form of communication resulting in coordination is defined as information.

Definition 9: Integration is an aggregate index of both coordination and rate of configurational change within the minimum interactive structure.

Theorem 4: An entity seems always to be less integrated than its component entities.

III.3 The Theory of Integrative Levels

III.3.1 Feibleman (see [66]) developed the Theory of Integrative Levels.

III.3.2 His work introduced some Laws of the Levels:

1) Each level organizes the level or levels below it plus one emergent quality.
2) The apparent complexity of the levels increases upwards.
3) In any organization, the higher level depends upon the lower.
4) In any organization, the lower level is directed by the higher.
5) For an organization at any given level, its mechanism lies at the level below and its purpose at the level above.
6) A disturbance introduced into an organization at any one level reverberates at all levels it covers.
7) The time required for a change in organization shortens as we ascend the levels.
8) The higher the level, the smaller its population of instances.
9) It is impossible to reduce a higher level to a lower.
10) An organization at any level is a distortion of the level below.
11) Events at any given level affect organizations at other levels.
12) Whatever is affected as an organization has some effect as an organization.

III.3.3 The work also introduced some Rules of Explanation:

1) The reference to any organization must be at the lowest level that will provide sufficient explanation.
2) The reference to any organization must be to the highest level that its explanation requires.
3) An organization belongs to its highest level.
4) Every organization has to be explained finally on its own level.
5) No organization can be explained entirely in terms of a lower or higher level.

III.3.4 Finally, an extended Theory of the Levels is introduced: We have been talking about the interactive levels of the scientific fields as if only some five (physics, chemistry, biology, psychology and anthropology) were involved. This was necessary to see clearly some of the relations. But the situation is more complex than that. For each level is the name for a very considerable group of sub-levels. This leads onto Hierarchy Theory.

III.4 Hierarchy Theory

III.4.1 Hierarchy Theory encompasses both the scalar hierarchy of nested extensions (represented as scalar levels), and also the specification hierarchy of ordered intentional complexity, modelled as integrative levels. For example:

```
{physical world {chemical world {biological world {social world {mental world }}}}}
```

III.4.2 Differences in the scale of objects or processes are measured as orders of magnitude, while integrative levels are apprehended when it is discovered that some discourse is insufficient to deal with certain phenomena, such as when we find it impossible to understand biological systems using only chemical discourse. This requires us to make a new discourse, signifying a new integrative level.

III.4.3 The specification hierarchy is fundamentally a pattern of thought, congenial to natural philosophy, and requires that we stipulate an observer in the inmost level, to whom the system is relevant. So it is not an objective approach, as the scalar hierarchy can be.

III.4.4 The specification hierarchy also supplies a model of development, with the inmost level being a unique individual material embodiment of the various classes in the outer levels, as in:

```
{dissipative structure {organism {animal {mammal
      {hominoid {human {male {white {middle class {ageing {Stan Salthe }}}}}}}}}}}
```

This form, as a model of development, originated with Aristotle, but was used prominently by Linnaeus merely to signify new taxonomic levels. As a model of development, it can also serve as the basis for a generation myth associated with natural philosophy (using "myth", not as a pejorative term, but as in ethnography).

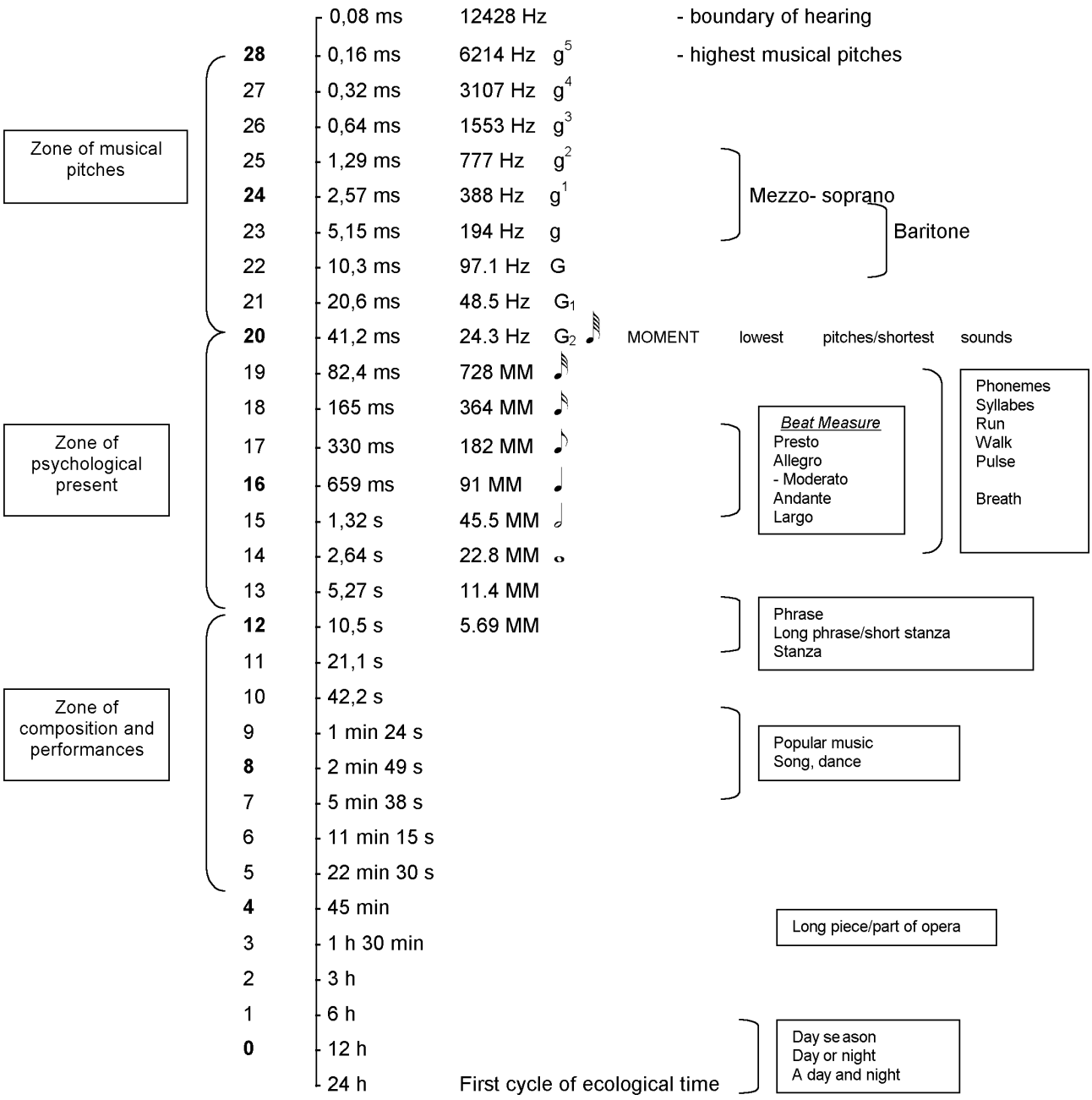
III.4.5 Simon (see [24]) defines a hierarchy in terms of intensity of interaction, but observes that in most biological and physical systems relatively intense interaction implies relatively close spatial propinquity. However, one of the interesting characteristics of both nerve cells and telephone wires is that they permit very specific strong interactions at great distances. (But note that in both cases, the ability of small-scale objects to convey information over large distances is because they are part of an encompassing large-scale system.) To the extent that interactions are channelled through specialized communications and transportation systems, spatial propinquity become less determinative of structure.

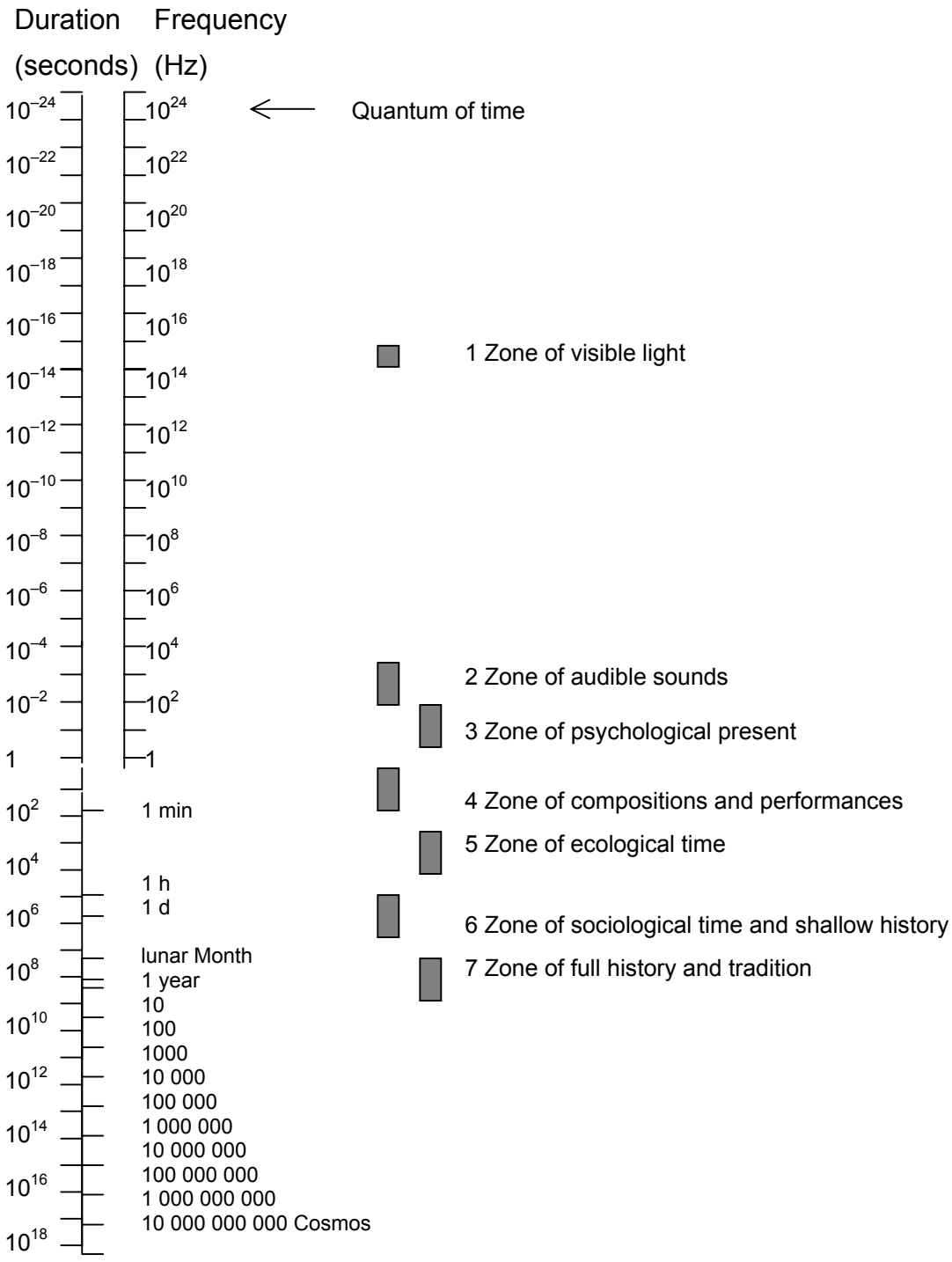
III.4.6 The concept of spatial propinquity is important in determining the safe limits for the operation of telecommunications and biometric devices, as a potential hazard is much greater the closer that device is to the human body. Thus recommendations on safe limits have to include measures of propinquity, and the concept of scale hierarchy is introduced for this purpose.

Appendix IV

Tables illustrating scale hierarchy

The following two tables are taken from Bielawski (see Bibliography) and illustrate the extremes of time-scale that can arise.





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