NEM contribution to the XR coalition

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1.Introduction

The NEM Initiative (the New European Media - www.nem-initiative.org) is one of the organizations supporting creation of the European XR coalition since beginning of the community discussions and has also already endorsed the adopted XR coalition strategic roadmap. As the European XR Coalition is currently being launched by the European Commission and other involved stakeholders, the NEM Initiative prepared this document, in order to lay down the planned contributions to the coalition activities.

The NEM Initiative community involves several relevant stakeholders, each of the highly interested to take part in the coalition activities form their own perspective, such as media industry representatives, XR technology providers at various levels, creative and cultural industries having a high potential to use the XR technologies, network operators and broadcasters, as well as a broad research community from universities and research institutions active in the area. From this perspective, the NEM community can cover and provide relevant inputs to the European discussion on future of XR, including related opportunities and challenges.

The document summarizes a first NEM view on future of the XR technologies and the needed actions in Europe from both industry and research point of view, particularly tackling XR environments in media landscape, also elaborating social and human centred XR and applications towards increasing diversity and accessibility for citizens, XR communications aspects, etc. Furthermore, social, economic, and ethical implication on and from XR in general are also considered in the document, followed by discussion on infrastructures, data flows and data spaces as well as on IDNs as a potential future XR framework; all together needed to shape future successfully and sustainable business models for XR in Europe.

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2.Industry point of view

From the industry's point of view, various utilisation scenarios can be imagined.

Some basic considerations: Industry has concentrated in recent years primarily on b2b industry financing the area of VR, AR and XR. This has essentially been for projects that represent internal training solutions, for example, for the training of workers on the assembly line or also for security and health scenarios. Due to the fragmentation of end-user devices, end user market project- financing like the film or games business was hardly conceivable, as end user devices were too few to finance a classic media project. At the same time, the various hardware manufacturers recognised this problem, and provided generous funding opportunities on their part, for example for non-mass-compatible health solutions. However, this tended to interrupt a content-driven evaluation strategy that exists in other media in the value chain. As a result, a production cascade from the end user and user level could hardly develop. For the last two decades therefore, the field remained experimental and eked out a niche existence.

Recent changes in the manufacturer market, however, suggest a strong reduction in fragmentation. There are now only 3-4 serious competitors. This creates a scenario that is comparable to consoles in the games sector, where at times 3-4 consoles competed and then a relevant market share emerged. In this respect, there is hope that in the next few years this area can be transformed into an economically viable end user driven scenario. However, it cannot be assumed that these technologies will experience a similar rapid rise as the mobile gaming did at the time. Mobile games also had a shadowy existence for many decades and only became suddenly present with the introduction of the App Stores. However, at that time there were already many billions of mobile phones on the market. On the other side we find comparatively few devices for VR & AR; so, in any case a demand-driven approach will not work without the help of public support and large private companies.

In the technical implementation, it can also be stated that the common game engines today support VR & AR play-out solutions, so that the implementation here remains closely intertwined with the computer game industry due to the advanced development technology. There are still unsolved problems in the area of motion sickness: Instead of developing technical solutions that deal with sound and other issues, for example, the industry has moved on in that sense, that designers take motion sickness seriously and try to minimise it by creating content-specifical work-arounds.

As far as usage scenarios are concerned, the areas of AR & VR clearly diverge. Many representatives of the industry believe that AR will be the first area to reach market maturity and that VR will come much later. Others place VR in the foreground. At this point, it is not yet certain which area will reach the goal first, but it is unlikely that there will be no common situation in which AR and VR will reach the goal of end user-driven market profitability at the same time.

In AR the focus remains on linking actual realities and geolocation-based adventures to virtual content, similar to the already successful computer games by Nintendo Pokémon GO or Ingress. But it is not likely, that the main users of virtual and interactive software – the core gamers – will start to move – even when for health reasons it would be recommended. They do what they like, as it is their free time.

For the field of VR, one can really think of narrations now. Possibly, it is initially about interactive experiences with the VR glasses, which - due to the circumstances - will possibly not require as long use time as, for example, corresponding computer games.

Especially in the context of the wave of crypto-based blockchain projects that is now starting and the so-called Metaverse (of which nobody knows exactly how it will look like yet) VR projects can be seen as an entry points. This also makes the technology more interesting for a larger business community.

3.XR environments in media

Media has always been perceived as a core application domain for immersive content. As already stated in the previous paragraph, the lack of penetration of immersive devices with citizens and inside living rooms or other personal media environments have slowed down the growth of immersive content. However, XR technologies have certainly taken off for **media production** processes. In the following paragraphs, we describe how media production is changing.

Current State-of-the-Art in media

Several media organisations, Audiovisual production houses and facility service providers have been implementing virtual studio infrastructure inside their organisation. The concept of virtual production itself is not new, with green key production being mainstream for many years. However, as legacy virtual production is merging 2D images together, the rise of XR technologies enabled by game engines has severely increased the possibilities, where 2D and 3D environments can now be merged seemlessly. Current production infrastructure typically still uses 2D cameras and integrates the camera image in a 3D world for live and on-demand production. Experiments with volumetric capturing are also currently running and are extensively used in the movie industry, there are however not yet ready for live production. In most environments, XER production still makes use of green key backdrops to facilitate the merging of the 2D image with the 3D world. This has the disadvantage that the studio environment is not immersive. However, led-wall equipped studios rendering the 3D environment into the studio are taking up in the industry. In any case, the flexibility offered by virtual production infrastructure, seamlessly switching from one production to another is causing opportunities for media companies to create more and better productions.

Beyond SotA

From the technology side, advances still need to be made to enable live fully 3D productions, where physical persons and objects are integrated live in the virtual environment using volumetric capturing. Due to delays in the processing, this is currently still not feasible using commodity hardware.

Challenges

From the business point of view, the challenges are multifold: the lack of common industry standards, the lack of trained people and the change management processes inside organisations.

- Lack of industry standards: for many years, media production has organised itself on 2D images, the lack of interoperability between media systems, game engines and cameras causes many challenges to set up an XR production pipeline inside an organisation. More standardisation activities would be highly welcome
- XR production needs different skillsets compared to 2D video production. Especially 3D designers and software developers capable of handling the video game engines are highly searched for, and talent is scarce in these disciplines. More training programmes, traineeships, internships and encouragement to follow such studies are needed on a EU scale.
- Finally there is the problem of change management inside organisations. As with every innovation, implementing those in practice requires changing business processes and retraining

personnel to handle the new technologies and applications whenever possible. This is an expensive and hard operation for every media company, but highly needed to remain competitive on the worldwide market.

4.Research perspective

European Media as represented by NEM have or at least can have a leading role in the world-wide media landscape. The major strengths and at the same time responsibilities NEM members emphasized for their research roadmap are:

- **Strengthen the Strengths**

Europe has a very strong position in volumetric media. Commercial successes in as well light field capturing (Raytrix, K-Lens) as in holographic rendering (Holografika) and several constituents with world-wide recognition on volumetric capture and processing (e.g. Volucap or Interdigital) show that Europe can play a significant role – or at least can prevent to be left behind again as in classical photography –in case its core strengths in media creation and processing are further strengthened.

In addition, the media sector (especially different facets of immersive and HD-video) starts to consume a significant amount of carbon, so that Europe's responsible handling of carbon footprints can manifest a leading position world-wide.

- **Serve the Citizen**

European values and personal preferences of citizens significantly differ between the geographies. While we (might) see Chinese data collection and handling of privacy critical, many of the citizens in China value the security they expect from their data pool, mostly against industry. In US this is nearly the other way round and in Europe we try to find a general view on privacy, independent of who is collecting data. This abstraction can lead to European solutions superior to the collector-driven solutions known from other geographies.

- **No-one Left Behind**

Heterogeneity with respect to languages, culture and ethnicity helps developing accessibility and inclusion. Putting inclusion and accessibility into the design process from the ground up hence can create European solutions applicable globally.

- **Don't over-privatize**

European Media have many constituents who can be named trustable source. Independent newspapers but also the public broadcast over radio and TV form a solid base of trustable sources. Solutions for trustable media, for detecting disinformation and even for detecting propaganda hence face an extremely favourable basis in Europe, so that European solutions have the potential to gain global recognition.

5.Towards Reality–virtuality continuum

If Extended reality (XR) is a term referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables, the terme represents very different representative forms such as augmented reality (AR), mixed reality (MR) and virtual reality (VR) and globally all immersive technologies. The areas interpolation areas among all these technologies bring into relief the unavoidable concept developed by Paul Milgram of reality-virtuality continuum and the emerging concept of "internet of sense".

Nevertheless due to the specifies of these various technologies, we need keep in mind that these technologies are quite recent and their development is not depending of the same actors. Some major companies are investing only in augmented reality, others only in virtual reality. The main question or challenge is to answer the following question “How can we reach this reality-virtuality continuum by considering as a whole the various states of art of the technologies (AR glasses, VR headset, game engine, IoT), the cultural considerations (content creation capacities), the environmental requirements (greening the screen) and social needs (accessibility, acceptability, etc.)?”

Among the considerations we may have to bring answers to this question are :

- To consider video industry ans music industry as key use case precursors
- To consider XR technologies as part of the global digital infrastructure and the correlated challenges in terms of cybersecurity, accessibility, carbon impact and so on.
- To differentiate individually and very precisely each technologies in order to define their contribution the map of the reality-virtuality continuum
- To evangelize the understanding of the cultural aspect of the new powerful technologies (academic research, content analysis, specialized media...)
- To reduce the gaps to the accessibility to these digital technologies (generational, cultural or economical gap)
- To facilitate the accessibility to the XR content.
- To create new paradigms and technologies to preserve digital artworks and creations made by XR technologies
- To encourage the convergence between traditional industries and cultural & creative industries.

6.XR Communications

XR technologies will enable new digital communication channels through new communication formats and tools. Nowadays already exist a set of platforms that provide shared 3D environments in which humans can communicate, wander, gather and interact for different purposes. We know them as **social VR platforms** and they are one of the original ingredients of the so called metaverse. With the arrival of the pandemic, the main purpose of these platforms moved from just entertainment to other relevant facets of our society and daily lives.

Many social events have been indeed moved to social VR platforms to offer an alternative to physical presence. Industrial fairs, scientific conferences, cinema festivals, cultural exhibitions and other events went to fully virtual or to hybrid formats. Similarly, companies have also used social VR platforms to hold internal meetings, collaboration tasks (e.g., co-creation), interactive simulations and even training. Well known examples of social VR platforms are Mozilla Hubs, Facebook Horizon (to be replaced by Meta / Presence), or AltspaceVR by Microsoft (to be replaced by Mesh), just to name a few.

In social VR platforms users typically interact with others within shared 3D environments, being represented by, and embodied as, more or less realistic avatars. Social VR becomes a promising medium to overcome key limitations of traditional 2D videocomunications in terms of comfortability, (co-)presence and quality of interaction, which allows providing richer and more productive experiences. The feeling of presence emerges from the blend of multiple ingredients like plausibility (i.e. how real the environment and its elements look like), immersion (how involved is the user in the environment and with the actions happening therein), interaction (how realistic and consistent is the action/reaction of the

environment with regards to the user's actions), co-presence (the feeling of being together, the feeling of togetherness), or embodiment (the feeling of ownership of the digital body), among others.

Three elements are key to the success of XR communications and to extend the use of social VR (or XR) platforms:

- devices must be lighter and provide better visual and audio qualities. To do so, it is necessary to explore the reduction of computation in these clients (e.g., via edge computing) and to miniaturize the involved HW components. An open hardware strategy in this domain would help to the proliferation of new devices and manufacturers as well as a reduction of costs.
- environment, i.e., the virtual environment, must be more realistic. New rendering techniques to deliver photorealism in real time are necessary. In addition to that, capturing systems that allow to capture the reality and represent it and reproduce it in a photorealistic and volumetric manner are necessary. This will enable the creation of new, more credible XR environments in which any type of communicative experience goes through the uncanny valley that somehow we are experienceing at the current level of environment (and user) representation qualities.
- user representation, which impacts directly on how users perceive their virtual body and how they are perceived by others in the communicative experience. Despite the importance of the user representation in the feeling of presence, most of the platforms still use synthetic 3D (cartoon-like or human-like) avatars. This is due to the cost and complexity to offer more realistic user representations, like those provided by real-time VV capturing systems. New light and low cost volumetric capture systems that can be embedded in current screens and PC set-ups are necessary to unveil a new set of XR experiences from home.

7.Social and human centred XR

There is a strong need to overcome limitation in XR in order to build concrete application scenarios that integrate the physical and the virtual world in a convincing way, from a human and social perspective. The virtual world will be a means to augment the physical world with new opportunities for social and human interaction. More in details, relevant limitations that to be address are:

- **Lack of solutions to develop scalable and cost-effective new XR applications**: building an XR application for a new physical environment requires creating from scratch its accurate digital twin, with both visual and physical/functional properties, with significant efforts and high costs.
- **Lack of convincing solutions for mixing of the virtual and physical environment:** generally, augmented reality is limited to visual alignment of physical and virtual components. However, a convincing XR requires physical and virtual elements to interact, and actions on one world to have effect in the other world.
- **Lack of plausible and convincing human interaction interfaces in XR:** human interaction in XR should include natural interaction, where actions in the physical world have convincing counterparts in the virtual one. Similarly, objects manipulated in the virtual environment should provide users with a realistic feeling.
- **Barriers due to resource limitations of end-user devices:** XR end-user devices at an affordable cost often have limited computing, memory, and networking resources. Therefore, they cannot handle highly realistic and convincing 3D models that embed visual, semantic, and physical properties.

The challenges is to develop solutions to surpass current limitations, including:

- **Scalable solutions to obtain plausible and convincing virtual copies of physical objects and environments**

  - The system will learn from the physical world, during its use. Like a baby, who learns how to recognize and use objects with the experience, SUN will use artificial intelligence, computer vision, and sensor analysis to incrementally learn, during its usage, visual and physical properties of real objects, and to generate, recognize, and use digital twins in the virtual environment.
  - Learned objects and environments will be incrementally added to the SUN Digital Twins Library of available items and re-used in various XR applications.
- **Seamless and convincing interaction between the physical and the virtual world**
  - Objects and environments of the physical world have a digital twin in the virtual world, with the same physical and visual properties.
  - Manipulating an object in the physical world will have the same plausible effect in the virtual word. For instance, a physical wrench could be used to unscrew a virtual bolt. Complementarily, a virtual wrench manipulated in the virtual world, will provide the user with a feeling consistent with a physical wrench.
  - The so-called Internet of Senses will imply the possibility of augmenting our senses beyond the boundaries of the human body, giving us augmented vision, hearing, touch and smell, and improve movement or relax feeling, among others.
- **Wearable sensors and haptic interfaces for convincing and natural interaction with the virtual environment**
  - Wearable haptics will enhance physical interaction with virtual menus and contextual information displayed to the user. In addition, solutions for body contextual information (such as skin stretch-vibration on body parts) will lightly guide the user in tasks such as remote training, home physical exercises, and interaction with other persons.
  - Novel wearable haptic interfaces will allow multisensory feedback (vibrotactile and thermal cues under fingertips) for XR scenarios, such as interaction with 3D virtual objects.
  - We will provide advanced solutions for user interaction, including gaze based and gesture-based interaction.
- **Artificial intelligence-based solutions to address current computing, memory, and network limitations of wearable devices**
  - AI will be used to generate plausible, high-quality renderings also for coarse-grained, low-resolution, or incomplete 3D models, leveraging on solutions similar to those used for deep-fake generation.

The solutions could be implemented in **three real-life scenarios**, focusing on **social interaction and collaboration**:

1. XR for rehabilitation after accidents or diseases.
2. XR in the industry to increase safety and improve social interaction among workers.
3. XR to remove interaction barriers for persons with disabilities.

8.XR and Metaverse: challenges and opportunities for the industry

XR (including AR and VR) hardware technologies are rapidly evolving. Today, standalone and cabled AR and VR headsets are becoming more lightweight and are now benefiting from 5G/Wifi6-powered remote computing capabilities. In five to ten years, we could expect the emergence of fully 5G or even 6G-powered glasses that could provide both AR and VR experiences. At the same time, at the application level, XR has demonstrated its interest for many uses-cases on B2C (social, entertainment, learning etc.) and B2B (training, remote assist, design, etc.) verticals. Beyond single and multi-user experiences, we also observe the trend of persistent shared virtual worlds for social, gaming and also professional purposes in which end-users can create, share and even sell content. These experiences that can be referred to as

"Monoverses" are not interoperable but can provide valuable technological and sociological knowledge for the industry to build and exploit the future Metaverse. However, the perspective of the Metaverse is still unclear. Are we heading towards a fully synthetic virtual world (VR), a virtual world that overlays and augments our real world (AR), or a combination of these two visions? From a technical but also business point of view will the Metaverse be fully open and decentralized thanks to a blockchain-based architecture or will it be fully controlled by one private stakeholder?

In the following years, the industry has the opportunity to define what will be the future of XR and Metaverse. Industrial stakeholders still have to develop several XR key technologies and provide infrastructures in order to reach these objectives including:

- **Connectivity**: High bandwidth and low-latency energy-efficient networks will be required by high end applications and devices. Public and private infrastructures will be required to meet the needs of all stakeholders.
- **XR-Cloud**: Based on the connectivity stack, remote computing for world-mapping and rendering will be deployed on cloud and edge infrastructures to reduce the computational load of lightweight devices.
- **Hardware**: Progress still needs to be made regarding display technologies, batteries and form factor of AR and VR devices.
- **Digital twin**: Creating and updating digital twins will strengthen the link between the real and the virtual world to create more believable and useful experiences. The Internet of Things (IoT) provides an interesting perspective to rely on.
- **Content and tools**: Creating and sharing immersive content is still a difficult task. Creation tools and interoperable formats still need to be developed.

Standardization organizations (ETSI, MPEG, 3GPP, etc.), sovereign open-source initiatives and more generally association of actors (NEM, EuroXR, etc.) must work together in order to accelerate the development of these technologies, ensure their interoperability, and deploy them at large-scale. All kinds of stakeholders are concerned including large groups, SMEs, start-ups, institutions and academics.

9.Diversity and accessibility

Europe is defined by its diversity in languages, cultures, and people. These need to be reflected also in XR at both creation and consumption. It has been proven that taking into consideration media accessibility from the designing stages result in better quality solutions and services, and cheaper in the long run. The result is a fully compliant service or product with EU standard EN 301549, fulfilling the European Accessibility Act.

Media content production in Europe is increasingly produced by consumers who take also the role of producers becoming **prosumers**. XR has been proven to be a successful format for training, hence teachers should be able to generate content easily. One of the successful indicators for XR will be that its content is easily generated by all, where people with disabilities are also active prosumers.

Easy and accessible web-based tools to produce XR content by non-professionals have been developed such as Fader or GreenVerse as part of H2020 funded projects MediaVerse and GreenScent respectively. Web editors for XR subtitles, XR audio description, and XR Sign Language are also available, with the possibility of collaborative production of accessibility services.

XR contents needs to be created bearing in mind the many **languages**, sign languages, with at least three written language alphabets (Latin, Greek and Cyrillic) in Europe. Language accessibility should be considered when designing XR content. Existing H2020 financed open source tools such as the ImAc accessible media player should be developed further. The media player is accessible, but it also features the possibility of activating many accessibility services such as subtitles, audio description, sign languages, audio subtitles, in different languages.

XR hardware needs also to be accessible: with alternative interaction by voice, eye-tracking, etc. This is essential for interaction with the accessible media player, to activate accessibility services and enjoy the content.

There is web based framework for **prototyping and visualisation of XR media accessibility**, which allows for the creation of accessible media towards testing for: usability, readability, quality of experience, and quality of service before fully developing a service or product.

The uses of XR with diverse groups have been tested in some EU projects MediaVerse, Traction, SOCLOSE, GreenScent from: refugees, displaced population, migrants, people in jail, people in remote areas, people with disabilities, carers of people with cognitive disabilities. In all cases the level of interest and engagement has proven the success of IT as a social enabler.

Other IT such as block chain, will aid the issues of creation by prosumers, allowing for monetisation, e-contracts, and right management. AI should also aid in the interaction to XR hardware, media player and accessibility choices turning the experience of producing and consuming XR content into an intuitive experience for all people in Europe.

Industry should develop and customise existing XR accessibility solutions and evidence based research results that have been EU funded. Research on XR accessibility should continue to show how Europe is an inclusive and diverse place. **Standardisation** and recommendations of existing XR accessibility research data and solutions should be sought, before industry starts adapting -wrongly- 2D accessibility services to XR environments.

10. Social, economic and ethical implications of XR

In the past two decades, we have seen many aspects of daily life become -at least partly- digital. This includes private communications, work relationships and processes, entertainment, finance, health, education, commerce and many other domains. In many ways, the internet empowers governments, organisations and citizens by lowering distances (real and perceived) and transaction costs for conveying ideas, goods and services. It holds many promises for more inclusivity, freedom and equality. However, the skills and assets required and the rapidly increasing scale and complexity of digital operations, also threatens to create new inequalities (“digital divides”), while powerful platforms potentially create new oligopolies, leveraging their power into ever expanding domains and stifling competition instead of lowering thresholds.

Where the real world and the digital realm have up until now mostly existed side by side, XR has the potential to completely eliminate the boundary between both. In virtual environments, in which citizens are immersed with all their senses, the virtual becomes the real, and whatever used to be reserved for the physical world, could be transferred to the digital domain. Again, this creates powerful new levers for empowerment, as users are no longer held back by physical constraints such as their location,

appearances or abilities to participate in important parts of economic and social life. At the same time, proponents of the so-called Metaverse announce it as a decentralized system where no party holds excessive power and everyone has equal access.

The latter statement has to be analysed critically. Since the virtual environments are not bound by real world constraints, they could willingly or unintentionally be designed to empower or to disempower; they could magnify existing inequalities or create new, artificial ones, for example by creating new scarcities and stratifying access, by requiring specific skills or assets to perform specific actions, or by actively selecting and filtering what is visible, true, accepted and so on. Moreover, it could be naïve to think that the disintermediated Metaverse would not soon be re-intermediated by organisations setting the standards and developing the systems for creating virtual environments and allowing interoperability between them. Finally, while virtual environments look like real ones, they do not necessarily behave in an organic fashion, but are instead governed by rulesets -algorithmic or human controlled- that follow their own logic and are not always transparent to the users of these environments.

In short, if large parts of future European life are to take place in XR, we must ensure that European values (such as freedom, equality, solidarity, resource efficiency, diversity, transparency, veracity and sovereignty) are enshrined within them. We must audit and analyse systems, identify opportunities and threats, and design implementation rules -what we don't allow in the real world, we should not allow in the virtual world. Only this way can XR truly deliver on its enormous potential

11. Infrastructure, data flows, data spaces, business models for XR-based services

The development of XR-based services put strong requirements on telecommunication networks in terms of bandwidth, much higher than most current internet applications and games.

As the complexity and importance of virtual words grows, the amount of data that needs to be streamed will increase. This is a focal point: if we want to interact in a real-time, shared, and persistent virtual environment, we will **need to receive a superabundance of cloud-edge-streamed data.** It will also be necessary **to collect, manage and transfer huge amounts of dynamically generated data**, essential if we want to seamlessly jump between different virtual worlds because we need the data that characterize all the virtual environments and all the data related to ourself to "follow" us.

The realization of XR-based services, as well as digital twins and extended reality, is already fuelling huge investments in cloud data centers, particularly **when it will require to serve "million concurrent users" and customizable experiences and items** (e.g., the ability to participate inside a virtual concert, or to customize an outfit or a backpack). The large amount of data will put a lot of pressure both on the networks and on the ability of data centers to process and transmit information.

Some XR-based services may require an infrastructure enabling thousands/millions of people to concurrently participate in a shared, synchronous activities, which is completely different from Internet designed to share files from one computer to another: let's say in one-to-one or one-to-many connection mode.

XR-based services may require an infrastructure supporting a persistent many-to-many communication that is symmetric (to enable interaction) and **synchronized in real-time**. Today, these are required by videoconferencing and gaming applications, even if, for them, the number of participants is small, so with low level of concurrency. The **XR-based immersive communication will require more and more**

symmetric communication, that is, the bandwidth of Up-link and Down-link channels should be comparable. 5G and future networks should, then, evolve towards a "smart" Up-link, giving much more slots to Up-link.

Edge compute can be considered a key infrastructure strategy for the XR-based services: it is compatible with, and additive to, cloud computing models, as it helps end-users supplement their local compute while also minimizing network-based latency and network-congestion risk. In any case, regardless of the computation models adopted, all **the infrastructures needed for the XR-based services will not be available overnight**. The new data centers, both cloud and edge computing, will require significant investments in processing, storage, communications and sustainable energy.

There is an urgent need for European alternatives to compete in the global market **ensuring the development, ownership, privacy and security of XR data flows and data spaces,** allowing European companies and users to take full advantage of the data generated and circulating between cyber and physical spaces. Data Analytics, Artificial Intelligence and Machine Learning, on top of these XR data spaces, will increasingly be a key enabler for new services and new revenue streams. At the same time, all this data traffic will put more and more pressure on **investments in the infrastructure and networks, needed to enable the use of XR devices in public-wide area scenarios**.

Furthermore, due to their high computational needs, XR solutions are adopting SaaS approaches, increasing the risk of **reliance on non-EU cloud and OTT providers**, and in particular hyperscalers.
Moreover impacts of the **decentralization of payments and media distribution** in XR-based services should be addressed.
Lack of clear business models and sustainable and fair return on investments for the infrastructure and network providers should be addressed to enable sustainability of these services for all the parties involved.

12. The future: IDNs as an XR framework

Storytelling plays a central role in human culture through the use of narrative as a cognitive tool for situated understanding [Gerrig, 1993]. This ability to organize experience into narrative form and structure has been applied across a range of practises, such as entertainment, education, or training. XR experiences encompass this ability and need a framework.

One of the most compelling applications of narrative intelligence is interactive digital narrative (IDN). IDN applications and prototypes have the potential for representing, experiencing, and comprehending complex phenomena [Murray 1, Koenitz, et al]. IDNs are digital experiences in which users create or influence a dynamic storyline through actions, either as the protagonist of the unfolding storyline (as in digital drama) or as an observer who is capable of navigating the story space aided by a system. The goal of interactive narrative is thus to immerse the user in an intellectual as well as emotional experience so that the user's actions can have a direct impact on the direction or outcome of the storyline.

The application of interactive digital narratives to the presentation of complex issues, such as Covid-19, racism, globalisation, global warming, the current war in Ukraine, etc, is seen a monumental endeavour, because it addresses complexity on several levels: content selection, mode of interaction, audience perception, and narrative generation. For example, the understanding of natural hazards and their impact on human lives requires knowledge on their

physical and statistical behaviour that is best understood through narratives that facilitate the reflection on solutions for prevention and emergency actions in a known context and environment (please see, e.g., (Havlik, et al., 2015)). In such instances, narrative representations of complexity are required that can make use of digital tools "to create representations that contain competing perspectives, offer choices, and show the resulting consequences while allowing for repeat experiences" [Koenitz and Eladhari].

Seen as such, IDNs form a triad composed of creators, active participants, and dynamic narrative mechanisms that are expected to:

- Contain many different – even competing – perspectives in the same instance. This will enable observers to look at phenomena from various point-of-views.
- Promote active participation of both end-users and stakeholders and facilitating self-directed experiences.
- Encode complex dependencies and allowing them to be experienced as narratives.

The COST action INDCOR (Interactive Narrative Design for COmplexity Representations)[1] is currently working on a comprehensive view of Interactive Digital Narratives (IDN) as a field of study and a design discipline, including work on a shared vocabulary, authoring tools, validation, and assessment of IDN prototypes. For IDNs, INDCOR have a particular focus on the representation of complex issues. This requires an interdisciplinary approach of understanding IDNs to address complexity as a societal challenge by representing, experiencing, and comprehending complex phenomena.

The above findings point towards the need for looking into new specific practices tools, and methodologies intended for designing and implementing IDNs that address in particular complex issues (please see Figure 1d). Breaking down these requirements, we can identify the following areas that need research and innovations.

- Design of IDNs;
- Authoring tools for IDNs;
- Evaluation methodology for IDNs.