Karlsruhe Institute of Technology

aifb

CRITICAL INFORMATION INFRASTRUCTURES RESEARCHGROUP

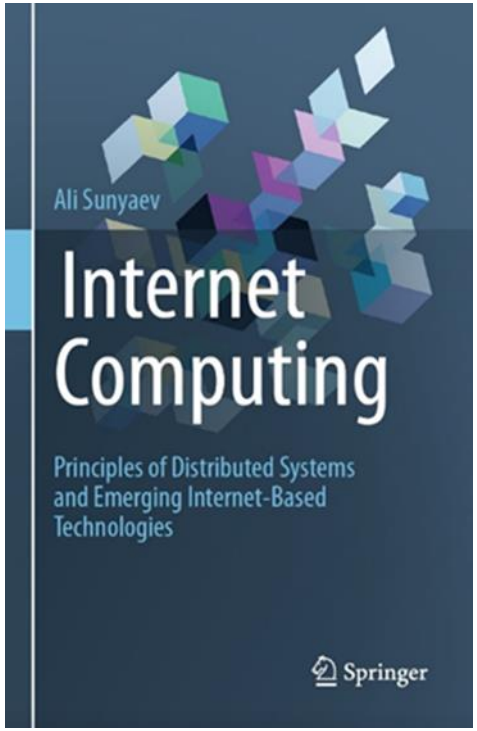
AI: Internet Computing

Lecture 12 — Emerging Technologies

Learning Goals of the Lecture

- Understand what emerging technologies are and what key attributes define them
- Learn about immersive technologies and their application in the health care sector
- Understand what virtual assistants are and how they can be applied
- Understand how AI is linked to emerging technologies
- Understand the difference between weak and strong AI and how artificial neural networks function

Reference to the Teaching Material Provided



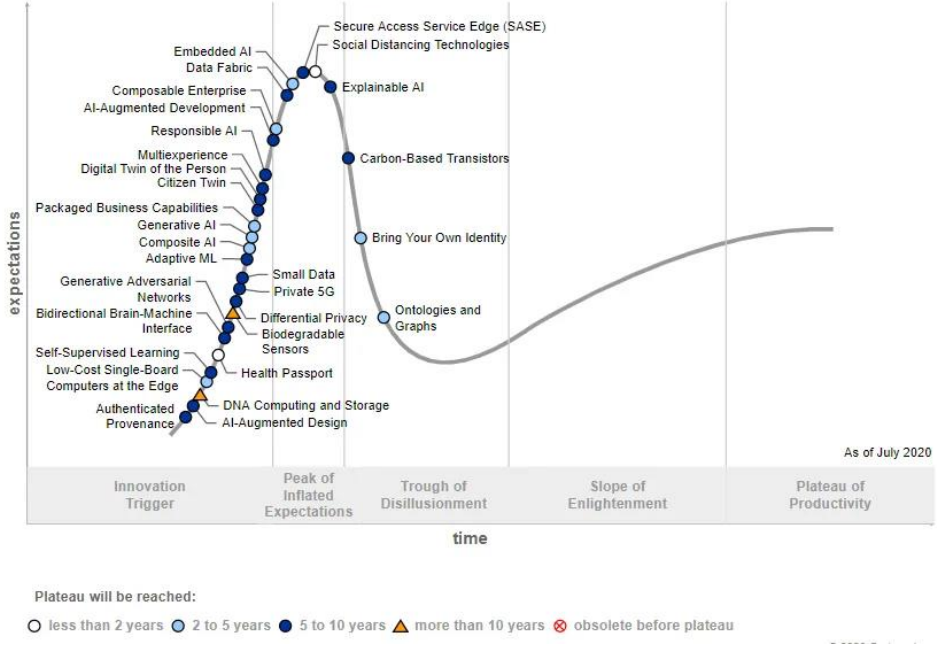
Chapter 12
Emerging Technologies

Abstract
Technological innovations have always played a key role in the human civilization's progression. Occasionally, these innovations develop to such an extent that they open up completely new pathways in individual fields and even reshape our society as a whole. However, to exert this prominent impact, a technology must first emerge, i.e. it must mature and become visible. This chapter introduces this process's underlying concepts and, thereby, provides a deep understanding of the emerging technologies' nature and their important implications, for example, affecting specific domains by changing the actors' and institutions' composition in this domain. To this end, this chapter gives an overview of the five most important attributes that characterize emerging technologies. The chapter also presents selected examples of currently emerging technologies, namely immersive technologies, virtual assistants, and artificial intelligence. Each technology is briefly described in accordance with its attributes, followed by a discussion of the technology's exemplary applications to highlight its emerging character, and, thus, provide an understanding of their potential future impact on specific application areas and our society as a whole.

The Learning Objectives of this Chapter
This chapter's main learning objective is to help readers understand the nature of

Emergence and Emerging Technologies

Emerging Technologies — Hype Cycle

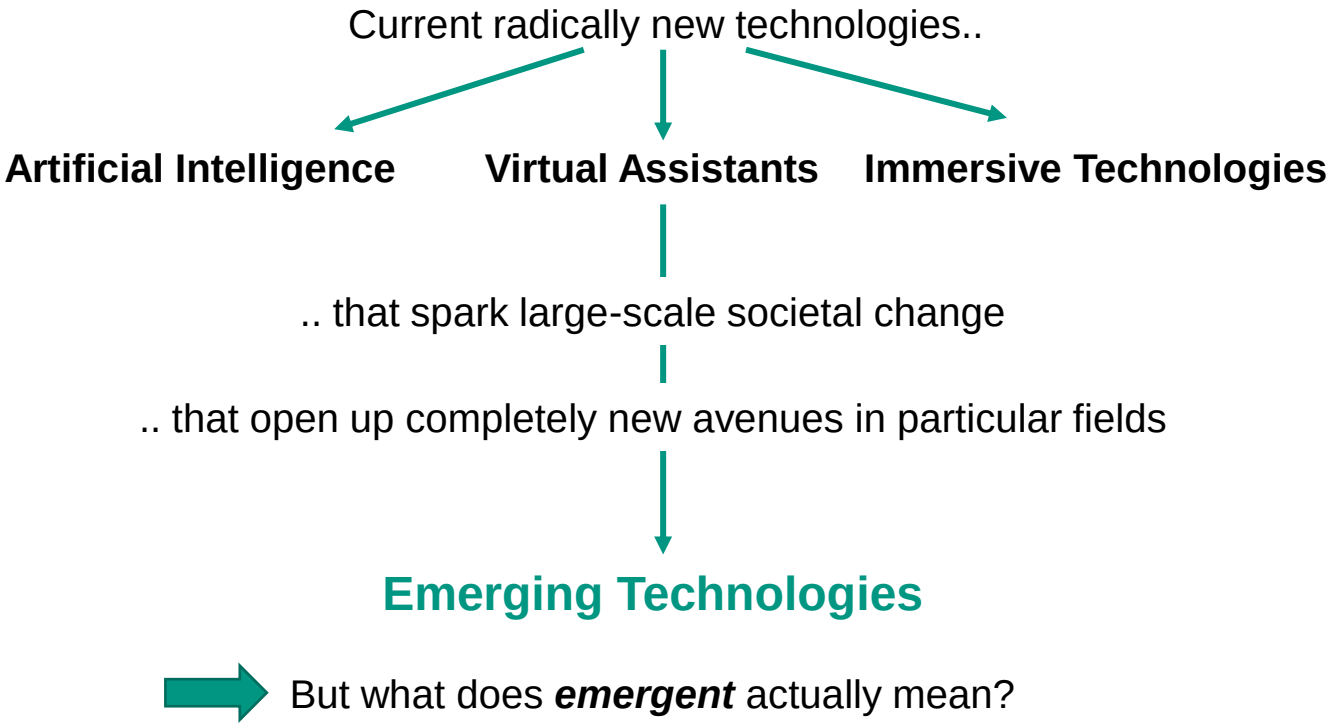


Gartner Hype Cycle for Emerging Technologies 2020

➡ Everyone knows the Gartners Hype Cycle—but do you know what exactly emerging technologies are?

Image source: "Hype Cycle for Emerging Technologies" by © Gartner 2018.

Emerging Technologies — Emergence?



Emergence

Definition

Emergent: “The process of **coming into being** or of becoming important and prominent”
Stevenson and Lindberg, 2010

- Other definitions:

“to rise up or come forth […] to become evident […] to come into existence”
The American Heritage Desk Dictionary and Thesaurus

“the process of coming into being, or of becoming important and prominent”
New Oxford American Dictionary, 2010

“to become manifest: become known […]”
Merriam-Webster's Collegiate Dictionary

“starting to exist or to become known […] to appear by coming out of something or out from behind something”
Cambridge Dictionaries Online

- What do all these definitions have in common?
  ➡ They do all have *“**becoming**”* in common!

Source: Stevenson A, Lindberg CA (2010) New Oxford American dictionary, 3rd edn. Oxford University Press, Oxford

Concepts and Key Attributes

Emerging Technologies — Key Attributes

- Key attributes of emerging technologies:
  - (1) radical novelty
  - (2) relatively fast growth
  - (3) coherence
  - (4) prominent impact
  - (5) uncertainty and ambiguity
- *Further Reading:* Adner R, Levinthal D (2002) The Emergence of Emerging Technologies. California Management Review 45 (1):50–66

➡ These attributes classify emerging technologies and differentiate them from other technologies.

- Let’s have a closer look at the individual attributes!

Emerging Technologies — Key Attributes

- (1) Radical Novelty — Radically novel technologies:
  - fulfill a **given function** by using a different basic principle as compared to what was used before to **achieve** the same or a similar function *(Rotolo et al., 2015; Arthur, 2007)*
  - transfer existing technologies from one domain to another, so they introduce **existing** technologies to new contexts *(Devezas, 2005)*

Definition

Innovation refers to a new idea, creative thoughts, new imaginations in form of device or method.
Merriam-Webster's Collegiate Dictionary

Emerging Technologies — Key Attributes

- (2) Relatively fast Growth
  - Growth must be viewed in context → *relatively*
  - Expansion rate of emerging technologies usually **exceeds** that of established technologies *(Rotolo et al. 2015; Cozzens et al. 2010; Small et al. 2014)*.
  - Different indicators for technology growth:
    - The amount of funding from public and private sources
    - The volume of knowledge output
    - Number of newly developed prototypes, products and services
    - …

Emerging Technologies — Key Attributes

- (3) Coherence
  - **Coherence of technology** can be characterized by its
    - Terminological maturity *(Reardon 2014)* e.g.:
      - Standardization of technical terms
      - Abbreviations
      - Acronyms
    - Emerging scientific communication *(Leydesdorff et al. 1994)* e.g.:
      - Formation of specialized conferences or journals
    - Existing of expert communities *(Rotolo et al. 2015)*
  - Growing **coherence** fuels expansion and application of emerging technologies

Emerging Technologies — Key Attributes

- (4) Prominent Impact:
  - Emerging technologies…
    - … impact a wide range of **sectors** *(Martin 1995)*
    - … gives rise to entirely **new industries**
    - … **fundamentally change** existing industries *(Day and Schoemaker 2000; Hung and Chu 2006)*
  - However, prominent impact lies in the **future !**
    → We can only make **propositions** (e.g., Gartner hype cycle)

    Further Reading: Fenn J, Blosch M (2018) Understanding Gartner's Hype Cycles. Gartner Inc., Stamford, CT, USA

Emerging Technologies — Key Attributes

- (5) Uncertainty and Ambiguity:
  - Ambiguity results from:
    - **Different meanings** social groups associate with the emerging technology *(Stirling 2007; Mitchell 2007)*
    - **Incomplete knowledge** of possible outcomes of emergence *(Mitchell 2007; Rotolo et al. 2015)*
  - Uncertainty relates to technologies **outcome** and **utilization** that could be intended/unintended and/or desirable/undesirable

Emerging Technologies

Definition

An **emerging technology** is a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous.

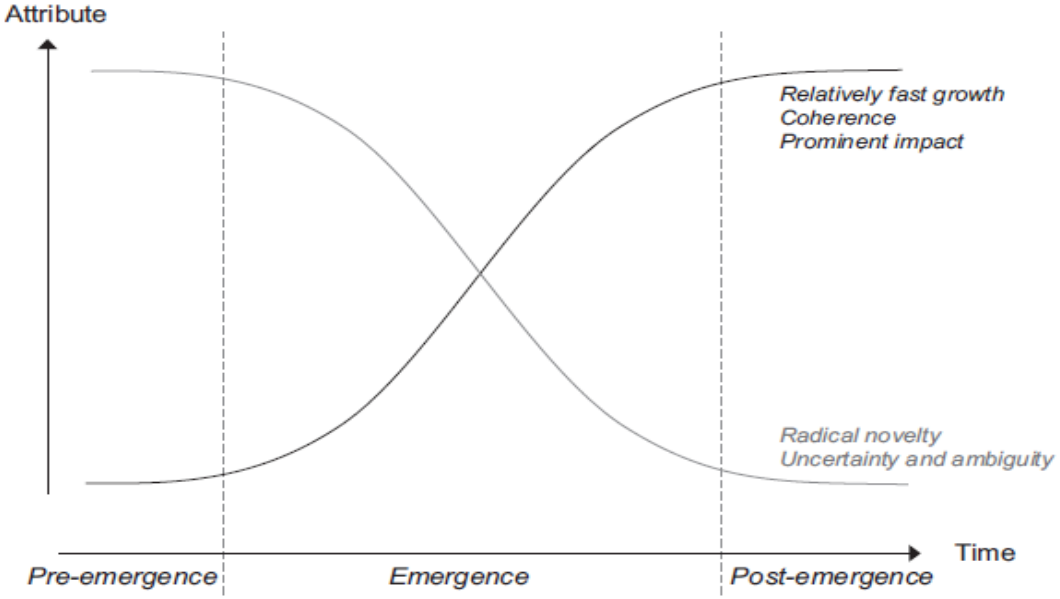
Rotolo et al., 2015

... but are the characteristics of the attributes always the same ?

Source: Rotolo D, Hicks D, Martin BR (2015) What is an emerging technology? Res Policy 44 (10):1827–1843

Emergence – Different Stages

No! The same technology at a **particular stage of emergence** will most likely show a different level for the different attributes.



Pre-Emergence, Emergence, and Post-Emergence (Rotolo et al. 2015)

Source: Rotolo D, Hicks D, Martin BR (2015) What is an emerging technology? Res Policy 44 (10):1827–1843

Immersive Technologies

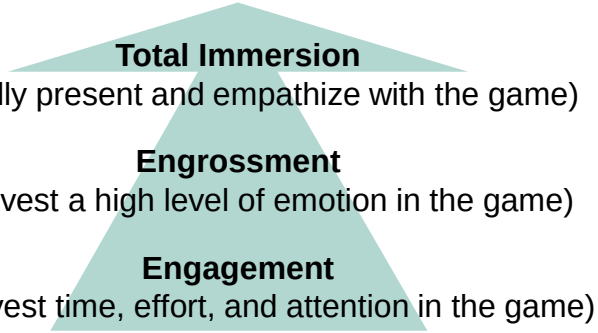
Immersive Technologies

Definition

Immersive technologies generate computer-based simulations of reality with physical, spatial, and visual dimensions that create a sense of immersion and enhancing the realism of virtual experiences.

Soares and Simão, 2019; Suh and Prophet, 2018

- What exactly does ***immersive*** mean ?

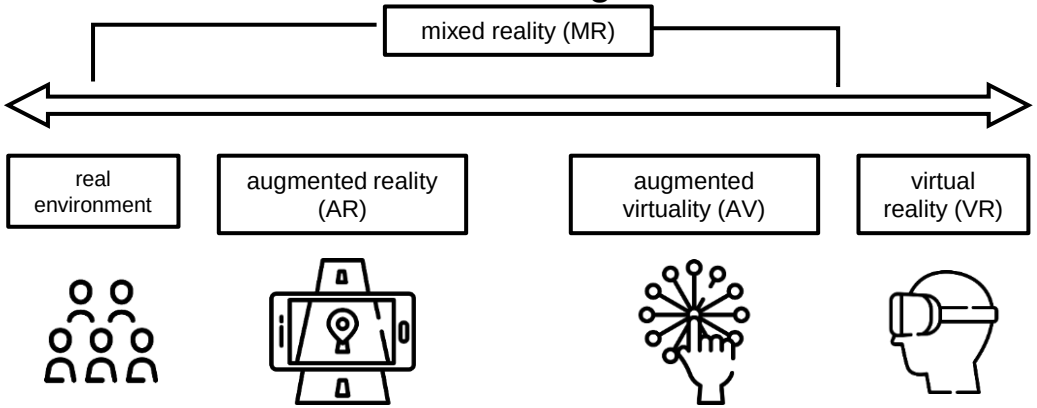


- *Further Reading*: Handa M et. al.: Immersive technology – uses, challenges and opportunities. International Journal of Computing & Business Research 6

Source: Soares C, Simão E (2019) Immersive multimedia in information revolution. In: Simao E, Soares C (eds) Trends, experiences, and perspectives in immersive multimedia and augmented reality. Advances in multimedia and interactive technologies. IGI Global, Hershey, PA, pp 192–210
Suh A, Prophet J (2018) The state of immersive technology research: a literature analysis. Comput Hum Behav 86:77–90

Immersive Technologies

- So, how does immersion work?
- The sense of immersion is created through temporarily **changing** a person's **sense of presence** by tricking her/his cognitive and perceptual systems into believing that s/he is somewhere other than her/his actual physical location
- There are many variations of immerse technologies:

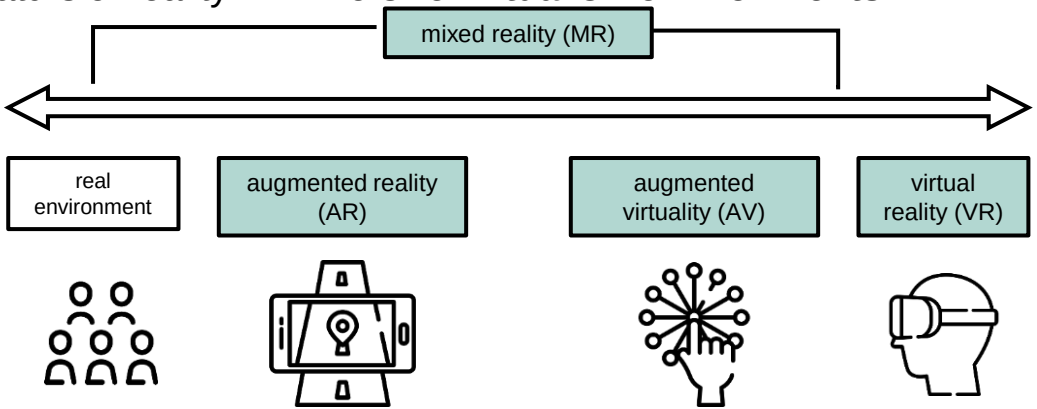


Reality–Virtuality Continuum, adapted from Milgram and Kishino (1994)

Source: Milgram P, Kishino F (1994) A taxonomy of mixed reality visual displays. IEICE Trans Inf Syst E77-D(12):1321–1329

Immersive Technologies

- VR creates a fully enclosed non-physical world, which is meant to be experienced as being physically present *(Freina and Canessa, 2015)*
- MR combines real and virtual contents using digital devices and is therefore seen as consisting of both AR and augmented virtuality (AV) *(Milgram and Kishino, 1994)*
  - AR refers to **virtual 3D objects** in immersive reality
  - AV captures featurs of reality in immersive **virtual 3D environments**



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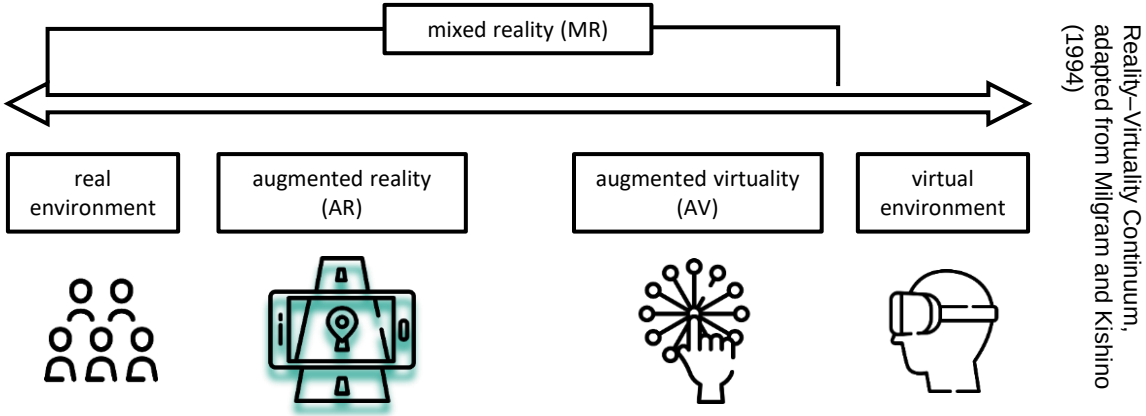
Source: Milgram P, Kishino F (1994) A taxonomy of mixed reality visual displays. IEICE Trans Inf Syst E77-D(12):1321–1329

Immersive Technologies — Augmented Reality

Definition

Augmented reality describes an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera).

Merriam-Webster, 2019



Source: Merriam-Webster (2019a) Definition of augmented reality. https://www.merriam-webster.com/dictionary/augmented%20reality. Accessed 19 Sept 2019
Milgram P, Kishino F (1994) A taxonomy of mixed reality visual displays. IEICE Trans Inf Syst E77-D(12):1321–1329

Immersive Technologies — Augmented Reality

[SEOUL and SALZBURG, AUSTRIA] by LG Electronics (LG) in corproation with Wikitude, May 11, 2011. CC BY 2.0.

[Pokemon Go] by Unknown, January 29th 2017. Public Domain.

[3D Agentur für Visualisierungen, Animationen und VR/AR] by tuneful, n.d.

[Google Glasses] by Reckmann Tim, May 12th 2014. Licensed under CC BY-SA 3.0.

Immersive Technologies — Augmented Reality

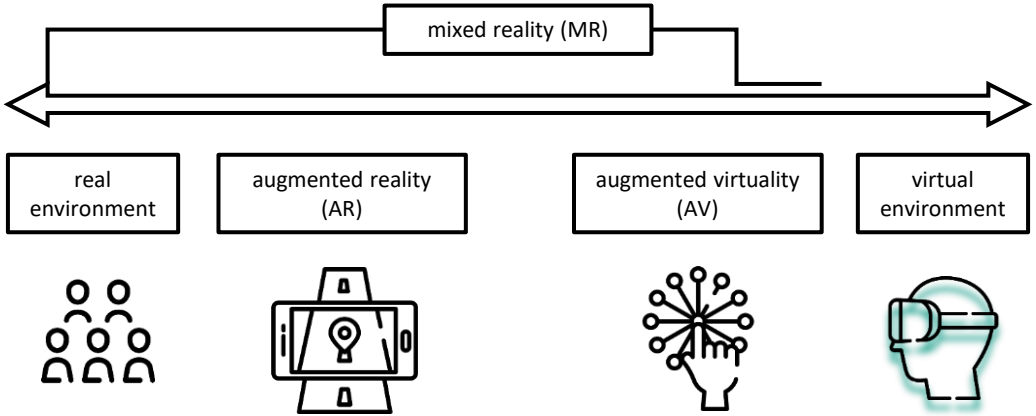
- Mobility through advancements made in mobile computing and telecommunications infrastructures *(Sommerauer and Müller 2018)*
- Necessary hardware components for Augmented Reality
  - (1) devices for displaying the virtual objects
  - (2) input devices to detect users' interaction with the real and virtual object
  - (3) sensors to capture users' positions and movements
  - (4) computing devices that combine the input data and create the virtual overlays
- AR has started to move from laboratories into consumer markets
  - **BUT** it is still too early to label the technology as established

Immersive Technologies — Virtual Reality

Definition

Virtual Reality refers to technology that generates an interactive virtual environment that is designed to simulate a real-life experience.

Suh and Prophet, 2018



Reality–Virtuality Continuum, adapted from Milgram and Kishino (1994)

Source: Suh A, Prophet J (2018) The state of immersive technology research: a literature analysis. Comput Hum Behav 86:77–90
Milgram P, Kishino F (1994) A taxonomy of mixed reality visual displays. IEICE Trans Inf Syst E77-D(12):1321–1329

Immersive Technologies — Virtual Reality

- Non-immersive VR
  - Virtual content on a computer screen (two- or three-dimensional)
  - E.g.: Smartphones, video game consoles, desktop computers
- Immersive VR
  - Utilizes complex sensors and visualization devices
  - E.g.: helmets or goggles holding one/two LCD (Liquid crystal display) screens in front of the wearer's eye
  - High usability in healthcare sector
    - 360-degree cameras filming difficult operations

Image source: [Mit stereoskopischen Bildern versetzen VR-Brillen den Nutzer in fremde Welten] by Stiftung Warentest, December 13th 2016. © Getty Images, Shutterstock.

Immersive Technologies — Health Sector

- Examples for Immersive Technologies in Health Sector
  - Augmented Reality
    - AED4EU allows locating the nearest automated external defibrillators (AEDs) and is projected onto the user's current environment via their smartphones' screens
    - AR smart glasses are used to support new mothers that struggle with breastfeeding. Counselors guide mothers through the breastfeeding process and give advice in the form of visual step-by-step instructions
  - Virtual Reality
    - Allowing medical students to be virtually present in an operating room
    - Embodied Labs (e.g., Alfred Lab) for medical students to experience how it feels to be a 74-year-old man
    - Using it for patients' pain therapy
- Referring to Gartner's hype cycle, immersive technologies have already passed the peak of inflated expectations and are on their way to the trough of **disillusionment**.

Virtual Assistants

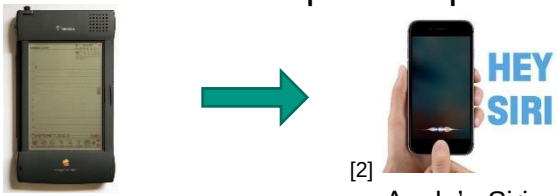
Virtual Assistants

Definition

Virtual assistants refer to software agents that are able to interpret human speech, autonomously execute the user-issued command, and respond via synthesized voices.

Hoy, 2018

- E.g., Google Assistant, Apple's Siri, Amazon's Alexa, ...
- Technical perspective: virtual assistants are a novel type of personal software agent
- Functional perspective: virtual assistants aim to provide personalized digital assistance to human users



[1] Apple's Newton

[2] Apple's Siri

Source: Hoy MB (2018) Alexa, Siri, Cortana, and more: an introduction to voice assistants. Med Ref Serv Q 37(1):81–88
Image source [1]: [Apple Newton] by Ralf Pfeifer, June 3rd 2005. Licensed under GNU-FDL.
Image source [2]: [Apple Siri] by iphonedigital, January 29th 2017. Licensed under CC BY-SA 2.0.

Virtual Assistants

- Now emerging virtual assistants…
  - … utilize recent advances made in AI to interpret human speech
  - … autonomously execute the interpreted command
  - … respond via synthesized voice
- Abilities of devices integrated into existing infrastructure at home:
  - (1) send and read text messages, make phone calls, as well as send and read e-mail messages
  - (2) answer simple questions (e.g., “What time is it?”) or even more tricky ones (e.g., “What do elves eat for Christmas?”)
  - (3) set reminders, make lists, and do basic math calculations;
  - (4) control media playback from connected services such as Amazon, Google Play, iTunes, etc.
  - …
- Referring to Gartner’s hype cycle, virtual assistant has also passed the peak of inflated expectations and is on its way to the trough of **disillusionment**.

Virtual Assistants — Chatbots

Definition

Chatbots refer to software agents that are designated for interactive communication with humans via text or voice.

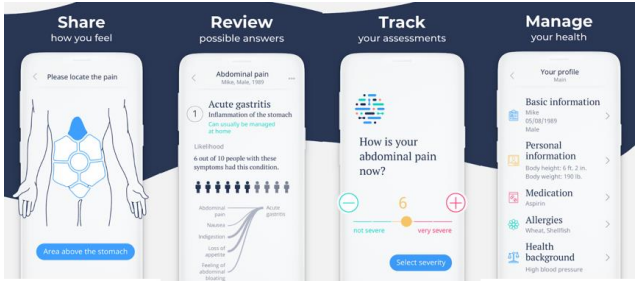
Chung et al., 2017

- Chatbots communicate with human users via text or voice
- Chatbots extend the concept of virtual assistants through engaging in a human-like, interactive conversation
- First chatbot: ELIZA (1966)
- Chatbots have the potential to complement or even replace existing direct or indirect communication channels
- *Further Reading:* Janarthanam (2017) Hands-On Chatbots and Conversational UI Development, vol Birmingham - Mumbai.

Source: Chung H, Iorga M, Voas J, Lee S (2017) Alexa, can I trust you? Computer 50(9):100–104
Image source: [Dawn of the Chatbots: What Do Consumers Want and Expect?] by Newton Mark, February 6th 2018.

Virtual Assistants — Chatbots

- Chatbots in Healthcare:
  - They could replace consultations with physicians
  - They may help to address diagnosable health concerns and unburden medical professors
  - They could support patients managing their health care and take more responsibility for their health
- Examples:
  - Medical app Ada
  - Babylon Health



Ada Health app for Android

Virtual Assistants have the potential to drastically decrease costs to the health care system and increase treatment quality by allowing medical professionals to focus on more critical or complicated treatment measures

Image source: [Ada Health app for Android] by Ada.

Artificial Intelligence

Artificial Intelligence

Definition

Artificial Intelligence refers to intelligence demonstrated by machines as opposed to natural intelligence displayed by humans or animals.

Russell and Norvig, 2010

- AI has been absorbed into (almost) every business sector
  - Automotive, retail, healthcare, …
- AI research has a twofold purpose:
  - Scientific view: AI aims at understanding the principles that make intelligent behavior possible in natural or artificial systems
  - Engineering view: AI has the goal of designing and synthesizing useful, intelligent artifacts *(Poole and Mackworth 2010)*

Source: Russell SJ, Norvig P (2010) Artificial intelligence. A modern approach, 3rd edn. Pearson Education, Upper Saddle River, NJ

Artificial Intelligence

- Strong AI (full AI or artificial general intelligence) requires the abilities to…
  - … autonomously solve problems
  - … plan, learn, adapt, and communicate in natural language
  - …represent knowledge
  - … make reasonable judgments under uncertainty
  - → **no** examples for working systems that can claim all the above criteria!

- Weak AI (applied AI or narrow AI) …
  - … includes all existing AI systems (e.g., Siri or Google Assistant)
  - … is neither self-aware nor capable of developing new abilities on their own to solve new problems

- Referring to Gartner's hype cycle, artificial intelligence is referring to an innovation trigger and is climbing up to the peak of inflated **expectations**

Artificial Intelligence — Artificial Neural Networks

- Artificial Neural Networks
  - Important technology that drives current advancements in AI field
  - ... simulate the functioning of the human brain for the purpose of solving AI problems (e.g., recognition of patterns in highly complex datasets) *(Mthunzi et al. 2019)*
  - ... have inputs (e.g., for datasets), outputs (e.g., for calculated results) and passages between them through various layers of **simulated neural connections**

    ➡ So how do artificial neural networks work?

Artificial Intelligence — Artificial neural networks

- A neural network is used by providing a dataset to processing nodes of the network's layer, where it is split into individual values:
  - **(1)** When a value is passed to a node through one or more of its input connections where an **individual multiplier** is applied for each input connection to the value. The node then **adds** these **weighted values** together.
  - **(2)** When the resulting value passes a node-specific threshold, the node sends the accumulated value to its successor nodes in the next layer.

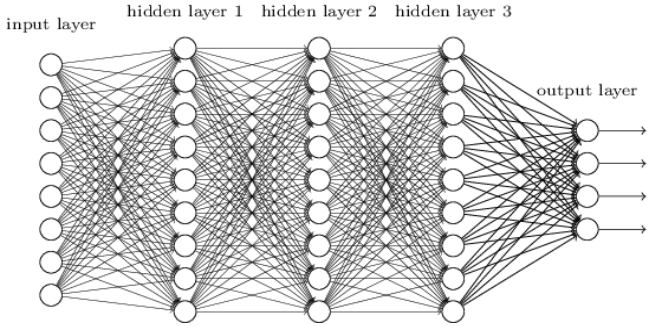


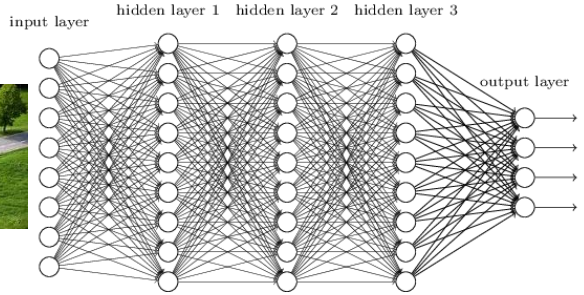
Image source: Goodfellow I, Bengio Y, Courville A (2016) Deep Learning, MIT Press, Cambridge MA

Artificial Intelligence — Artificial neural networks

- **(3)** The **values** finally arriving at the **output layer** form the result calculated by the network. Changing the multipliers and threshold of individual nodes allows changing the path values take and how they accumulated and, thus, change the output or behavior of the neural network.
- → The process of configuring a neural network's behavior by adjusting node properties is **called training**: the network is fed with training datasets for which the desired outcome is already known. By gradually adjusting the processing nodes, the network **adapts its behavior** until the desired output is generated.


[1]

Is there a car in this picture?



Yes

[2] Goodfellow et al., Deep Learning, MIT Press, 2016

Image source[1]: [Landside Road] by Unknown, January 10th 2018. Licensed under CC0 1.0.
Image source[2]: Goodfellow I, Bengio Y, Courville A (2016) Deep Learning, MIT Press, Cambridge MA

Artificial Intelligence

- Artificial Intelligence in the Automotive Industry
  - Contemporary example of the **emergence of AI**
  - The automotive industry permanently transmit data from driving and the Autopilot feature back to their R&D department, where it is used to **train** and further **improve** the **underlying algorithms** → Each individual driver contributes to the training of an AI that will enable future car generations to drive fully autonomously
  - Tesla Autopilot relies on cameras, ultrasonic sensors, and radar, as well as on-board computing hardware that allows it to process sensor data using machine learning **approaches**
    (*Further Reading:* Tesla Inc. (2019) Autopilot: Future of Driving. https://www.tesla.com/autopilot.)

Definition

Artificial Intelligence refers to intelligence demonstrated by machines as opposed to natural intelligence displayed by humans or animals.

Russell and Norvig, 2010

Source: Russell SJ, Norvig P (2010) Artificial intelligence. A modern approach, 3rd edn. Pearson Education, Upper Saddle River, NJ

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- Sommerauer P, Müller O Augmented Reality in Informal Learning Environments: Investigating Shortterm and Long-term Effects. In: Proceedings of the 51st Hawaii International Conference on System Sciences (HICSS 2018), 2018. pp 1423-1430
- Stirling 2007
- Suh A, Prophet J (2018) The State of Immersive Technology Research: A Literature Analysis. Computers in Human Behavior 86:77-90

Questions

Questions

1. What attributes distinguish established from emerging technologies?
2. What are the different stages an emerging technology goes through?
3. Where are the differences between virtual reality (VR), augmented reality (AR), and mixed reality (MR)?
4. What are the reasons for the prominent impact of immersive technologies in the healthcare context?
5. What are the reasons for the prominent impact of chatbots in the healthcare context?
6. How do artificial neural networks work?
7. Why is artificial intelligence an emerging technology?

Further Reading

- **Emergence and Emerging Technologies**
  - Small H, Boyack KW, Klavans R (2014) Identifying Emerging Topics in Science and Technology. Research Policy 48 (8):1450–1467
- **Concepts and Key Attributes**
  - Adner R, Levinthal D (2002) The Emergence of Emerging Technologies. California Management Review 45 (1):50–66
- **Immersive Technologies**
  - Suh A, Prophet J (2018) The State of Immersive Technology Research: A Literature Analysis. Computers in Human Behavior 86:77-90
- **Virtual Assistants**
  - Hoy MB (2018) Alexa, Siri, Cortana, and More: An Introduction to Voice Assistants. Medical Reference Services Quarterly 37 (1):81-88
- **Artificial Intelligence**
  - Russell SJ, Norvig P (2010) Artificial Intelligence. A Modern Approach. Third Edition edn. Pearson Education, Inc., Upper Saddle River, New Jersey