XR Standardization – a Global Overview

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I. SCOPE

The landscape of XR norms, standards, guidelines and recommendations (hereafter summarized for the sake of simplicity as: XR norms) is extremely broad, scattered and confusing today. It was already evident from the preliminary work that dozens of organizations are working on the topic, some of which in turn host several working groups. At least hundreds of documents are estimated to be relevant. Today, there is no institution that comprehensively sifts, classifies and transfers the knowledge on XR standards available to the public. This work attempts to create transparency in the field of XR standardization.

Due to the scattered nature of this topic, the research was conducted with different starting points. Standards organizations, but also associations of XR user industries were identified and searched for XR committees, XR working groups and XR standardization projects. Based on further known XR standards, it was again possible to infer working groups, standards organizations and associations. The search for documents was also initiated via (university) libraries and a free WWW search. This process has been run through cyclically many times. As a result, completed lists of standards organizations, working groups, ongoing activities and XR standards are available.

II. Norming and Standardization

Standardization is generally the unification of products, components or processes to one or a few variants. It is a standardization of objects according to certain templates. The procedures for standardization are norming and typification. The term can be applied to various fields. In the economic fields: Manufacturing area norming and typification of parts, intermediate or final products.

Standardization refers to the formulation, issuing and application of rules, guidelines or characteristics by a recognized organization and its standards bodies. They shall be based on the established results of science, technology and experience and aim at promoting optimal benefits for society. The specifications shall be established by consensus and adopted by a recognized institution. Recognized standardization institutions are, for example, ISO, IEC, EN, DIN.

a. Arguments in favor of Standardization

The main purpose of standardization is to save costs and simplify work. Standardization leads to an increase in market transparency and a reduction in costs (in manufacturing costs, information costs, transaction costs, shipping costs, distribution costs, switching costs). By using standards, manufacturers can concentrate on the really innovative aspects of their products.

On the part of the buyers of standardized products, services and services, the reduced switching costs and compatibility are particularly interesting: purchased products and services become much easier to exchange and technically compatible, and thus integrable. This intensifies competition, which must lead to price degression and increased performance.

A very important advantage of standardization is the attainment of a certain legal certainty for products brought onto the market. Of particular legal interest is the so-called reversal of the burden of proof: in the event of damage to a non-standardized product, the manufacturer must prove that the product was developed without defects. If, however, a case of damage occurs with a standardized product, the manufacturer is deemed to have acted in accordance with the state of the art. In this case, the customer must prove that the manufacturer acted incorrectly. Here, the burden of proof is reversed.

b. Arguments against Standardization

However, the positive aspects of standardization also have possible disadvantages.

For the success of a product, a service and thus the entire company, a USP ("unique selling proposition") should be given. Thus, it may seem problematic that a standard solution can be the basis of a good USP, as it has to stand out from the crowd. This inevitably means that the special added value of the product, instead of coming from a standardized value chain, can only come from a deviation from the standard.

If one analyses existing standards, it becomes clear that the criteria formulated are always minimum requirements (i.e. what the customer should be able to expect anyway).

The consistent pursuit of standards can thus lead to companies always finding themselves at the bottom of the range and even giving up their unique selling propositions. Blue Ocean strategies include - somewhat abbreviated - in particular the omission of learned features of a product or service if this makes it possible to create significant added value for the customer elsewhere. Here it makes sense not to meet standards if this serves the unique selling proposition and the success of the product.

Standardization creates the dangers of schematization and loss of flexibility. It can happen that aspects that cannot be standardized are neglected. Standardization is a coordination-intensive process that incurs high costs and normally takes several years to complete. This results in a framework that is too static. Standardization can lead to a restriction of creative freedom. This stifling of innovation fields is undesirable, especially in the environment of the development of innovative technologies.

III. Approach of this Work

The landscape of XR norms, standards, guidelines and recommendations (hereafter summarized for simplicity as: XR norms) is extremely broad, scattered and confusing today. It was already evident from the preliminary work that dozens of organizations are working on the topic, some of which in turn host several working groups. At least hundreds of documents are estimated to be relevant.

Today, there is no institution that comprehensively sifts, classifies and transfers the knowledge on XR standards available to the public. This work shall achieve this task.

a. Standardization in the V/AR context

Virtual Reality (VR) is a spatial user interface for 3D data. VR can be defined as a computer-generated, real-time 3D environment in which one or more persons are immersed by uniquely locating them in the spatial coordinate system of the 3D scene via position detection. Only in this way does the perception of the 3D content (change of perspective, direction-dependent hearing, scanning, etc.) react as we are used to from natural reality. This enables people to better grasp the 3D content presented and understand it in its spatiality. With the help of VR, 3D environments can thus be perceived better than with simple desktop computer systems. At the same time, VR supports spatial interaction with the presented 3D data. The basic prerequisite for the meaningful use of VR is spatially-geometrically complex 3D data. Augmented Reality (AR) is the superimposition of the natural perspective of sight with (3D) computer graphics. AR thus merges a virtual environment with reality. This can be useful for assistance systems or target/actual comparisons (digital plan versus physical reality). Mixed Reality (MR) is the simultaneous presentation of natural and artificial sensory stimuli, mostly digital visualization in combination with physical-haptic interfaces.

Virtual reality and augmented reality are not new methods: the first implementations of VR began in the 1960s at the latest, those of AR in the 1970s at the latest. VR and AR (also V/AR or XR) are cross-cutting technologies and methods that can encompass a huge number of knowledge domains. These include perception/cognitive psychology, work sciences, computer graphics, acoustics, haptics, user interface design, hardware development, software development, etc. In addition, for practical use, there is often concentrated knowledge from the application field (such as design, maintenance, ergonomics, industrial engineering, marketing communication, etc.) and from the industry. This diversity of subject areas is also directly reflected in the consideration of the standardization fields.

b. Monitoring organizations, XR standards and standardization projects

The identification of all relevant XR standardization organizations, XR standards and standardization projects implies very extensive research tasks. We did so by active, personal exchange with representatives of standardization organizations and by participation in relevant events at which XR standardization.

Due to the scattered nature of this topic, the research was conducted with different starting points. Standards organizations, but also associations of XR user industries were identified and searched for XR committees, XR working groups and XR standardization projects. Based on further known XR standards, it was again possible to infer working groups, standards organizations and associations. The search for documents was also initiated via (university) libraries and a free WWW search. This process has been run through cyclically many times. As a result, completed lists of standards organizations, working groups, ongoing activities and XR standards are available.

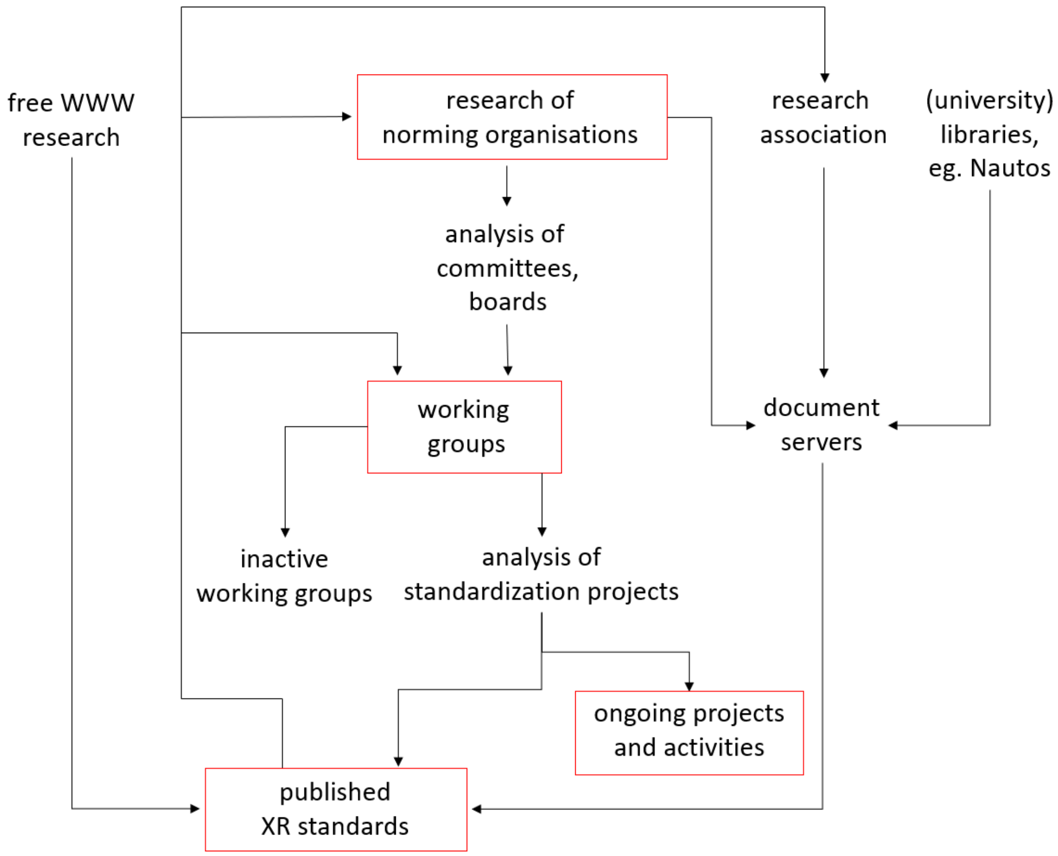

Figure 1. research strategy for XR norms and XR standards

IV. Thematic classification of norms

a. Categorization of XR standards

From the knowledge of the topics dealt with in the XR standards and working groups, categories are formed after content analysis that are sufficiently detailed (and thus enable selectivity), but at the same time still manageable in number. We generated 7 categories and 31 sub-categories (c.f. Fig. 2).

fundamentals of VR AR	▪ basics / terms ▪ XR management ▪ regulation / ethics / governance ▪ evaluation / conformity
XR management	▪ basics / terms ▪ XR management ▪ regulation / ethics / governance ▪ evaluation / conformity
UX, ergonomics, human factors	▪ user experience (UX) / user interface design (UID) ▪ ergonomics / usability ▪interaction / pattern
coding, mapping, interoperability, communication	▪ API application programming interface ▪ formats / coding / compression ▪ communication / interoperability ▪ mapping
graphics software, CGI	▪ graphics software / algorithmics
hardware: optics, haptics, acoustics, tracking, mobile	▪ graphics hardware / optics / displays ▪ haptics ▪ auralisation / audio / acoustics ▪ tracking / sensor technology / motion capturing ▪ mobile XR ▪ other XR hardware
XR applications	▪ human models ▪ content creation / modelling ▪ applications: education / training ▪ applications: design / engineering ▪ applications: health ▪ applications: assistance ▪ applications: collaboration ▪ applications: marketing ▪ applications: entertainment / culture ▪ applications: geo & construction ▪ applications: other

Figure 2. categories for XR norms and XR standards

The sub categories are further explained under sections b) to h).

When analyzing what areas of XR have already been subject to standardization, we find that many documents have been edited on formats/coding, graphics software, however much less on certain application fields of on interaction (c.f. fig. 3). Figure 4 shows a grouped perspective on this issue with according numbers.

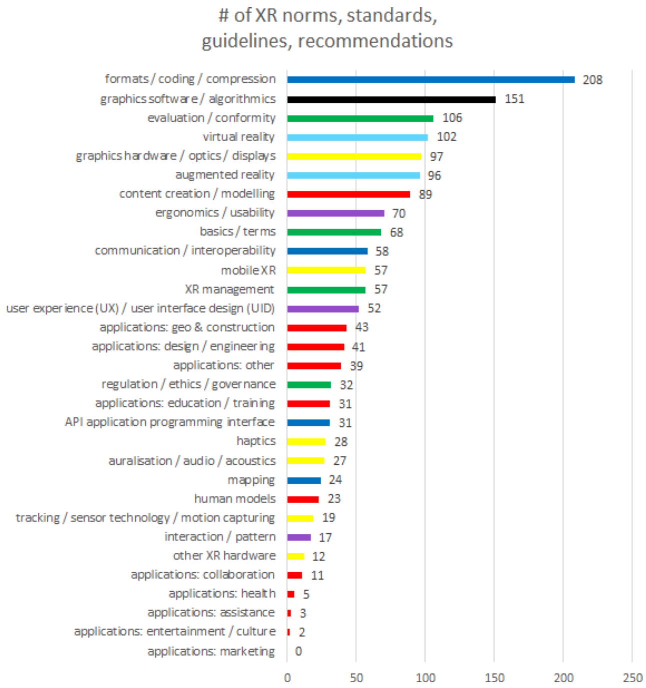

Figure 3. number of existing XR norms and standards in relation to their topic

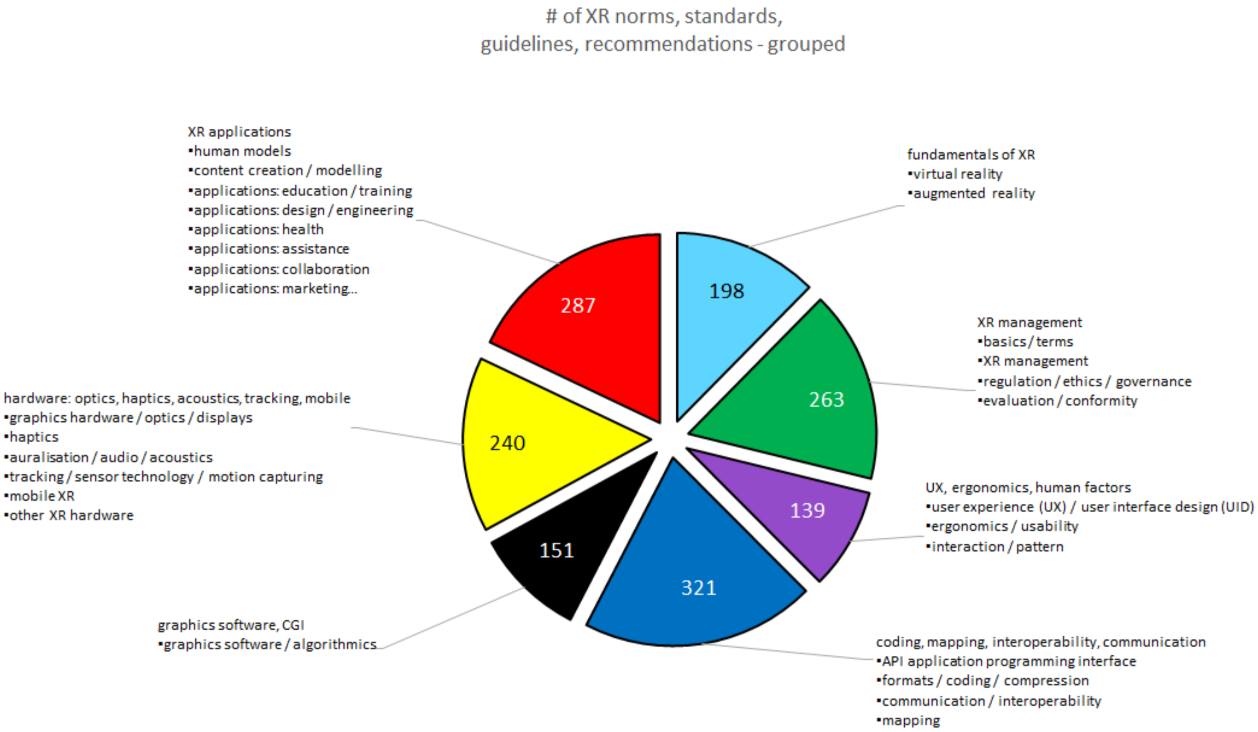

Figure 4. number of XR norms, standards, guidelines, recommendations - grouped

b. area 1: Fundamentals of XR

In the first topic area of "*Fundamentals of XR*", terms, definitions, characteristics, taxonomies are discussed. The aim here is to use uniform terminology and definitions: only if a common language is spoken can meaningful action be taken together. Relevant standards include e.g.:

- CTA: Definitions and Characteristics of Augmented and Virtual Reality Technologies
- IEEE P2048.1 Standard for Virtual Reality and Augmented Reality: Device Taxonomy and Definitions
- IEC 63203-101 Wearable electronic devices and technologies – Part 101-1: Terminology

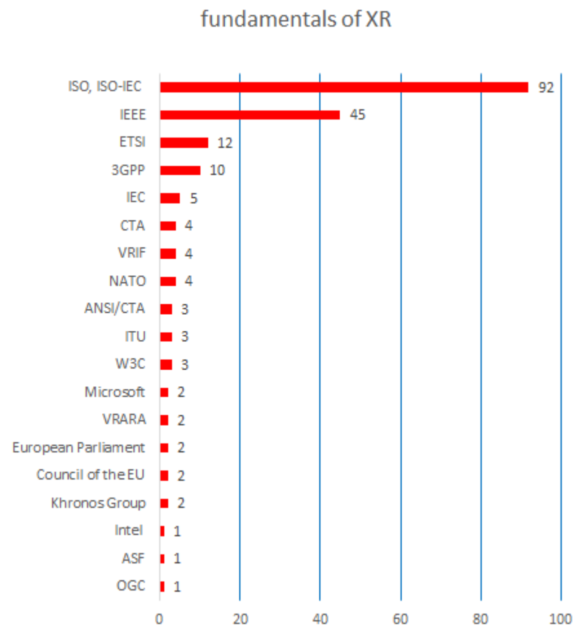

Figure 5. number of standards publications on fundamentals of XR by organization

c. area 2: XR management

In the V/AR management subject area, organizational, administrative and managerial aspects are central. Relevant standards include e.g.:

- ANSI/CTA: Recommendations and Best Practices for Connection and Use of Accessories for XR Technologies
- Council of the European Union: Metaverse - Virtual World, Real Challenges
- ETSI: Augmented Reality Framework (ARF). Industrial use cases for AR applications and services
- ISO-IEC. AR/VR safety-- guidance on safe immersion, set up and usage

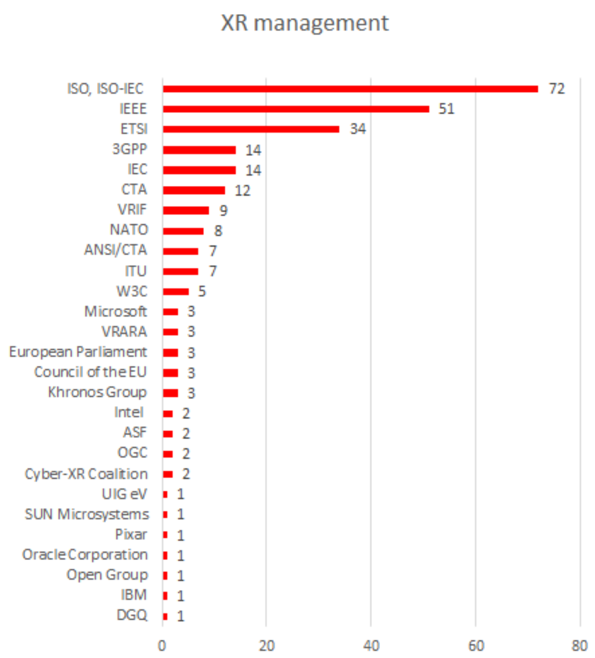

Figure 6. number of standards publications on XR management by organization

d. area 3: UX, ergonomics, human factors

Compared to standard desktop interaction systems, consisting of mouse, keyboard, mouse pointer and window display, V/AR involves much more complex interaction mechanisms, which makes separate standards necessary. However, there is still no generally accepted or even adopted, binding set of rules. For the most part, only guidelines and practicable examples (best practices) are available. Examples are:

- ISO-IEC: Information technology for learning, education, and training – Human factor guidelines for virtual reality content
- IEEE: Standard for Head-Mounted Display (HMD)-Based Virtual Reality(VR) Sickness Reduction Technology
- ISO: Ergonomics of human-system
- ITU:Influencing factors on quality of experience for virtual reality services

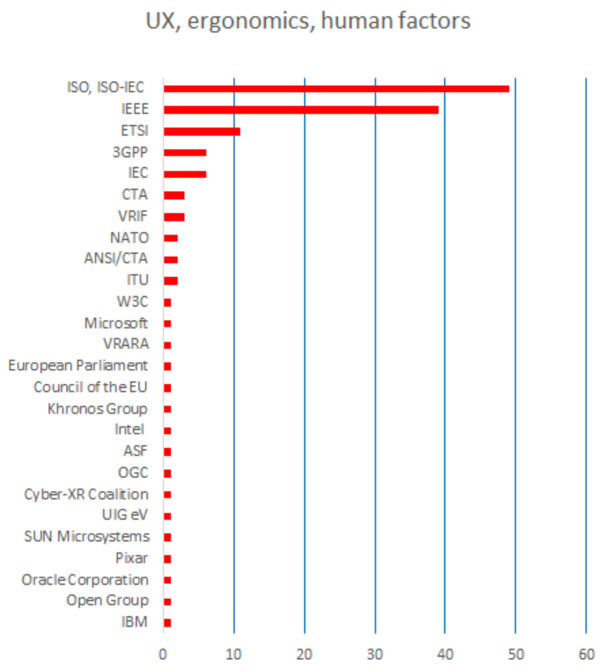

Figure 7. number of standards publications on UX, ergonomics, human factors by organization

e. area 4: coding, mapping, interoperability, communication

The topic of interoperability and communication deals with aspects that have the background of allowing V/AR components to work together with other systems, be it legacy IT or physical reality components. Some examples of relevant standards are:

- 3GPP Virtual Reality (VR) streaming interoperability and characterization
- ETSI Augmented Reality Framework (ARF) Interoperability Requirements for AR components, systems and services; Part 1: Overview
- IEEE Standard for VR and AR: Interoperability between Virtual Objects and the Real World
- ITU Interoperability testing requirements for a virtual broadband network gateway

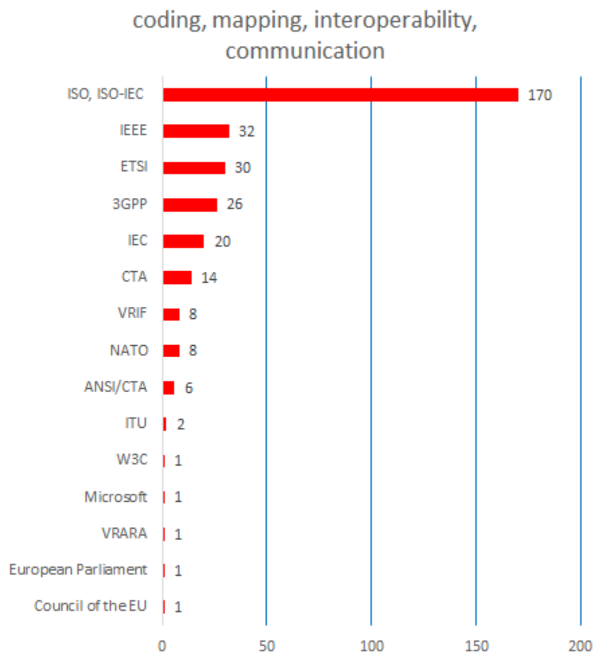

Figure 8. number of standards publications on coding, mapping, interoperability, communication by organization

f. area 5: graphics software, CGI

There is a whole range of different mathematical description methods for 3D geometries, which differ in terms of various properties (generality, precision, one-to-one uniqueness, speed of representation, etc.). Accordingly, there are numerous different 3D data formats. These certainly move on different levels of abstraction (up to semantic aspects) and thus cross over into a border area to the subject area of content and applications. The relevant standards include, for example:

- 3GPP: VR profiles for streaming applic.
- VRIF: Volumetric Video Guidelines
- ISO-IEC: Information technology - Computer graphics, image processing and environment data representation
- ISO-IEC: Extensible 3D (X3D)

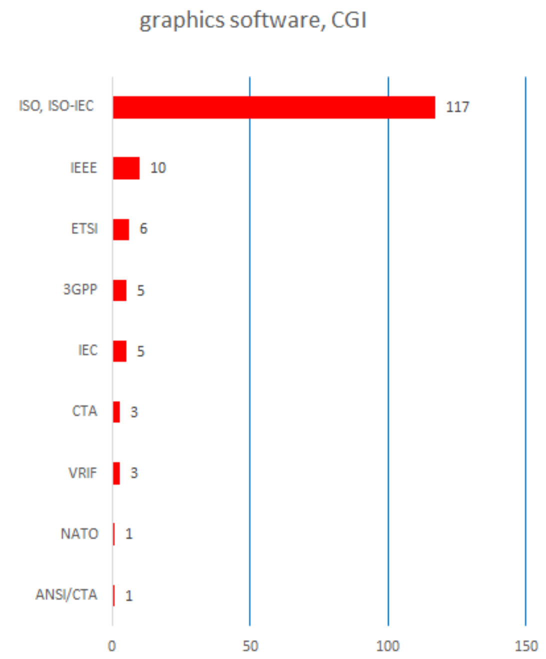

Figure 9. number of standards publications on graphics software, CGI by organization

g. area 6: hardware: optics, haptics, acoustics, tracking, mobile

Hardware standards deal with optical properties of graphic output systems, haptic properties of tactile, haptic and kinaesthetic output systems, auditory properties of acoustic output systems and measurement methods for recording them. Other hardware areas not explicitly mentioned may also be relevant to the V/AR environment. Examples are:

- IEC: Specific measurement methods for AR type - Image quality
- IEC: Touch and interactive displays - Measuring methods of touch displays
- Khronos Group: OpenSL ES standard for three-dimensional audio systems
- IEC: Wearable electronic devices and technologies

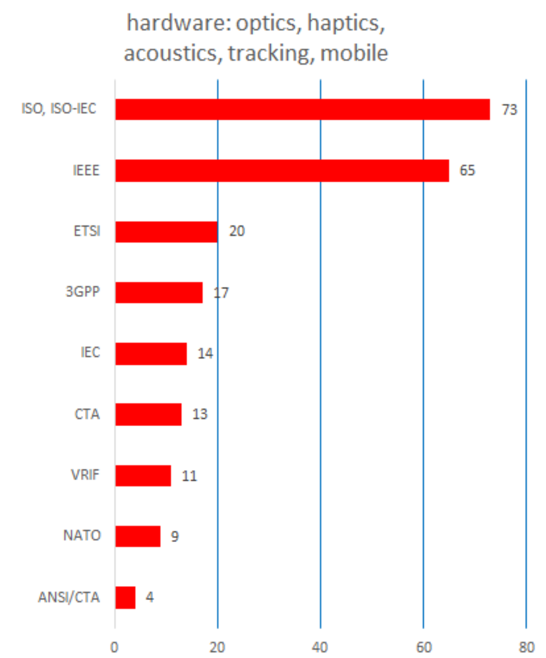

Figure 10. number of standards publications on hardware: optics, haptics, acoustics, tracking, mobile by organization

h. area 7: XR applications

The norms and standards in the context of content and applications go beyond the pure mathematical descriptions of geometries, scene graphs, colors, materials, etc. They define the application of 3D scenes in a specific context and must therefore also provide meaning-related information. They define the application of the 3D scenes in a specific context and must therefore also provide meaning-related information. Some important applications of V/AR today are product development, industrial engineering or training. Examples are:

- ETSI: Augmented Reality Framework (ARF). Industrial use cases for AR applications and services
- NATO: Guidance in the use of simulation and virtual prototyping in ship design
- ISO: Clothing - Digital fittings - Attributes of virtual garments
- ISO: Health informatics - Reference model for VR based clinical practice simulation
- XRA: Designing Immersive Learning for Secondary Education

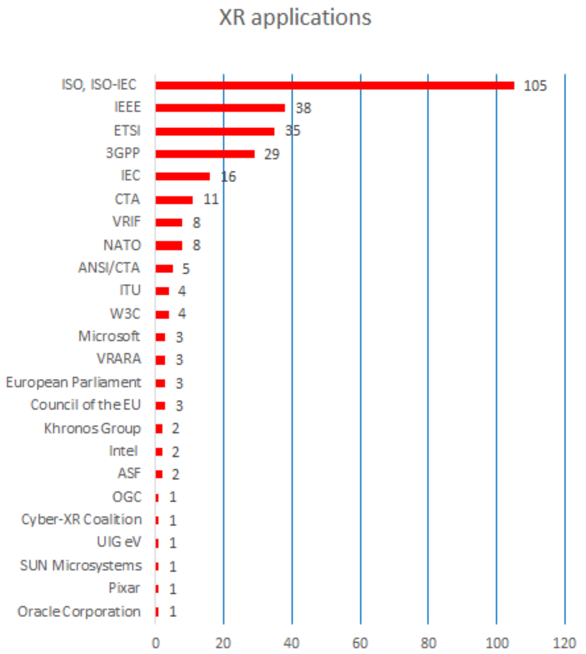

Figure 11. number of standards publications on XR applications by organization

V. XR Standardization Organizations

a. Relevant Stakeholder Organizations

We found more than 40 organizations that are actually active in V/AR standardization and that already published relevant documents. Fig. 12 shows the most relevant organizations.

Figure 12. XR standardization organizations today

These above illustrated organizations published more than 600 relevant XR norms, standards, guidelines and recommendations. Fig. 13 shows how many documents have already been released by them.

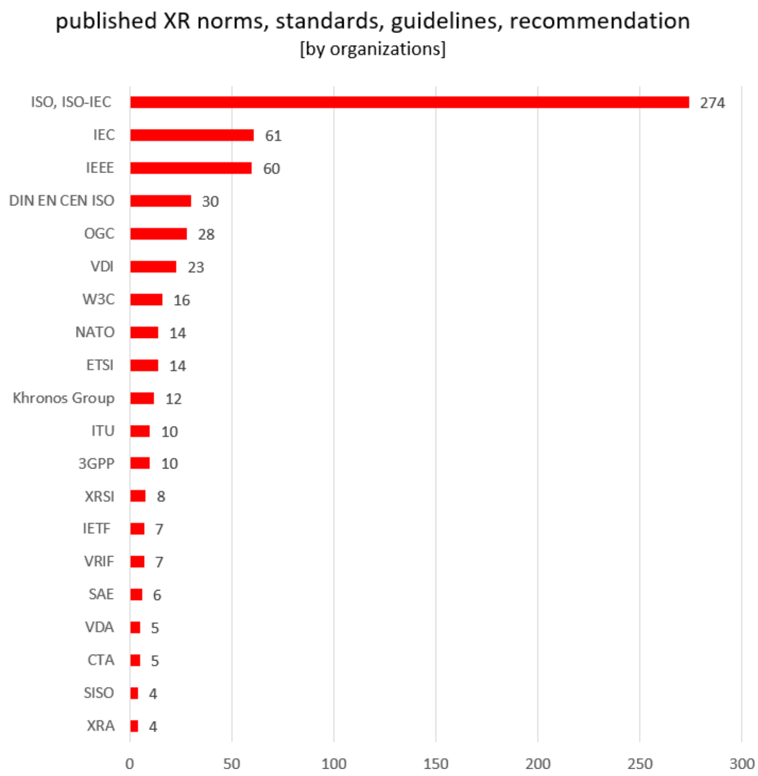

Figure 13. published XR norms, standards, guidelines, recommendation [by organizations]

b. Focal areas of the work of the standards organizations

When analyzing the standards organizations' areas of activities, it is obvious that they focus on different priorities. Whereas e.g. ETSI, ITU, 3GPP are very active in the field of communication, IEC is intensively working on hardware, and NATO, SAE and VDI care for XR applications. We visualized those findings in the following spider net / radar diagrams.

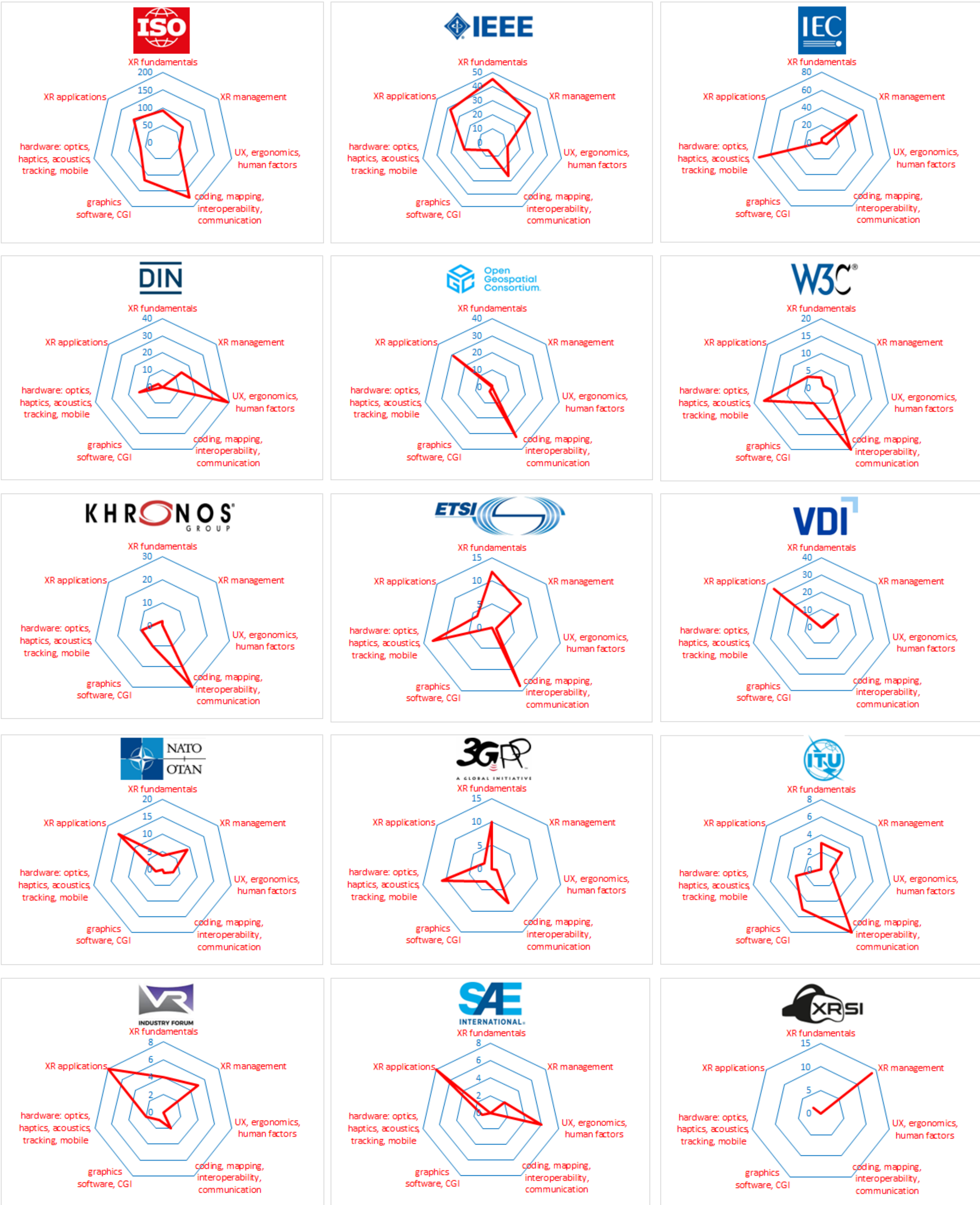

Figure 14. Focal areas of the work of the standards organizations

VI. The Global XR Standards Monitor

We have created a web-based standards directory. This is based on the commercial library software ZOTERO. The directory now contains more than 640 entries on XR standards, guidelines and recommendations. The title of the document, the date of publication, the author and a short summary are stored in each case. The entry is also classified according to the categories presented above. The standards documents themselves are, of course, not part of the ZOTERO database, as they are protected by copyright.

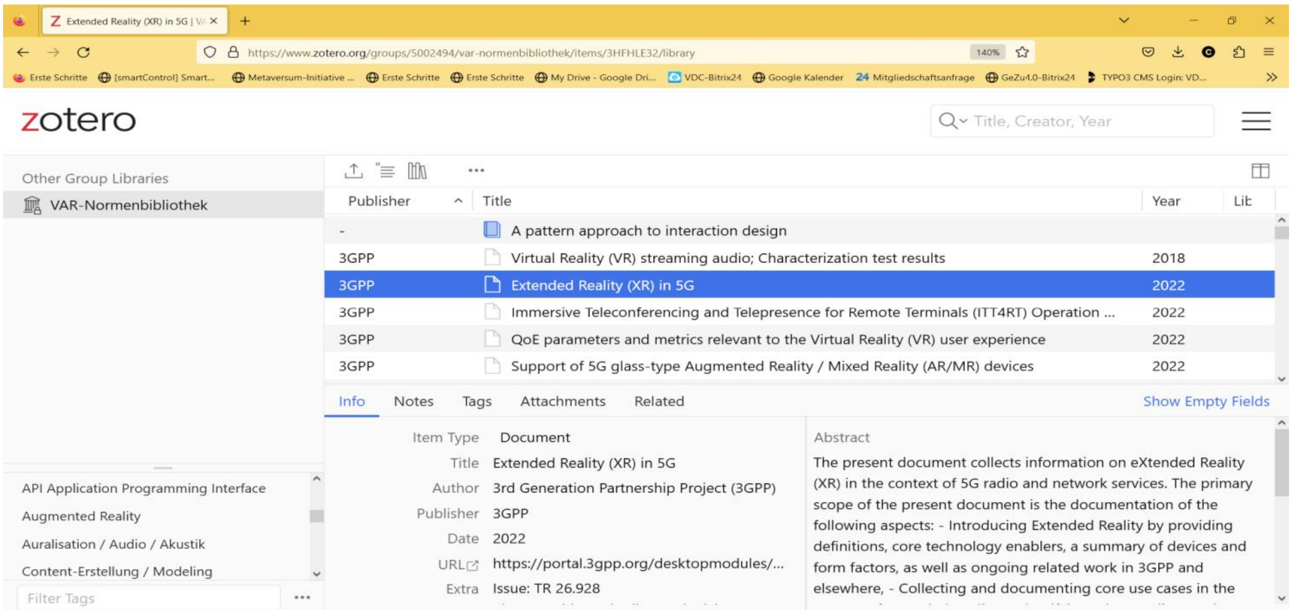

Figure 15. Web-based XR Standards Directory

Secondly, the database also contains a list of the currently active V/AR working groups in standardization. Users of the database can thus get a very good picture of which organisation is currently working on which XR topic. In this way, it should be much easier for interested parties to get started with the right topic. This section currently contains over 85 entries.

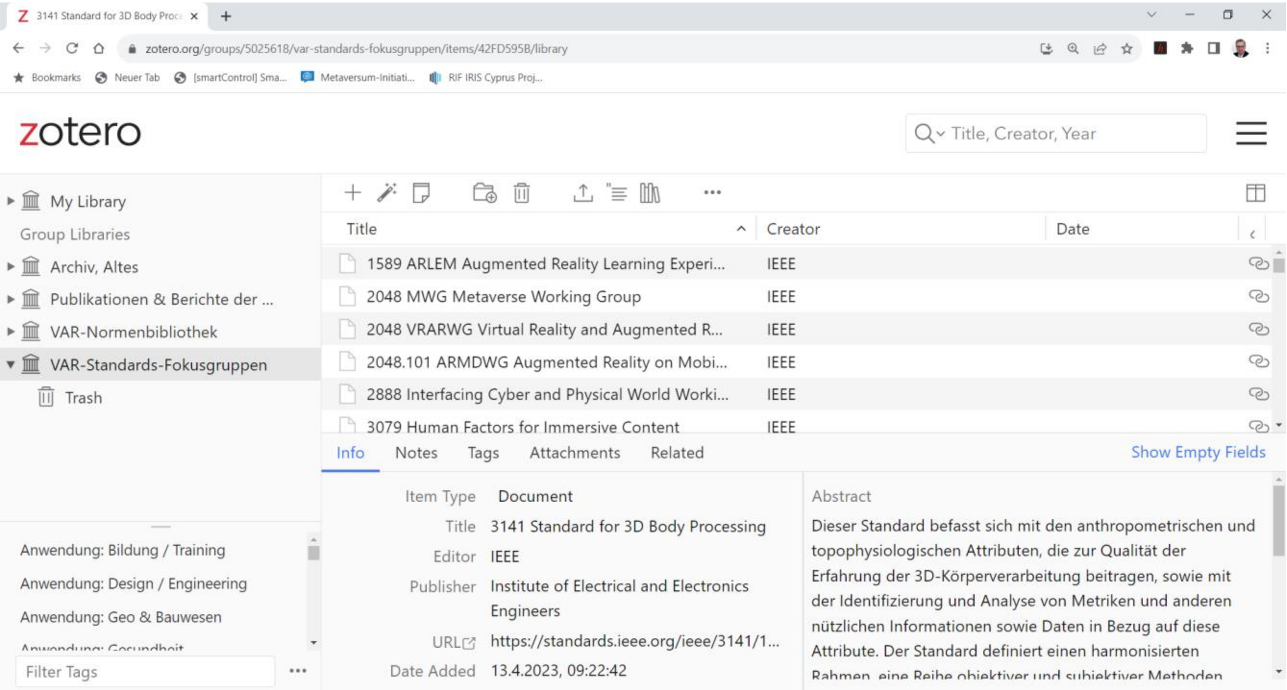

Figure 16. Active V/AR focus groups working actually on XR Standardization

VII. Further Demands for XR Standardization

The British Standards Institution (bsi) [bsi] published the paper "The Requirement for Standards in the VR and AR Sectors" in March 2018. In addition to an assessment of the current market development and the positioning of the British industry in the V/AR segment (focus: Creative Industries, Health, Safety, Skilled Workforce), some topics would also be mentioned in which the bsi would like to see more standardization activities. Overall, the bsi's focus is very much on the creative industries and their V/AR applications. Timmerer [Timmerer] gives an overview of standardization activities in the field of immersive media in "Immersive Media Delivery: Overview of Ongoing Standardization Activities". At the same time, he mentions some points where he sees a need for further standardization in the V/AR context. Stockhammer [Stockhammer] presents the MPEG MP20 Standardization Roadmap. Won Lee [Won Lee] created with "White Paper. Guidelines for Developing VR and AR Based Education and Training Systems", a guide for the development of V/AR-based training systems. In it, he also makes some recommendations on how to proceed. In his opinion, his approach is transferable to other fields of application of V/AR. Price [Price], in her paper "The role of international standards in virtual education and training systems", expands the view especially into neighboring subject areas when she deals with the topic of V/AR-based training. In particular, she advocates using the existing competences and standards there and adapting them to the V/AR application. Wajahat [Wajahat] explains in his lecture "New Proposal: Mixed methods User Experience Evaluation in AR/VR. A lean process for selecting appropriate UX evaluation methods and techniques in AR/VR" the proposal for the new ISO/IEC JTC 1/SC 24. In his presentation "Medical 3D Printing Scanning and Standards Requirements", Shim [Shim] deals with application-oriented standardization and standardized process chains in the work process of medical 3D image processing and 3D printing. In the "Augmentend5G" project [04], the project partners Aixemtec GmbH and oculavis GmbH from Aachen, together with Hella GmbH und Co. KG from Lippstadt, are developing new augmented reality applications for the production and assembly of optical systems under the leadership of the Fraunhofer Institute for Production Technology IPT. For the development work, the production machines and systems are integrated into a "Remote Expert Platform". The project team also wants to test the use of high-performance 5G mobile radio technology for data transmission in remote service. In his article "Standardization Could Be A Major Problem For Virtual Reality", Mirt [Mirt] raises awareness of the disadvantages of closed V/AR ecosystems, such as those promoted by the companies Facebook (Oculus Store), Sony (Playstation VR) and HTC (Steam platform).

Overall, the demands of the above-mentioned authors can be classified into the following five topics:

a. system integration

Mirt [Mirt] pleads for open V/AR standards such as WebVR at the time, today WebXR, in order to prevent the formation of closed technical ecosystems. Won Lee [Won Lee] also sees a need for standardization in the development of a system integration methodology for V/AR-based education and training systems as well as for V/AR-based health information systems and wearable systems.

b. data transmission, interoperability

The bsi [bsi] calls for industry-wide standards for metadata and subtitles in V/AR content. These should be supported by VR platforms, content acquisition, software companies, content rights holders. Stockhammer [Stockhammer] and Timmerer [Timmerer] call for more efficient mapping (Projection) formats instead of today's "equirectangular" method for 360° content, as well as better encoding and encapsulation mechanisms for adaptive delivery of multimedia content. Price [11] advocates the use of ISO/IEC SC 24 (see above, graphical data processing), as well as SC 29 (data transmission, encoding / decoding) in the V/AR context. In the "Augmentend5G" project [04], the partners want to set the first industry standards for data conversion for AR.

c. content

The bsi [bsi] calls for standards for content (for health and safety). The bsi continues to see advantages in standards for the placement of subtitles in VR content. Won Lee [Won Lee] identifies new areas of work in a framework for V/AR-based education and training systems. Price [11] advocates the use of ISO/IEC SC 36 (learning/education/training LET, along with associated data processing). LET information should be stored in a standardized format in a knowledge database. Shim [Shim] proposes a secure data processing process while respecting already existing legacy systems and standards (CT, MRI, DICOM, segmentation, 3D handling, STL imager, CAD/CAM, slicer/G-coder, 3D printer).

d. guidelines for application

The bsi [bsi] calls for Best Practice Guidelines for the safe use of V/AR. Furthermore, standards and best practice guidelines for 360° video content were mentioned as necessary. In the "Augmentend5G" project [04], the partners would like to set the first industry standards for the software-supported creation of AR instructions.

e. terms, quality, user experience (UX)

The bsi [bsi] sees a need for clarification of terms, nomenclature and quality assurance through the assignment of protected terms "VR", "AR", etc. (by the bsi). Timmerer [Timmerer] also sees a strong need for a standardized definition and treatment of aspects of user experience (UX) and quality of experience (QoE). Price [11] demands that suitable user interfaces must ensure the handling and control of the interaction with LET (see above) in virtual environments. Wajahat [Wajahat] advocates standardizing a UX evaluation of V/AR systems using several combined UX analysis methods.

VIII. Conclusion

a. Expectations to Policy Makers

Secluded technical V/AR ecosystems lead to higher customer loyalty due to the "customer lock-in effect". This hinders competition and reduces the pressure to innovate. Open standards such as WebXR (W3C, Mozilla) and OpenXR (Khronos Group) provide a remedy. The same applies to the lack of 3D data processing standards: they lead to increased workloads, may require customized solutions and thus also have a lock-in effect. The added value to be achieved with V/AR is reduced. Poor V/AR interaction standards lead to increased training efforts and make it difficult to change from one 3D or V/AR tool to another, regardless of whether this is within the framework of an existing work process or in the course of replacing the 3D or V/AR tool with another. The value added that can be achieved with V/AR is reduced, a lock-in effect can set in. Policymakers should make it their task to promote innovation measures and reduce barriers to competition. The barriers to the introduction, use and change of V/AR mentioned here must be counteracted. The most important thematic fields in V/AR standardization and -standardization were elaborated in the previous two chapters. Policy could promote the dissemination and intensity of use of V/AR technologies and methods through the following accompanying measures in the context of V/AR standardization:

1. <u>Promoting standardization activities in the V/AR context</u>
   As shown in the previous two chapters, there are still massive needs and activities in various standardization fields. Here, policy could support the ongoing activities organizationally, financially and in terms of marketing.
2. <u>Prefer standardized and normed solutions</u>
   Standardized, open V/AR solutions should be favored and demanded in public tenders and awards.
3. <u>Identify and occupy important, unoccupied standardization fields</u>
   The standardization of V/AR content and 3D data processing chains is an important lever for the economic success of V/AR use in companies. In the area of specific applications (vehicle development, machine development, Industry 4.0, medical technology, optics, active ingredient development, ...), there may well be thematically unoccupied areas in which standardization initiatives from Germany or Europe would have a realistic chance of gaining international acceptance. Here, politics could work

together with science and associations to identify topics of great importance for Germany as a business location.

4. Promote the involvement of domestic industry in V/AR standardization activities.
   Domestic industry and science should be encouraged and, where appropriate, promoted by policy-makers to contribute domestic concerns to ongoing and future V/AR standardization activities/committees.

5. Provision of information on V/AR standards and norms
   The success of domestic V/AR solutions can be promoted by supporting existing and upcoming norms and standards. This requires transparent information on relevant existing norms, standards and guidelines as well as on ongoing and planned initiatives. This position paper is already a first contribution to this.

b. Expectations to Industry

The economy, especially V/AR end users, can benefit massively from standardization. This can be a very direct, concrete benefit, such as keeping the option of switching open. But there are also indirect, more medium- to long-term benefits, such as contributions to a standard to which one's own solutions are already aligned. Industry could support V/AR standardization through the following flanking measures:

1. Prefer standardized and normed solutions
   In its own interest, the economy should also favor and demand standardized, open V/AR solutions in tenders.

2. Identify and occupy important, unoccupied standardization fields
   Companies are encouraged to look for "white spots" on the standardization map in their respective V/AR application areas or V/AR technology fields. If such a topic is found, it could be developed into a standardization initiative with partners - such as DIN or with competitors within the framework of a pre-competitive cooperation (coopetition).

3. Engagement in V/AR standardization and standardization activities
   Domestic industry should articulate its specific concerns in ongoing and future V/AR standardization activities/committees.

4. Use existing V/AR standards and norms.
   Companies should develop their V/AR solutions based on existing norms, standards and guidelines.

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