International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

X.1081

(10/2011)

SERIES X: DATA NETWORKS, OPEN SYSTEM COMMUNICATIONS AND SECURITY

Information and network security – Telebiometrics

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

Recommendation ITU-T X.1081

ITU-T X-SERIES RECOMMENDATIONS

DATA NETWORKS, OPEN SYSTEM COMMUNICATIONS AND SECURITY

PUBLIC DATA NETWORKS	X.1–X.199
OPEN SYSTEMS INTERCONNECTION	X.200–X.299
INTERWORKING BETWEEN NETWORKS	X.300–X.399
MESSAGE HANDLING SYSTEMS	X.400–X.499
DIRECTORY	X.500–X.599
OSI NETWORKING AND SYSTEM ASPECTS	X.600–X.699
OSI MANAGEMENT	X.700–X.799
SECURITY	X.800–X.849
OSI APPLICATIONS	X.850–X.899
OPEN DISTRIBUTED PROCESSING	X.900–X.999
INFORMATION AND NETWORK SECURITY	
General security aspects	X.1000–X.1029
Network security	X.1030–X.1049
Security management	X.1050–X.1069
Telebiometrics	X.1080–X.1099
SECURE APPLICATIONS AND SERVICES	
Multicast security	X.1100–X.1109
Home network security	X.1110–X.1119
Mobile security	X.1120–X.1139
Web security	X.1140–X.1149
Security protocols	X.1150–X.1159
Peer-to-peer security	X.1160–X.1169
Networked ID security	X.1170–X.1179
IPTV security	X.1180–X.1199
CYBERSPACE SECURITY	
Cybersecurity	X.1200–X.1229
Countering spam	X.1230–X.1249
Identity management	X.1250–X.1279
SECURE APPLICATIONS AND SERVICES	
Emergency communications	X.1300–X.1309
Ubiquitous sensor network security	X.1310–X.1339
CYBERSECURITY INFORMATION EXCHANGE	
Overview of cybersecurity	X.1500–X.1519
Vulnerability/state exchange	X.1520–X.1539
Event/incident/heuristics exchange	X.1540–X.1549
Exchange of policies	X.1550–X.1559
Heuristics and information request	X.1560–X.1569
Identification and discovery	X.1570–X.1579
Assured exchange	X.1580–X.1589

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T X.1081

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

Summary

The telebiometric multimodal model has been developed from two main sources that provide the solid foundation for the model. The first is a considerable body of theoretical work on systems, scale propinquity, hierarchies and modalities of interaction between a human being and the environment. The second comes from the specifications in the ISO/IEC 80000-series 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. It also recognizes the importance of examining all possible interactions using the insights provided by a number of different fields of academic study. 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 the ISO/IEC 80000-series. This provides a taxonomy of all possible interactions, which contains more than 1600 combinations of measurement units, modalities and fields of study.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T X.1081	2004-04-29	17
1.1	ITU-T X.1081 (2004) Cor. 1	2007-02-13	17
1.2	ITU-T X.1081 (2004) Amd.1	2009-10-29	17
1.3	ITU-T X.1081 (2004) Amd.2	2010-05-29	17
1.4	ITU-T X.1081 (2004) Amd.3	2011-10-14	17
2.0	ITU-T X.1081	2011-10-14	17

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). 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.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

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, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

Table of 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/IEC 80000], 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/IEC 80000-series specification of SI units", contains a copy of a table from [ISO/IEC 80000] 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.

Appendix V, "Hierarchy theory principles", summarizes the hierarchy theory and is supplemented by the extensive Bibliography that references most of the major papers in this area.

Recommendation ITU-T 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/IEC 80000]. 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.

[ITU-T X.660] Recommendation ITU-T X.660 (2008) | ISO/IEC 9834-1:2008, *Information technology – Open Systems Interconnection – Procedures for the operation of OSI Registration Authorities: General procedures and top arcs of the International Object Identifier tree*.

[ITU-T X.68x] Recommendation ITU-T X.68x-series (2008) | ISO/IEC 8824-x:2008, *Information technology – Abstract Syntax Notation One (ASN.1)*.

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

[ISO/IEC 80000] ISO/IEC 80000-series (in force), *Quantities and units*.

ISO 80000-1 – Part 1: *General*.

ISO 80000-2 – Part 2: *Mathematical signs and symbols to be used in the natural sciences and technology*.

ISO 80000-3 – Part 3: *Space and time*.

ISO 80000-4 – Part 4: *Mechanics*.

ISO 80000-5 – Part 5: *Thermodynamics*.

IEC 80000-6 – Part 6: *Electromagnetism*.

ISO 80000-7 – Part 7: *Light*.

ISO 80000-8 – Part 8: *Acoustics*.

ISO 80000-9 – Part 9: *Physical chemistry and molecular physics*.

ISO 80000-10 – Part 10: *Atomic and nuclear physics*.

ISO 80000-11 – Part 11: *Characteristic numbers*.

ISO 80000-12 – Part 12: *Solid state physics*.

IEC 80000-13 – Part 13: *Information science and technology*.

IEC 80000-14 – Part 14: *Telebiometrics related to human physiology*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 The following terms are defined in [ISO/IEC 80000]:

– base quantity;

– derived quantity.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 1-m radius 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.

3.2.2 base unit: A unit that cannot be expressed in terms of any other base unit, and that is used in the specification of derived units.

NOTE – Examples of base units are metre, kilogram, second, candela, etc. (see [ISO/IEC 80000]).

3.2.3 biometric: Pertaining to the field of biometrics.

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

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

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/IEC 80000]).

3.2.7 interaction modality: A distinct form of interaction across a 1-m radius biosphere, each of which may have subcategories.

NOTE – Examples of interaction modality across the 1-m radius 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 1-m radius 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 telebiometric multimodal model: A model of the interactions of a human being with its environment using modalities based on the human senses.

3.2.15 telebiometrics: The application of biometrics to telecommunications and of telecommunications to remote biometric sensing.

3.2.16 telebiometrology: The area of metrology relating to the activities which concern measurements, units of measurement and methods of measurement, applied to telebiometrics.

3.2.17 telebiometronomy: The study of the use of automatic biometric measurements and the transmission of data from remote sources.

3.2.18 TMM metric layer: A layer in the telebiometric multimodal model (TMM) taxonomy that identifies the SI units used to describe an IN or OUT interaction.

3.2.19 TMM scientific layer: A layer in the telebiometric multimodal model (TMM) taxonomy that identifies the scientific discipline that investigates the properties and thresholds of an IN or OUT interaction.

3.2.20 TMM sensory layer: A layer in the telebiometric multimodal model (TMM) taxonomy that identifies the human senses involved in producing or detecting an IN or OUT interaction.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

MIS Minimum Interative Structure

PPS Personal Privacy Sphere

SI International System of Units

TMM Telebiometric Multimodal Model

TS Telecommunication Services

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 1-m radius biosphere (see clause 6). The internal processes of the human being that produce or react to such interactions are not modelled. Thus the 1-m radius biosphere is essentially a black box representing a human being.

NOTE – The term 1-m radius 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.

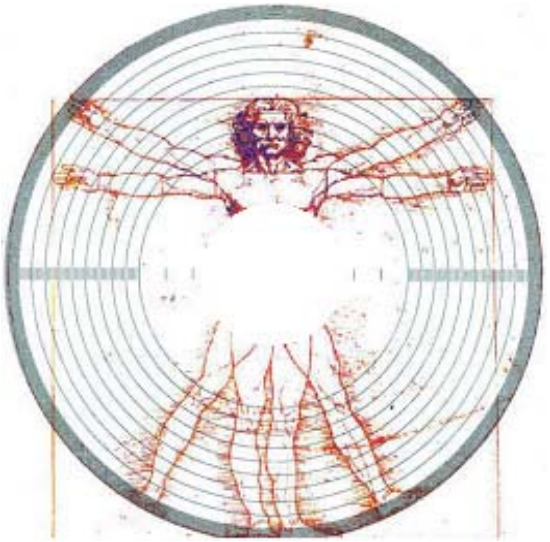


Figure 1 – Drawing by Leonardo da Vinci

5.2 When constraints act upon the interactions that can take place across the 1-m radius 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 1-m radius biosphere are classified into 14 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 seven become 14, 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/IEC 80000] 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 1-m radius biosphere.

5.7 Clause 11 develops the concept of a three-layer model, following the work described in [b-Lalvani6], 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 1-m radius 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 1-m radius 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/IEC 80000] (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 1-m radius 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.

6.5 Fourteen 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 PPS. Signals enter and leave the 1-m radius biosphere: the guiding principle is harmlessness in the set of signals going inward from telecommunication devices and full accessibility and ability to be authenticated 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/IEC 80000].

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 seven 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 seven 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 (seven outgoing interaction modalities). The seven 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 (seven 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 clause 7.8). This information can be transmitted using any of the seven basic interaction modalities of the behavioural modality ideal-type.

7.4 The fourteen (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);

– Calor in (I feel heat);

– Calor out (I emit heat);

– Electro in (I feel electrical current);

– Electro out (I emit electrical current).

7.5 Voluntarily emitted, biometrically unique signs are thus of seven basic interaction modalities in the behavioural modality ideal-types, and are the "out" bullets of clause 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 seven modalities in the perceptual modality ideal-types, and are the "in" bullets of clause 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, mother's maiden name and date of birth.

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 the disambiguation of meaningful information. They are adequate in a security policy for protecting users, telecommunication operators and service providers, by using 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;
– Calor basic interaction modality;
– Electro 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

Table 1 – Biometric type modalities

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, Footprint	Tango out
Gait	Postural
Body Odour, DNA	Chemo out
Finger minutiae, Palm print, Finger pattern	Depends on the technology used, Video out or Tango out

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 Table 1. Column 2 gives the interaction modality (or modalities) in which each biometric type operates.

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/IEC 80000], 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/IEC 80000], 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 80000-1].

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 (Figure 2) 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			

Figure 2 – Sample template

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 [b-Salthe2] 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 a particular 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 [b-Salthe2] 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 (fingerprint 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 simply 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 [b-Lalvani6] (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 (see clause 3.2.19);

– the sensory layer (see clause 3.2.20);

– the metric layer (see clause 3.2.18).

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/IEC 80000], listed in Table I.1.

11.6 This Recommendation makes use of proposals given in [b-Lalvani6] to assign numerical labelling for all elements of the model, recognizing all possible combinations of the five disciplines, of the 14 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 binary vector (eight values that are all either zero or one, one representing the presence of an interaction of that in or out modality).

NOTE – The radio interaction modality and the calor interaction modality are not present in the model described in [b-Campbell].

11.9 The labelling for the metric layer (combinations of the seven base units), is a little more complex. Many measurable quantities (e.g., 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

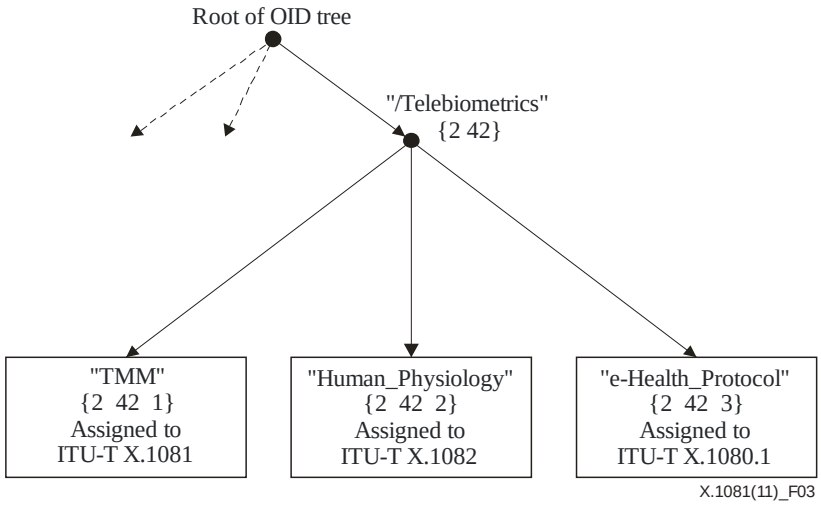
The model described in [b-Lalvani6] provides a labelling of many (but not all) of the elements (see 11.8) of the telebiometric multimodal model, and is recommended for use where such labelling is needed.

12 Object identifier assignments

12.1 Under the procedures of [ITU-T X.660], the object identifier:

{joint-iso-itu-t(2) telebiometrics(42)}
has been allocated for the work on telebiometrics, with the top level oid-iri value "/Telebiometrics".

12.2 Beneath the "`/Telebiometrics`" arc, allocations have been made as shown in Figure 3 below:



NOTE – Other arcs beneath {2 42} are reserved by ITU.

Figure 3 – Top-level arc allocations for telebiometrics

12.3 Annex A provides an ASN.1 module that defines object identifier values, and `OID-IRI` values (using `RELATIVE-OID-IRI` as appropriate) for the associated nodes.

12.4 The arc {`joint-iso-itu-t(2) telebiometrics(42) tmm(1) modules(0)`} is allocated for module definitions in this Recommendation. This, and its sub-arcs, are not shown in Figure 3.

12.5 Further allocations of arcs under the node allocated to ITU-T X.1081 are shown in Figure 4.

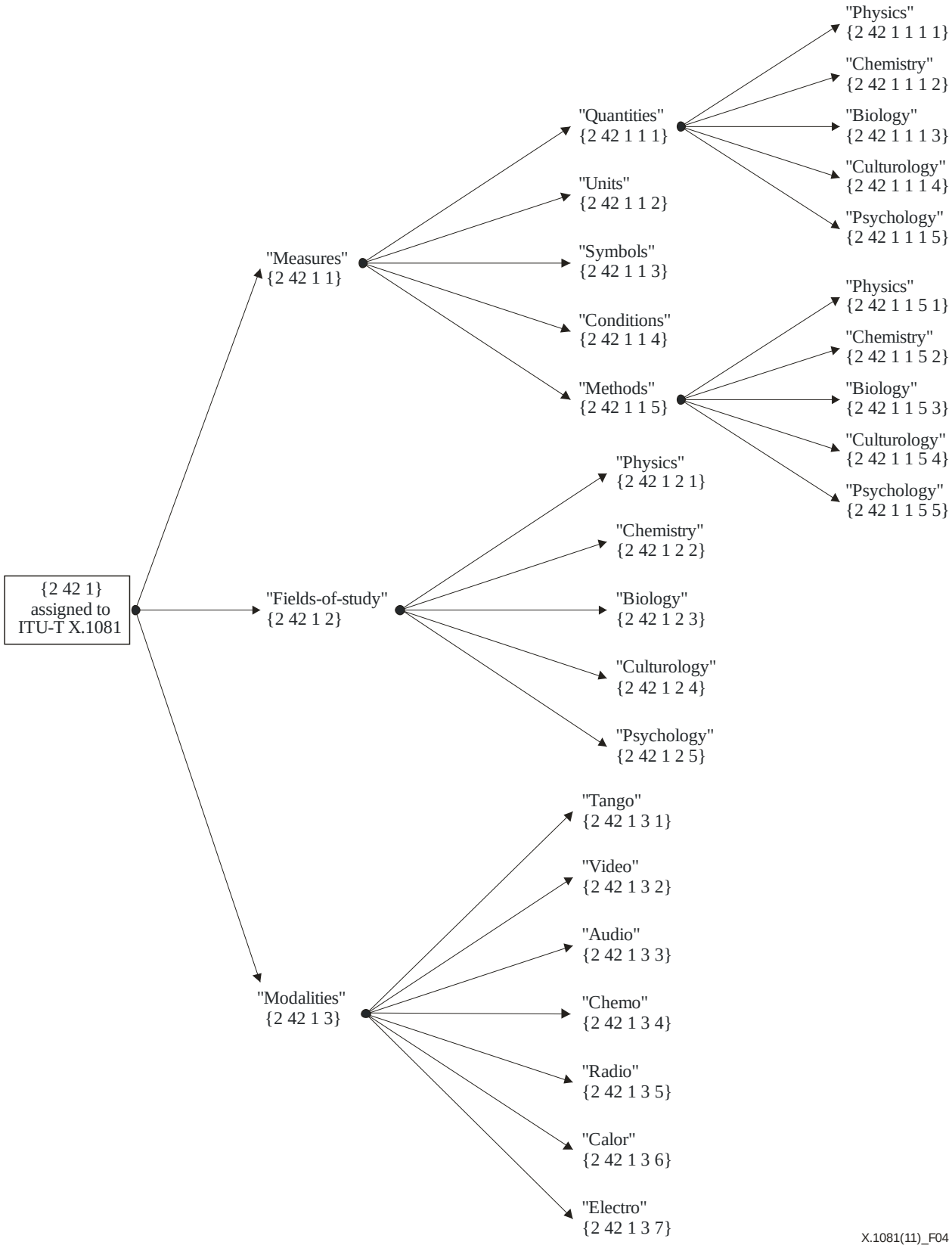


Figure 4 – Allocations made by ITU-T X.1081

12.6 The ASN.1 module in Annex A defines object identifier values and `OID-IRI` (or `RELATIVE-OID-IRI` values) for the nodes identified in Figure 3.

Annex A

Formal ASN.1 OID allocations

(This annex forms an integral part of this Recommendation.)

A.1 General

This annex provides the formal allocation of top-level OID arcs beneath the "/Telebiometrics" arc, together with arcs beneath that for ITU-T X.1081 allocation.

A.2 ASN.1 module

NOTE – This module is normative text in ITU-T X.1081. Relevant parts are imported into modules in [b-ITU-T X.1082] and in [b-ITU-T X.1080.x], as necessary.

```
Telebiometrics
{joint-iso-itu-t(2) telebiometrics(42) modules(0) main(0) version1(1)}
"/Telebiometrics/Modules/Main_Module/Version1"
DEFINITIONS::=
BEGIN
-- *1* OBJECT IDENTIFIER names for top-level biometric nodes
id-telebio OBJECT IDENTIFIER ::= {joint-iso-itu-t(2) telebiometrics(42)}
id-tmm OBJECT IDENTIFIER ::= {id-telebio tmm(1)}
id-hum-phys OBJECT IDENTIFIER ::= {id-telebio human-physiology(2)}
id-th OBJECT IDENTIFIER ::= {id-telebio telehealth(3)}

-- *2* OID-IRI or RELATIVE-OID-IRI names for top-level telebiometric nodes
-- Note that all RELATIVE-OID-IRI names are relative to the last OID-IRI
-- value specified in this module
iri-telebio OID-IRI ::= "/Telebiometrics"
iri-tmm RELATIVE-OID-IRI ::= "TMM"
iri-hum-phys RELATIVE-OID-IRI ::= "Human_Physiology"
iri-th RELATIVE-OID-IRI ::= "Telehealth"

-- *3* OBJECT IDENTIFIER allocations specific to ITU-T X.1081
id-measures OBJECT IDENTIFIER ::= {id-tmm metric(1)}
id-fields-of-study OBJECT IDENTIFIER ::= {id-tmm scientific(2)}
id-modalities OBJECT IDENTIFIER ::= {id-tmm sensory(3)}
-- *3.1* OIDs for measures
id-quantities OBJECT IDENTIFIER ::= {id-measures quantities(1)}
id-units OBJECT IDENTIFIER ::= {id-measures units(2)}
id-symbols OBJECT IDENTIFIER ::= {id-measures symbols(3)}
id-conditions OBJECT IDENTIFIER ::= {id-measures conditions(4)}
id-methods OBJECT IDENTIFIER ::= {id-measures methods(5)}
-- *3.1.1* OIDs for quantities
id-quantities-physics OBJECT IDENTIFIER ::= {id-quantities physics(1)}
id-quantities-chemistry OBJECT IDENTIFIER ::= {id-quantities chemistry(2)}
id-quantities-biology OBJECT IDENTIFIER ::= {id-quantities biology(3)}
id-quantities-culturology OBJECT IDENTIFIER ::= {id-quantities culturology(4)}
id-quantities-psychology OBJECT IDENTIFIER ::= {id-quantities psychology(5)}
-- *3.1.2* OIDs for methods
id-methods-physics OBJECT IDENTIFIER ::= {id-methods physics(1)}
id-methods-chemistry OBJECT IDENTIFIER ::= {id-methods chemistry(2)}
id-methods-biology OBJECT IDENTIFIER ::= {id-methods biology(3)}
id-methods-culturology OBJECT IDENTIFIER ::= {id-methods culturology(4)}
id-methods-psychology OBJECT IDENTIFIER ::= {id-methods psychology(5)}
-- *3.2* OIDs for fields of study
id-physics OBJECT IDENTIFIER ::= {id-fields-of-study physics(1)}
id-chemistry OBJECT IDENTIFIER ::= {id-fields-of-study chemistry(2)}
id-biology OBJECT IDENTIFIER ::= {id-fields-of-study biology(3)}
id-culturology OBJECT IDENTIFIER ::= {id-fields-of-study culturology(4)}
```

```
id-psychology OBJECT IDENTIFIER ::= {id-fields-of-study psychology(5)}
-- *3.3* OIDs for modalities
id-tango OBJECT IDENTIFIER ::= {id-modalities tango(1)}
id-video OBJECT IDENTIFIER ::= {id-modalities video(2)}
id-audio OBJECT IDENTIFIER ::= {id-modalities audio(3)}
id-chemo OBJECT IDENTIFIER ::= {id-modalities chemo(4)}
id-radio OBJECT IDENTIFIER ::= {id-modalities radio(5)}
id-calor OBJECT IDENTIFIER ::= {id-modalities calor(6)}
id-electro OBJECT IDENTIFIER ::= {id-modalities electro(7)}

-- *4* RELATIVE-OID-IRI allocations specific to ITU-T X.1081
--    These are all relative to iri-tmm
iri-measures RELATIVE-OID-IRI ::= "Measures"
iri-fields-of-study RELATIVE-OID-IRI ::= "Fields_of_study"
iri-modalities RELATIVE-OID-IRI ::= "Modalities"
-- *4.1* OID-IRIs for Fields of Study
iri-quantities RELATIVE-OID-IRI ::= "Measures/Quantities"
iri-units RELATIVE-OID-IRI ::= "Measures/Units"
iri-symbols RELATIVE-OID-IRI ::= "Measures/Symbols"
iri-conditions RELATIVE-OID-IRI ::= "Measures/Conditions"
iri-methods RELATIVE-OID ::= "Measures/Methods"
-- *4.1.1* OID-IRIs for Quantities
iri-quantities-physics RELATIVE-OID-IRI ::= "Measures/Quantities/Physics"
iri-quantities-chemistry RELATIVE-OID-IRI ::= "Measures/Quantities/Chemistry"
iri-quantities-biology RELATIVE-OID-IRI ::= "Measures/Quantities/Biology"
iri-quantities-culturology RELATIVE-OID-IRI ::=
"Measures/Quantities/Culturology"
iri-quantities-psychology RELATIVE-OID-IRI ::= "Measures/Quantities/Psychology"
-- *4.1.2* OID-IRIs for Methods
iri-methods-physics RELATIVE-OID-IRI ::= "Measures/Methods/Physics"
iri-methods-chemistry RELATIVE-OID-IRI ::= "Measures/Methods/Chemistry"
iri-methods-biology RELATIVE-OID-IRI ::= "Measures/Methods/Biology"
iri-methods-culturology RELATIVE-OID-IRI ::= "Measures/Methods/Culturology"
iri-methods-psychology RELATIVE-OID-IRI ::= "Measures/Methods/Psychology"

-- *4.2* OID-IRIs for Fields of Study
iri-physics RELATIVE-OID-IRI ::= "Fields_of_Study/Physics"
iri-chemistry RELATIVE-OID-IRI ::= "Fields_of_Study/Chemistry"
iri-biology RELATIVE-OID-IRI ::= "Fields_of_Study/Biology"
iri-culturology RELATIVE-OID-IRI ::= "Fields_of_Study/Culturology"
iri-psychology RELATIVE-OID-IRI ::= "Fields_of_Study/Psychology"

-- *4.3* OID-IRIs for ModalitiesFields of Study
iri-tango RELATIVE-OID-IRI ::= "Modalities/Tango"
iri-video RELATIVE-OID-IRI ::= "Modalities/Video"
iri-audio RELATIVE-OID-IRI ::= "Modalities/Audio"
iri-chemo RELATIVE-OID-IRI ::= "Modalities/Chemo"
iri-radio RELATIVE-OID-IRI ::= "Modalities/Radio"
iri-calor RELATIVE-OID-IRI ::= "Modalities/Calor"
iri-electro RELATIVE-OID-IRI ::= "Modalities/Electro"

END
```

Appendix I

ISO/IEC 80000-series specification of SI units

(This appendix does not form an integral part of this Recommendation.)

This table is fundamental to the approach taken by the telebiometric multimodal model, and is copied from [ISO/IEC 80000] for the convenience of users of this Recommendation. The normative specification is in [ISO/IEC 80000].

Table I.1 – ISO/IEC 8000-series specification of SI units

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

Appendix II

Use of the telebiometric multimodal model

(This appendix does not form an integral part of this Recommendation.)

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" [b-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 does not form an integral part of this Recommendation.)

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 understanding or to using 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 a 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 [b-Kolasa] 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 the 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 a 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 [b-Feibleman] 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 [b-Simon] 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.

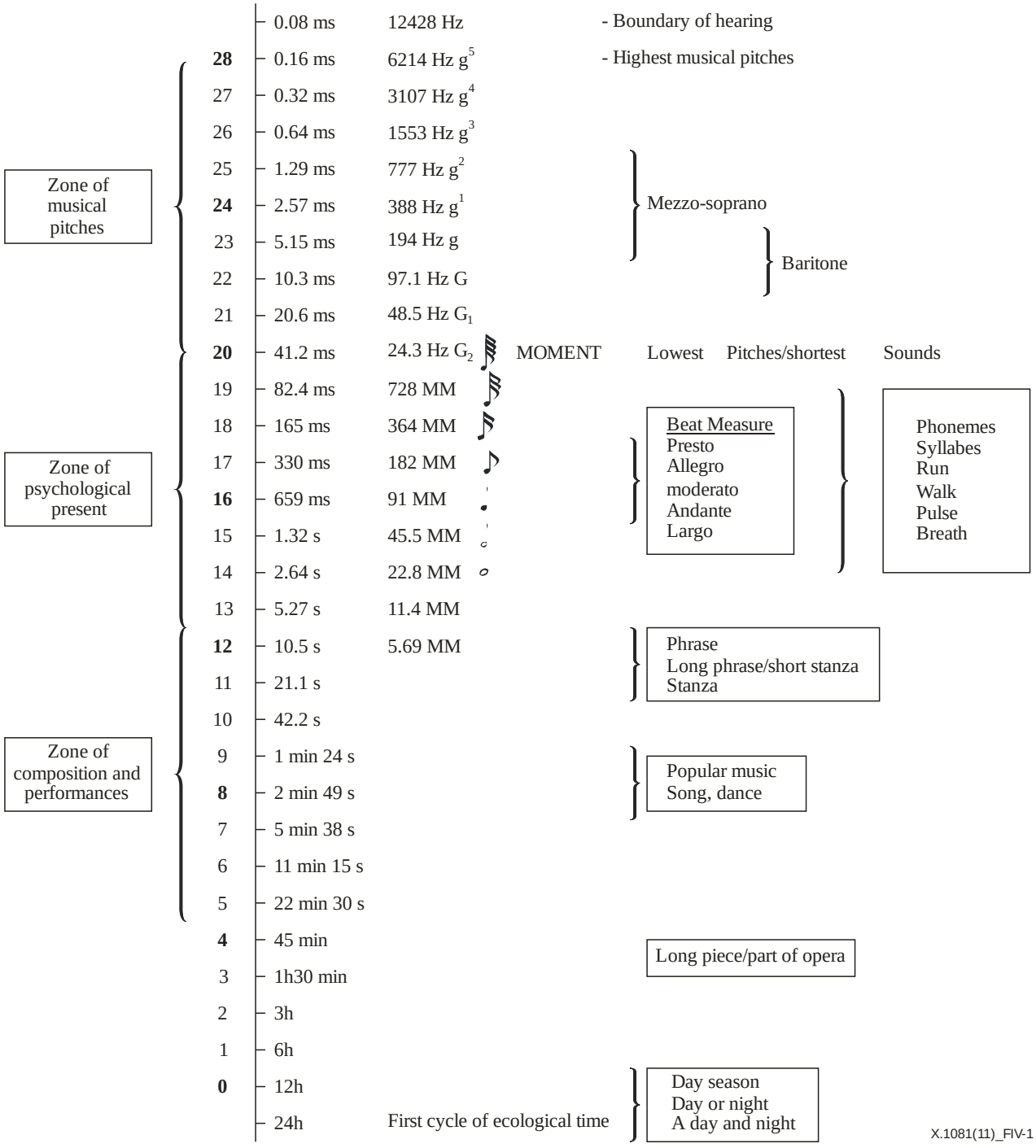
III.4.6 The concept of spatial propinquity is important in determining the safe limits for the operation of telecommunications and biometric devices, as a potential hazard is much greater the closer that device is to the human body. Thus recommendations on safe limits have to include measures of propinquity,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

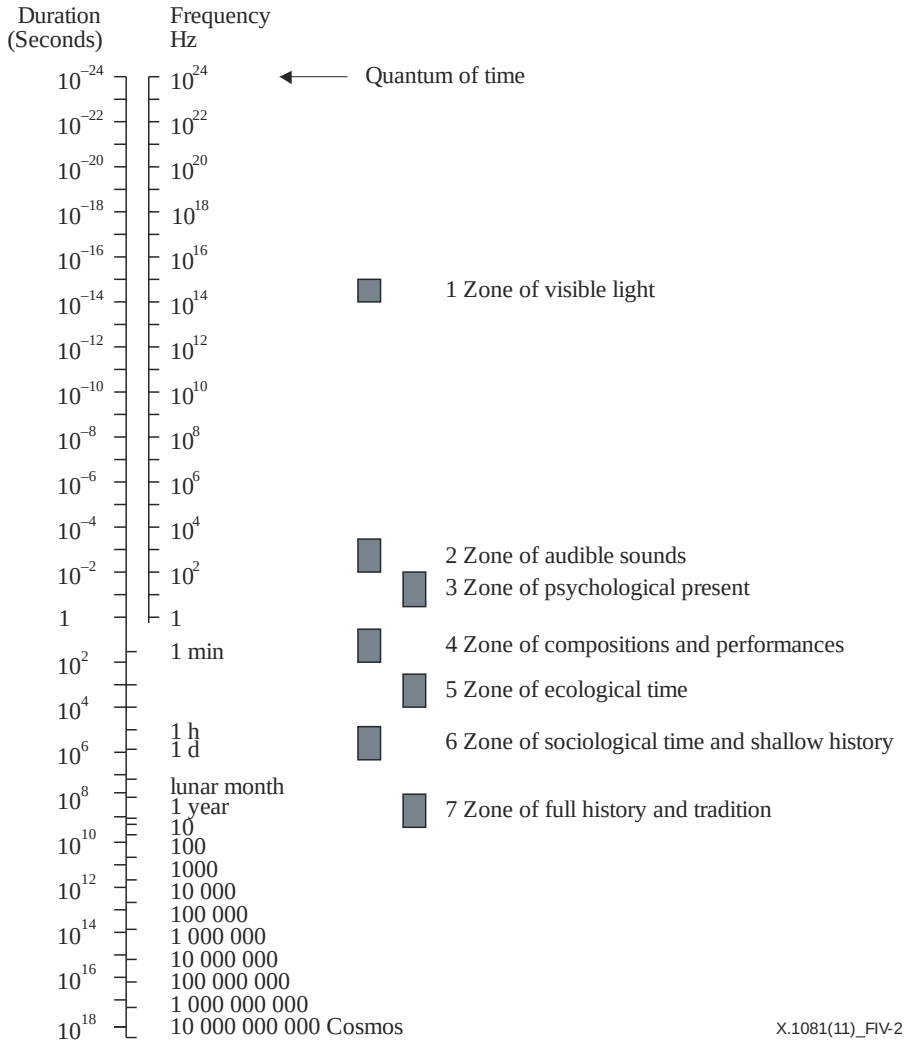
Appendix IV

Tables illustrating scale hierarchy

(This appendix does not form an integral part of this Recommendation.)

The following two tables are taken from [b-Bielawski2] and illustrate the extremes of time-scale that can arise.





"Concepts of time ancient and modern", edited by Kapila Vatsyayan 1996, Published by Indira Gandhi National Centre for the Arts. p.448

Appendix V

Hierarchy theory principles

(This appendix does not form an integral part of this Recommendation.)

In order to allow further development and application of this Recommendation, this theory is introduced for clarification purposes in this world of complexity, together with a useful bibliography.

V.1 Hierarchies have two known logical forms

V.1.1 The first logical form is the compositional hierarchy (including a synchronic map of the command hierarchy), which in applications is called the 'scale hierarchy'. The picture of macromolecules inside a living cell, inside an organism is a familiar image of one important application. This form is suited to synchronic modelling of systems as they are at any given moment.

V.1.2 The second logical form is the subsumption hierarchy (including a diachronic model of the trajectory of a given command), which is called the 'specification hierarchy'. The Linnaean hierarchy in biological systematics has this form. This form is suitable to diachronic modelling of emergent forms.

V.1.3 Table V.1 compares the logical properties.

The two columns show the two hierarchies.

Each line distinguishes the signifying elements of the two hierarchies:

Table V.1

Taxonomy	Meronomy
General/specific	Whole/part
is-a-kind-of	is-a-part-of
Subsumption	Composition
Inheritance	Containment
Specification	Modularity

V.2 General properties

Hierarchies are examples of 'partial ordering' in logic. That is, the items being ordered could be ordered in other ways as well. Hierarchies order entities, processes or realms into a system of levels. The ordering principle ('is-a-part-of' or 'is-a-kind-of') is transitive across levels. In both of these hierarchies, when used to model systems, higher levels control (regulate, interpret, harness) lower levels, whose behaviours are made possible by properties generated at still lower levels. So higher levels provide boundary conditions on the behaviours of lower levels; behaviours initiated by still lower level configurations (see below for the usage of 'higher' and 'lower'). It is important to realize that only some users of hierarchical forms would insist that particular levels exist in actuality. Levels are discerned from hierarchical analysis, aimed at constructing/discovering nature's 'joints' with respect to given projects. Hierarchies thus provide models of systems that are susceptible to analysis into different levels.

V.2.1 To use the compositional hierarchy we need to stipulate a focal level, as well as a lower and a higher, making up a 'basic triadic system'; as, e.g., when the behaviour of living cells is initiated by chemical events, and controlled by organismic events. The three-level form ensures stability

because with it in place (a third level always anchoring relations between the other two), the focal level cannot be reduced either upward or downward by assimilation into a contiguous level. Here it should be noted that this hierarchy has been invoked to explain how the world manages to be as stable as it is. The triadic form reflects the putative way in which levels would have evolved, by interpolation between primal highest and lowest ones, as when biology would have emerged as organizational forms between chemical activities in an environmental energy dissipative configuration.

V.2.2 In the subsumption hierarchy the highest relevant level is always the one in focus, with all the lower levels of the hierarchy providing cumulative initiating conditions simultaneously upon it. This reflects the fact that this hierarchy is implicitly developmental, with the levels being viewed as having emerged consecutively from the lowest or most general (or generally present), up – as with, e.g., biology emerging from chemistry, both historically and at any given moment. The two-level form is unstable, allowing new levels to emerge at the top of the hierarchy. Use of this form provides us with a model allowing for emergent changes in the world.

Hierarchical analysis is always driven by a given problem or project.

V.3 Formal relations between levels

V.3.1 The compositional hierarchy is one of parts nested within wholes, as, e.g., [... [species [population [organism [gene [...]]]]]], where [higher level [focal level [lower level]]]. The logic reflects Russell's logical types. In principle the levels just keep going, receding at both ends from the focal level. (It may be noted that this structure probably is rooted in our visual experiences.)

If the parts are functional in some given analysis, they are referred to as components, if not they are constituents. As one goes down the hierarchy, the relative number of constituents per level increases, giving a measure of the 'span' of the hierarchy.

V.3.2 The subsumption hierarchy is one of classes and subclasses, as, e.g., {material world {biological world {social world}}}, where {lower level(s) {highest level}}. The focus of analysis is always the highest level, which is the innermost level of the hierarchy. The logic reflects Ryle's categories. Higher levels inherit all the properties of the lower levels.

V.3.3 A note on levels terminology: The levels in a subsumption hierarchy have been referred to as 'integrative levels' inasmuch as the higher levels integrate the lower levels' properties and dynamics under their own rules. 'Levels of reality' and 'ontological levels' have been used in subsumption as well. One sees other labels, such as 'levels of organization' or 'levels of observation' used for either kind of hierarchy. The term 'scalar levels' or 'levels of scale' are used for the application of the compositional hierarchy to material systems for dynamical reasons (see clause V.5 below, 'Criteria').

V.4 Style of growth of the hierarchy

V.4.1 A compositional hierarchy adds levels by interpolation between existing levels. In this way, the system must be an expanding one. Therefore, an assumption required for application of this hierarchy would be the Big Bang (or other expanding system). The actual process of formation of a level would involve the cohesion of entities out of lower level units guided by higher level boundary conditions. This process is little understood since this hierarchy has largely been used for synchronic analyses.

V.4.2 In the subsumption hierarchy, new levels would emerge from the current highest one. So this system too can grow – but not in space. Growth here is by the accumulation of informational constraints, modelled as a process of refinement by way of adding specification. New levels, marked by subclasses reflect thresholds of system structural reorganization.

V.5 Criteria

V.5.1 On application of the compositional hierarchy to actual natural systems, components at different levels must differ in size roughly by orders of magnitude. Otherwise, components at different levels would interact dynamically, in which case there would not be different levels functionally.

V.5.2 Levels in a subsumption hierarchy mark the qualitative differences of different realms of being, as in the 'physical realm' versus the 'biological realm'. This hierarchy is open at the top; the innermost level is unbounded above, and so free to give rise to ever higher levels.

V.6 Complexity

V.6.1 A compositional hierarchy provides a model of 'extensional complexity', the sign of which is non-linear and chaotic dynamics, allowed by the fact that at any locale at any level in this hierarchy, there could be a mixture of different kinds of information (relations, variables, constants of different kinds, attractors) which are not governed by a single overall structure. It is useful here to contrast complexity with complication. A flat hierarchy with few levels could tend to show more complicated behaviour than a hierarchy with more levels, which would have more constraints imposed top-down.

V.6.2 A subsumption hierarchy embodies intentional complexity, which characterizes a system to the degree that it is susceptible to many different kinds of analyses.

V.7 Dynamical relations

V.7.1 A compositional hierarchy represents a single moment in space, so its dynamics represent homeostasis, not change. Large scale moments "contain" many small scale moments. It is often suggested that scalar levels fundamentally signal rate differences rather than component size differences. It may be noted that the two most often go together. The problem appears in cases that are said to be non-nested, where, e.g., a much slower rate in a component of a cycle would regulate the rate of the entire cycle. It would be rare, however, for such rates to differ by orders of magnitude, and so many of these examples are likely not hierarchical at all. If mere size differences rather than scale differences were allowed to be the criterion, then the constraint of nestedness would be lifted. In any case:

– Because of the order of magnitude differences between levels in the compositional hierarchy, dynamics at different levels do not directly interact or exchange energy, but transact by way of mutual constraint (i.e., via informational connections). The levels are screened off from each other dynamically. Because of this dynamical separation of levels, informational exchanges between levels are non-transitive, requiring interpretation at the boundaries between levels.

– So, if focal level dynamics are represented by variables in an equation, then the results of dynamics at contiguous levels would be represented by (non-recursive) constants. Larger scale dynamics are so slow with respect to those at the focal level, that the current value of their momentary result appears relatively unchanging at the focal level. Cumulated results of lower scale dynamics also appear relatively or statistically unchanging at the focal level, as it takes a very long time in lower scale moments to effect a change detectable at the focal level – these points are the essence of dynamical 'screening off' in compositional hierarchy models.

– Note that, because of these relations, thermodynamic equilibria would be more rapidly achieved per unit volume at a lower scalar level, delivering an adiabatic principle relating to screening off. While change of any kind (development, acceleration, diffusion) is relatively more rapid at lower levels, absolute translational motion is more rapid at higher levels. Thus, higher levels provide modes of convection for the dissipation of energy gradients,

which would otherwise proceed by slow conduction instead. In relation to these matters, it should be noted that metabolic rates and development are much faster in smaller dissipative structures (organisms, fluid vortices, etc.), and their natural life spans are shorter than in larger scale ones.

– One sometimes sees the term 'heterarchy' posed in opposition to the scale hierarchy because of supposed failures of actual systems to conform to hierarchical constraints. One needs to recall here again that hierarchy is a conceptual construction, an analytical tool, and use of it does not imply that the world itself is actually hierarchically organized. Although, it seems so in many ways, it would be naive to suppose that this is the sole principle needed in understanding the world. It is one tool among many. But often this 'hetero' opposition to hierarchy is based merely on faulty understanding. For example, the tides are affected (partially controlled) by gravitational effects associated with the moon; yet the oceans are not nested inside the moon. As in classical thermodynamics, it is important to see the whole system correctly. The oceans are nested, along with the earth itself, within the solar system, and from the hierarchical point of view, these effects on the tides emanate from the solar system, not merely from the moon. Hierarchical constructs model events in the material world, defined as the realm of friction and lag in the affairs of chemical elements and their compositions.

V.7.2 Dynamics in a subsumption hierarchy are entrained by development, which is modelled as a process of refinement of a class, or increased specification of a category. It is important to note that this process is open-ended in the sense that there could be many coordinate subclasses of a given class. That is, the potential arising within any class form a tree. So, in {physical realm {material realm {biological realm}}}, or {mammal {primate {human}}} each hierarchy follows just one branch of a tree. Rylean categories can branch into new distinctions (and this forms a link with the scalar hierarchy because this would also give rise to new logical types). Evolution (unpredictable change) is one of many, and thus we have been able to picture organic evolution using the Linnaean hierarchy.

The fact that functionally this is a two-level hierarchy makes it susceptible to change, because, without the anchoring provided by a third level, it could be reduced to a single level. How is its direction into new subclasses ensured (giving rise to the hierarchy)? In models of the material world this is afforded by the fact that information, once in place (or once having had an effect), marks a system irrevocably. Marks in material systems are permanent. If a system continues to exist, it must march forward if it changes; there can be no reversal of evolution. Since change in the material world is entrained by the second law of thermodynamics, we have here a link between the two hierarchy models because the second law can be seen to be a result of universal expansion being too fast to allow the global equilibration of matter. As noted above, this expansion is also what affords the interpolation of new levels in a compositional hierarchy.

So, development of a subsumptive hierarchy model requires a two-level basic form. Yet these hierarchies involve more than just two levels. Why do the more general levels not prevent change, as by the weight of their accumulated information? Here we are led to note another aspect of development, which is perfectly general. The amount of change required to launch a new level is ever smaller as a hierarchy develops – refinements are just that. The more general levels do continue to exert their influence; e.g., biology is a kind of chemistry, and humans are a kind of mammal. The key to understanding this situation is that in the subsumption hierarchy informational relations between levels are transitive. Thus, physical dynamics are fully active players in a biological system. This means that development in this hierarchical model using only two contiguous levels can be fully understood. New levels may branch off anywhere in the hierarchy, potentially giving rise to collections of coordinate subclasses.

V.8 Informational relations and semiotics

V.8.1 As noted above, informational relations between levels in a compositional hierarchy are non-transitive. The levels are screened off from each other dynamically, and influence each other only indirectly, via transformed informational constraints. Signals moving from one level to another are transformed at boundaries between the levels. When this is not the case, as when a signal from a higher level occasionally transits to a much lower level, that level suffers damage (as when an organism is hit by lightning, or, going the other way, if a given cell affects the whole organism, this could only be if its effect is promoted by the likes of cancer). Here, we can note again the idea that levels different in scale dynamics deliver stability to a system, via the screening-off effect.

The interpolation of a new level between two others can be viewed as involving the appearance of a capability at the uppermost level (via fluctuation, self-organization and/or selection) for making a significant (to it) interpretation of events at what then becomes the lowermost level of the three. The upper level effectively disposes – facilitates cohesion among – some of what the lower level proposes. This requires energetic screening off between levels. As the arena of the upper level's interpretants, the new level acts as a filter or buffer between upper and lower. This allows us to see levels succeeding each other by a classification procedure whereby topological difference information is converted to (or coheres as) typological distinction information in an essentially top-down procedure.

V.8.2 In a subsumption hierarchy the lower levels also make possible the emergence of a new realm, in an epigenetic process. And here too the process is top-down, but in a different sense, involving finality. Thus, e.g., it can be seen that organism sociality implies biology in the sense of material implication or conceptual subordination. Then, as organism sociality implies biology, biology implies chemistry, and so, because this is a process of refinement, only a very narrow set of possibilities could imply organism sociality. That is, chemistry could give rise to many kinds of supersystems, biology to fewer, and sociality to even fewer as the epigenetic system develops. Developments (in distinction from evolution) are always entrained by final causes, and approach them asymptotically with each emergence of a new realm. Here, as in all developments, is the process of senescence, a condition of information overload (recall that information in this hierarchy is transitive across levels), leading to overconnectivity, leading in turn to functional underconnectivity, leading in its turn to inflexibility and habit driven responses (loss of requisite variety), leading ultimately to loss of adaptability (inability to produce interpretants of novel situations).

The following sources emphasize the historically important, logically basic, and recent references that seem to bring in new departures.

Bibliography

NOTE 1 – Starred (*) references deal with the subsumption hierarchy, either exclusively or along with the compositional hierarchy.

[b-ITU-T X.1080.x] Recommendation ITU-T X.1080.x-series (in force), *e-Health and world-wide telemedicines*.

[b-ITU-T X.1082] Recommendation ITU-T X.1082 (2007) | IEC 80000-14:2008, *Telebiometrics related to human physiology*.

[b-Ahl] Ahl, V., and Allen, T.F.H. (1996), Hierarchy theory: a vision, vocabulary, and epistemology, Columbia University Press.

[b-Allen] Allen, T.F.H., and Starr, T.B. (1982), Hierarchy: perspectives for ecological complexity, University of Chicago Press.

[b-Aoki1] Aoki, I. (2001), *Entropy and exergy principles in living systems*, S.E. Jorgensen (ed.), Thermodynamics and Ecological Modelling, Lewis Publishers.

[b-Aoki2] Aoki, I. (1991), *Entropy principle for human development, growth and aging*, Journal of theoretical biology, Vol. 150, pp. 215-223, Elsevier.

[b-Aronson] * Aronson, L.R. (1984), *Levels of integration and organization: a reevaluation of the evolutionary scale*, in G. Greenberg and E. Tobach, (eds.), Behavioral Evolution and Integrative Levels, Erlbaum.

[b-Auger] Auger, P. (1989), *Dynamics and thermodynamics in hierarchically organized systems*, Pergamon Press.

[b-Auletta] Auletta, G., Ellis, G.F.R., and Jaeger, L. (2008), *Top-down causation by information control: from a philosophical problem to a scientific research programme*, Journal of the Royal Society Interface.

[b-Aulin] Aulin, A. (1979) *Law of Requisite Hierarchy*, Kybernetes, Vol. 8, pp. 259-266

[b-Barkley] Barkley Rosser, J. Jr., Folke, C., Günther, F., Isomaki, H., Perrings, C., and Puu, T. (1994), *Discontinuous change in multilevel hierarchical systems*, Systems Research, 11: 77-94.

[b-Bateson] Bateson, G. (1972), *Form, substance and difference* in Steps to an ecology of mind, Chandler Publishing Co.

[b-Bertalanffy] Bertalanffy, L. von (1968), *General system theory: foundations, development, applications*. George Braziller, NOTE 2 – See especially the Introduction.

[b-Bielawski1] Bielawski, L., and Mossakowski, S., *The Human perspective of time*, The foundation of music, Polish Art Studies II, pp. 133-144.

[b-Bielawski2] Bielawski, L., Fraser, J.T., Lawrence, N., and Park, D. (1981), *The zones of time, music and human activity*, The study of time IV, Springer-Verlag, New York, pp. 173-179.

[b-Bielawski3] Bielawski, L. (1986) *Historical time and zonal theory of time*, Polish musicological studies, pp. 336-337.

[b-Blitz] * Blitz, D. (1992), *Emergent Evolution*, Springer.

[b-Bonabeau] Bonabeau, E., Dorigo, M., and Theraulaz, G. (1999), *Swarm intelligence: from natural to artificial systems*, Oxford University Press.

[b-Bonner] Bonner, J.T. (1969) *The Scale of Nature*, Pegasus

[b-Brody] Brody, S. (1945), *Bioenergetics and growth*, Reinhold.

[b-Brown] Brown, J.H., and West, G.B. (2000), *Scaling in biology*, Oxford University Press.

[b-Calder] Calder III, W.A. (1984), Size, function and life history, Harvard University Press.

[b-Campbell] Campbell, D.T. (1974), "*Downward causation*" *in hierarchically organized biological systems*, in F.J. Ayala and T. Dobzhansky (eds.), Studies in the philosophy of biology, University of California Press.

[b-Csanyi] Csanyi, V., and Kampis, G. (1985), *Autogenesis: the evolution of replicative systems*, Journal of Theoretical Biology, Vol. 114, pp. 303-321, Elsevier.

[b-Collier1] Collier, J. (2003), *Hierarchical dynamical information systems with a focus on biology*, Entropy, Vol. 5, pp. 57-78.

[b-Collier2] Collier, J. (1988), *Supervenience and reduction in biological hierarchies*, Canadian Journal of Philosophy, Supplement 14, pp. 209-234.

[b-Conrad1] Conrad, M. (1983), Adaptability*: The significance of variability from molecule to ecosystem*, Plenum Press.

[b-Conrad2] Conrad, M. (1996) *Cross-scale information processing in evolution, development and intelligence*, BioSystems, Vol. 38, pp. 97-109, Elsevier.

[b-Feibleman] * Feibleman, J.K. (1954), *Theory of integrative levels*, British journal for the philosophy of science, Vol. 5, pp. 59-66.

[b-Floridi] Floridi, L. (2008), *The method of levels of abstraction*, Minds and Machines, Vol. 18, pp. 303-329, Springer.

[b-Havel] Havel, I.M. (1996), *Scale dimensions in nature*, International Journal of General Systems, Vol. 24, pp. 295-324, Taylor and Francis.

[b-Hershey] Hershey, D., and Lee III, W.E. (1987), *Entropy, aging and death*, Systems Research, Vol. 4, pp.269-282.

[b-Jamshidi] Jamshidi, N., and Palsson, B.Ø. (2008), *Top-down analysis of temporal hierarchy in biochemical reaction networks*, PLoS Computational Biology.

[b-Jolley] * Jolley, J.L. (1973), *The Fabric of Knowledge: A Study of the Relations Between Ideas*, Barnes and Noble.

[b-Joslyn] Joslyn, C. (1991), *Hierarchy, strict hierarchy, and generalized information theory*, Proc. International Society for the Systems Sciences, Vol. 1, pp. 123-132.

[b-Kampis] Kampis, G. (1991), *Self-modifying systems in biology and cognitive science: A new framework for dynamics, information and complexity*, Pergamon Press, Oxford.

[b-Kolasa] Kolasa, J., and Pickett, S.T.A. (1989), *Ecological systems and the concept of biological organization*, Proceedings of the National Academy of Sciences, 86: 8837-8841.

[b-Kleiber] Kleiber, M. (1961), *The fire of life*, John Wiley and Sons.

[b-Lalvani1] Lalvani, H. (1990), *Continuous transformations of subdivided periodic surfaces and space structures* (special issue), Vol. 5, Nos. 3 and 4, Multi-Science, UK.

[b-Lalvani2] Lalvani, H. (1983), *Explorations in Hyper Space*, LIMS Newsletter, Laban/Bartenieff Institute for Movement Studies. NOTE 3 – This publication includes a diagram showing the 4-dimensional organization of Rudolf Laban's movement "efforts" characterized by space, time, weight and flow.

[b-Lalvani3] Lalvani, H. (1997), *Families of multi-directional periodic space labyrinths*, Structural Topology, Vol. 22, Canada.

[b-Lalvani4] Lalvani, H. (1997), *Higher-Dimensional periodic table of regular and semi-regular polytopes*, Morphology and architecture, Guest Ed. H. Lalvani, Space Structures, Vol. 11, Nos, 1 & 2.

[b-Lalvani5] Lalvani, H. (1982), *Multi-dimensional arrangements of transforming space structures*, University Microfilms, Ann Arbor, Michigan. NOTE 4 – Based on author's doctoral dissertation, University of Pennsylvania, 1981, and self-published in a slightly extended form as Structures on hyper-structures, Lalavani, New York.

[b-Lalvani6] Lalvani, H. (2003), *Patterns for a Coherent Standardisation*, Aulm, Geneva.

[b-Lalvani7] Lalvani, H. (1982), *Patterns in Hyper-spaces*, Lalvani, New York.

[b-Lalvani8] Lalvani, H. (1998), *Visual morphology of space labyrinths: A source for architecture and design, Beyond the cube, the architecture of space frames*, Ed. Francois Gabriel, John Wiley.

[b-Lemke] Lemke, J.L. (2000), *Opening up closure: semiotics across scales*, in J.L.R. Chandler and G. Van de Vijver (eds.), Closure: emergent organizations and their dynamics. Annals of the New York Academy of Sciences, Vol. 901, pp. 100-111.

[b-Mahner] Mahner, M., and Bunge, M. (1997), *Foundations of biophilosophy*, Springer-Verlag, pp. 177-180.

[b-Mandelbrot] Mandelbrot, B. (1983), The *Practical Geometry of Nature*, W.H. Freeman & Co.

[b-Maurer] Maurer, B.A. (1999), *Untangling ecological complexity: the macroscopic perspective*, University of Chicago Press.

[b-Mesarovic] Mesarovic, M.D., Macko, D., and Takahara, Y. (1970), *Theory of hierarchical, multilevel, systems*, Academic Press.

[b-Montagu] Montagu, A. (1989), *Growing young* (Second edition), Bergin and Garvey.

[b-Morrison] Morrison, P., and Morrison, P. (1982), *Powers of ten*, Scientific American Books.

[b-Nicolis] Nicolis, J.S. (1986), *Dynamics of hierarchical systems: an evolutionary approach*, Springer.

[b-Odum] Odum, H.T., and Odum, E.C. (2000), *Modeling for all scales: an introduction to system simulation*, Academic Press.

[b-Paine] Paine, R.W., and Tani, J. (2005), *How hierarchical control self-organizes in artificial adaptive systems*, Adaptive Behavior, Vol. 13 pp. 211-225.

[b-Pattee] Pattee, H.H. (1973), *The physical basis and origin of hierarchical control*, in H.H. Pattee (ed.), Hierarchy theory: the challenge of complex systems, George Braziller.

[b-Patten] Patten, B.C. (1982), *Environs: relativistic elementary particles for ecology*, American Naturalist, Vol. 119, pp. 179-219.

[b-Pearl] Pearl, R. (1928), *The rate of living: Being an account of some experimental studies of life duration*, Alfred, A. Knopf, New York.

[b-Pennycuick] Pennycuick, C.J. (1992*), Newton rules biology, a physical approach to biological problems*, Oxford University Press.

[b-Peters] Peters, R.H. (1983), *The ecological implications of body size*, Cambridge University Press.

[b-Petterson] Petterson, M. (1996), *Complexity and evolution*, Cambridge University Press.

[b-Polanyi] * Polanyi, M. (1968), *Life's irreducible structure*, Science, Vol. 160, pp. 1308-1312.

[b-Poli] * Poli, R. (2006), *The theory of levels of reality and the difference between simple and tangled hierarchies*, in G. Minati, E. Pessa, and M. Abrams (eds.), Systemics of emergence: research and development, Springer.

[b-Purvis] Purvis, A., and Harvey, P.H. (1997), *The right size for a mammal*, Nature, Vol. 386, pp. 332-333.

[b-Queiroz] Queiroz, J., and El-Hani, C.H. (2001), *Towards a multi-level approach to the emergence of meaning process in living systems*, Acta Biotheoretica, Vol. 54, pp. 179-206.

[b-Ratze] Ratze, C., Gillet, F., Müller, J.-P., and Stoffel, K. (2007), *Simulation modelling of ecological hierarchies in constructual dynamical systems*, Ecological Complexity, Vol.4, pp. 13-25.

[b-Reiss] Reiss, M.J. (1989), *The allometry of growth and reproduction*, Cambridge University Press.

[b-Sabelli] * Sabelli, H.C., and Carlson-Sabelli, L. (1989), *Biological priority and psychological supremacy: a new integrative program derived from process theory*, American Journal of Psychiatry, Vol.146, pp. 1541-1551.

[b-Salthe1] * Salthe, S.N. (1993), *Development and evolution: complexity and change in biology*, MIT Press.

[b-Salthe2] * Salthe, S.N. (1985), *Evolving hierarchical systems: their structure and representation*, Columbia University Press.

[b-Salthe4] Salthe, S.N. (1998), *Naturalizing semiotics* (review of Hoffmeyer's Signs of meaning in the universe), Semiotica, Vol. 120, pp. 381-394.

[b-Salthe5] * Salthe, S.N. (1988), *Notes toward a formal history of the levels concept*, in. G. Greenberg and E. Tobach (eds.), Evolution of social behavior and integrative levels, Erlbaum.

[b-Salthe6] Salthe, S.N., and Matsuno, K. (1995), *Self-organization in hierarchical systems*, Journal of social and evolutionary systems, Vol. 18, pp. 327-338, Elsevier.

[b-Salthe7] Salthe, S.N. (2002), *Summary of the principles of hierarchy theory*, General Systems Bulletin, Vol. 31, pp. 13-17.

[b-Salthe8] * Salthe, S.N. (1991), *Two forms of hierarchy theory in Western discourses*, International Journal of General Systems, 18: 251-264.

[b-Schmidt] Schmidt-Nielsen, K. (1984), *Scaling, Why is animal size so important?*, Cambridge University Press.

[b-Simon] Simon, H.A. (1962), *The architecture of complexity*, Proceedings of the American Philosophical Society, Vol. 106, pp. 467-482.

[b-Sommers] * Sommers, F. (1963), *Types and ontology*, Philosophical Review, Vol. 72, pp. 327-363.

[b-Soodak] Soodak, H., and Iberall, A. (1978), *Homeokinetics: a physical science for complex systems*, Science, Vol. 201, pp. 579-582.

[b-Ulanowicz] Ulanowicz, R.E. (1997), *Ecology, the ascendent perspective*, New York, Columbia University Press.

[b-Van de Vijver] Van de Vijver, G. (ed.) (1992), *New perspectives on cybernetics: Self-organization, autonomy and connectionism*, Dordrecht, Kluwer Academic Publishers.

[b-Weiss] Weiss, P.A. (1971), *The basic concept of hierarchic systems*, in P.A. Weiss (ed.), Hierarchically organized systems in theory and practice, Hafner.

[b-West1] West, G.B., Brown, J.H., and Enquist, B.J. (1997), *A general model for the origin of allometric scaling laws in biology*, Science, Vol. 276, pp.122-126.

[b-West2] West, G.B., Brown, J.H., and Enquist, B.J. (2001), *A general model for ontogenetic growth*, Nature, Vol. 413, pp. 628-631.

[b-Whyte] Whyte, L.L., and Wilson A.G. (1969), in Hierarchical Structures, Elsevier, New York. NOTE 5 – This includes: Wilson, (D.), Forms of hierarchy: a selected bibliography, pp. 287-293.

[b-Woodger] Woodger, J.H. (1929), *Biological Principles: A Critical Study*, Harcourt.

[b-Zhirmunsky] Zhirmunsky, A.V., and Kuzmin, V.I. (1988), *Critical Levels in the Development of Natural Systems,* Springer-Verlag.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	**Data networks, open system communications and security**
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2012