# Virtual Reality 1

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## 1. Chapter 1: Introduction into Virtual Reality

### 1.2. The development of the computer

- **the constant increase of computational power available in modern computer** → today's abundance of virtual reality.

#### Numbers

- 6000 years ago: the earliest use of numbers.
  - 3300 B.C. Egypt: battle report in hieroglyphs.
- number system
  - The first number systems exist in hieroglyphs e.g. $1 =$ *line*, $10 =$ *horseshoe* ...
  - Roman:

| | |
|---|---|
| I $= 1$ | V $= 5$ |
| X $= 10$ | L $= 50$ |
| C $= 100$ | D $= 500$ |
| M $= 1000$ | |

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  - Addition-system (Roman, Greeks, Syrians, Slavic tribes ...): large numbers are made by adding up the symbols
  - Indo-Arabian: the system used until today (1, 2, 3, 4, 5, 6, 7, 8, 9, 0)
    - more complicated calculation can be performed very easily.
    - very forgery-proof
    - 6th century: Indian to Mesopotamia (Severus Sebakt)
    - 10th century: came to Europe (Leonardo Fibonacci)
    - 16th century: printing numbers were introduced (Adam Ries and Albrecht Dürer)

#### Calculation and calculation machine

- First means to calculate
  - calculating with the fingers - Rome: 40 finger positions, displays up to 200000
  - tally stick (Europe), knots (native Americans)
- The first scientific calculation: **abacus**
- **Written calculation became popular (since 15c)**
  - eased calculations and reduced the required time.

- lowered the failure rate.
- The first calculation machine (W. Schickardt, 17c) **Figure 1.16, page 1-12**
  - add numbers up to 6 digits
  - multiplication were possible.
  - toothed gears and slide rules.
- B. Pascal(1623 - 1662) **Figure 1.17, page 1-12**
  - made money with calculation machine (the first one)
  - add and subtract numbers with 8 digits.
  - more than 50 pieces were produced.
- G. W. Leibniz (1646 - 1716) **Figure 1.18, page 1-12**
  - introduced the machine suitable for all four basic calculation.
- The calculating machines of 18c: more reliable, but became a piece of jewelry than a device for daily use **Figure 1.19, page 1-13**
- C. X. Thomas (1785 - 1870) **Figure 1.20, page 1-13**
  - precise, efficient and ergonomic.
  - "arithmometer": multiplied two numbers with 8 digits in 18 sec.
  - more improved later
- **Programmable calculation machines** (C. Babbage, 1792 - 1871)
  - punched cards for programming.
  - could run the program autonomously.
  - used steam machine and weights, but failed to realize his idea.
- **Calculation machine with electrical devices** (H. Hollerith, 1860 - 1929)
  - **Figure 1.22, page 1-15**
  - control mechanism activated by electrical devices (relays, motors ... ) with punched cards
  - American Census in 1890: shorten the time for analysis 7 yrs → 1 yrs
  - founded IBM

**Computer era**

- Theoretical background of the first programmable electrical calculation machine (The first computer): **L. Couffignal and A. M. Turing**
- The first computer: **ZUSE Z3** by K. Zuse (1941)
  - Z1 (didn't work) → Z2 (simple tests) → Z3
  - could handle 64 numbers with 22 digits.
  - 2600 relays and 8 line punched tape
  - Z4 (1950s) worked at ETH
- **The first encryptor & decryptor**: Enigma vs Colossus (1941)
  - MARK 1 (1943) in US
  - MARK 2 (1944) in US
- **The first electronical computer, ENIAC (1946) Figure 1.25, page 1-16**
  - J. P. Eckert, J. Mauchley and H. H. Goldstine
  - 18000 tubes, 1500 relays, 1000 capacitors and 6000 switch.
  - very fast... 0.0002 sec for addition, 0.0028 sec for multiplication
- **Transistor** invented (1948) **Figure 1.26, page 1-17**
  - **smaller, faster, less heat, longer life cycle, manufactured automatically**
  - **switch: relays → tubes → transistor**

- **single chip computer(CPU)** (Integrated Circuits)
  - 4-bit processor INTEL and Texas Instrument in 1970
  - 8-bit (1972), 16-bit (1978) ... now 32 bit / 64 bit
- **Personal Computer (PC)**
  - because of IC, the size of computers could be drastically reduced
  - Kenbak1 (1971): the first single chip computer
  - ALTAIR 880 (1974): mass market
    - **Basic**: a new programming language developed for ALTAIR
  - Apple II & Commodore PET: the first commercial success
  - IBM PC became very popular
- SGI were used for high-performance computer graphics: Virtual Reality...

### Moore's law and the development of computer

- **Moore's law** (1965): **the amount of transistors** in a computer is doubled all 18 months. **Figure 1.34, page 1-22**
- but also the required space for the transistors becomes smaller and smaller. i.e. **the available memory per chip** is increases: x4 every 3 yrs
- **chip size** also increases: x2 every 10 yrs
- **CPU speed** increases: x2 every year

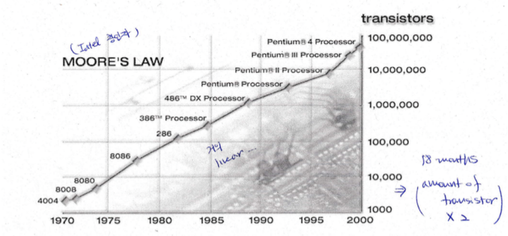



Figure 1.34 Moore's law (https://www4.in.tum.de/misc/perlen/perlen-folien/schaetz-Produktivitaet.pdf)

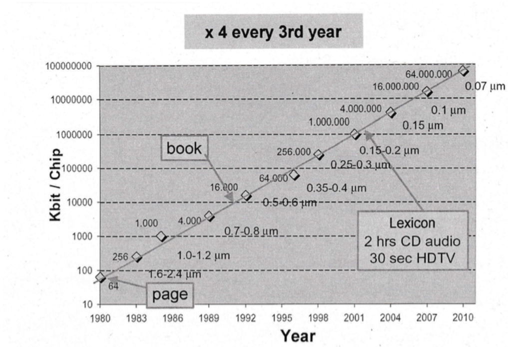
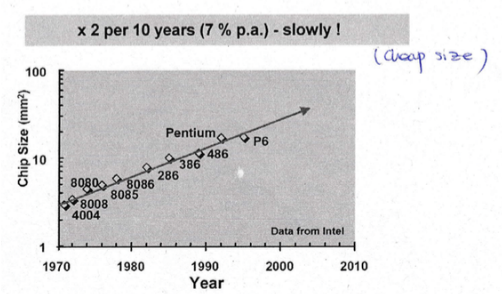
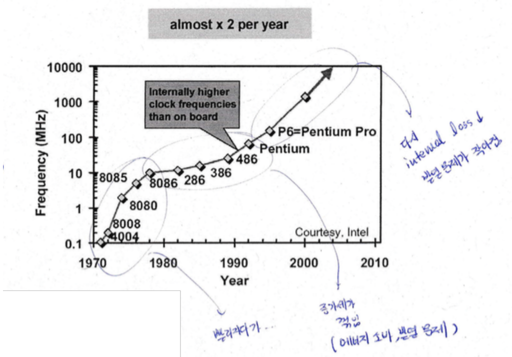



Figure 1.35 Available memory per chip




### 1.3. Definitions

- Reality (exist): real object $\gg$ virtual object
- Mixed Reality
  - Extended Reality (Augmented Reality): real obj $>$ virtual obj
  - Extended Virtuality (Augmented Virtuality): real obj $<$ virtual obj
- Virtual Reality (non exist): real obj $\ll$ virtual obj
- **Note: Figure 1.39, page 1-25**

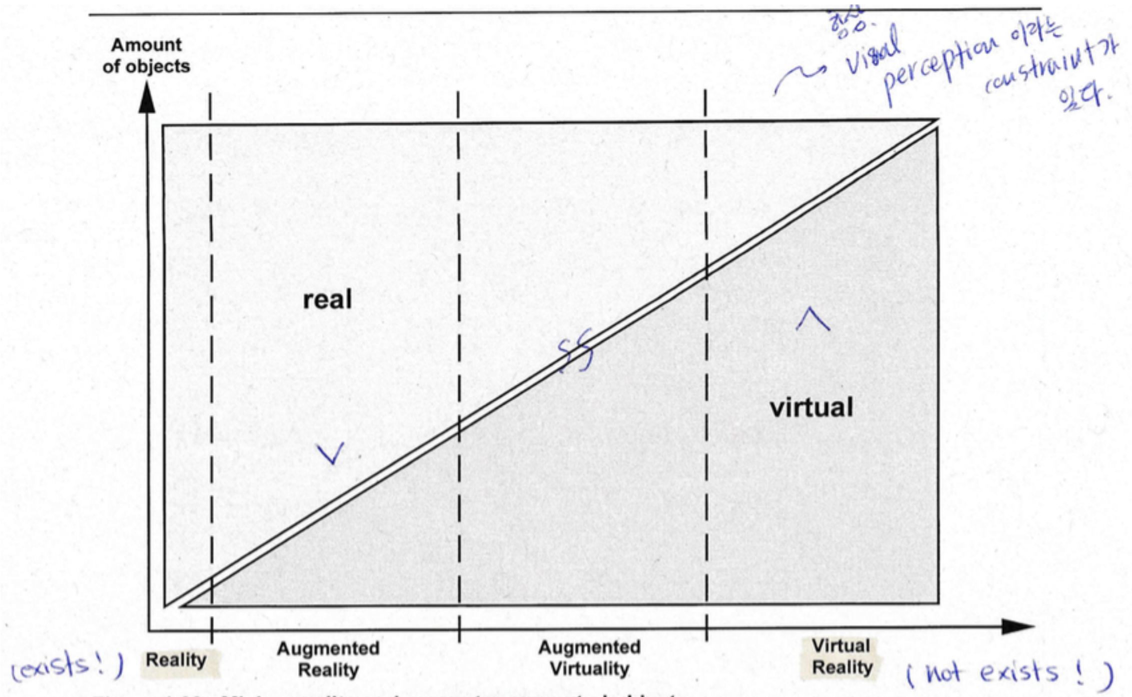



Figure 1.39 Mixing reality and computer generated objects

### 1.3.1. Extended Reality (augmented reality)

- **real object > virtual object**
- the computer generated objects are characterized by the fact but usually differ from reality in scale, shape or color.
- e.g. AR on copy machine: indicate parts to be fixed

### 1.3.2. Extended Virtuality (autmented virtuality)

- **real object < virtual object**
- comparing to AR, virtual objects are much more detailed and fit much better to reality.
- e.g. Reconstruction of ruins **Figure 1.40**

### 1.3.3. Virtual Reality

#### Definition

- Former Definition: a possible or considered reality, which is not available yet.
- Complete Definition: **"Virtual Reality is a computer generated, interactive and three-dimensional environment, in which the user is completely immersed"**
    1. a fictive and non-real world (e.g. TV, movie, dream are fictive and non-real world)
    2. "cybernetic room" or "cyberspace": controllable and manageable room, in which information is processed. (e.g. chess, board games)

3. generated by computer, using specialized program: imaginary reality can only be reached by processing numerous infos.

**The VR reference model**

- **Figure 1.41, page 1-27**
- Three component (three axis)
  - interaction (none → interactive → immersive)
  - semantics of data (none → static → dynamic)
  - presentation (single event → sequence of events → real time)
- optimal VR application = <u>immersive interaction</u> + <u>dynamic semantics</u> + <u>real time presentation</u>
- Note, but not each VR application requires the maximum amount of all three criteria.

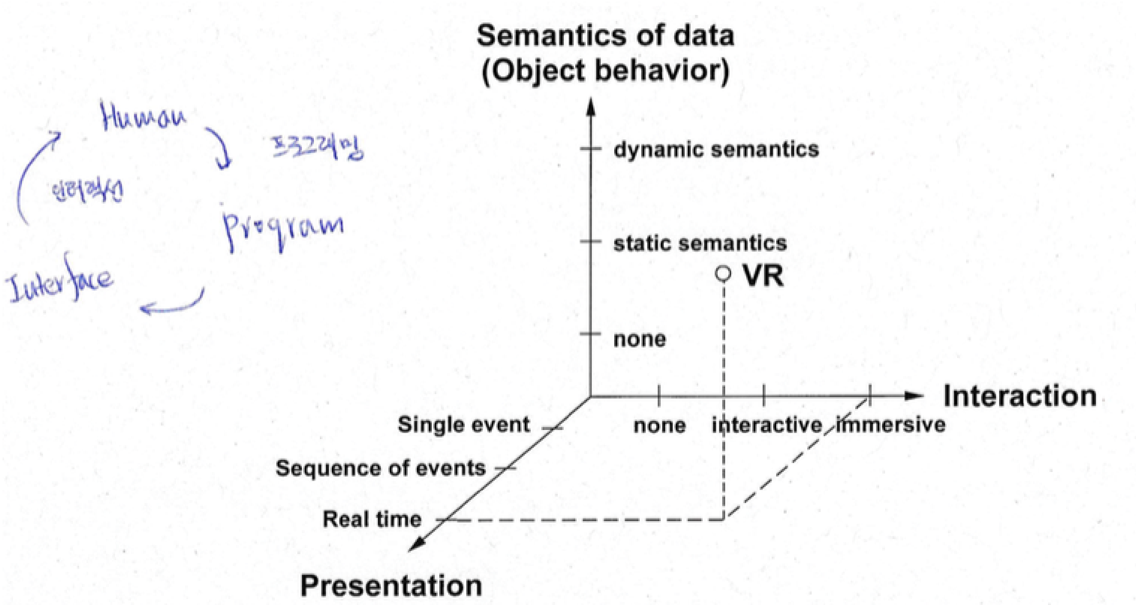



Figure 1.41 The VR reference model

**$I^3$ - Immersion - Interaction - Imagination**

- technology provided by VR ...
  - is used to immerse into the virtual env. (immersion)
  - is used to interact with its objects. (interaction)
    → VR addresses all perception channels of the user and thus he is convinced of the reality of VR env. (imagination)
- i.e. Two prerequisites for VR: immersion & interaction (**immersion & interaction** → imagination)
- **latency time should be smaller than 0.1 sec!**

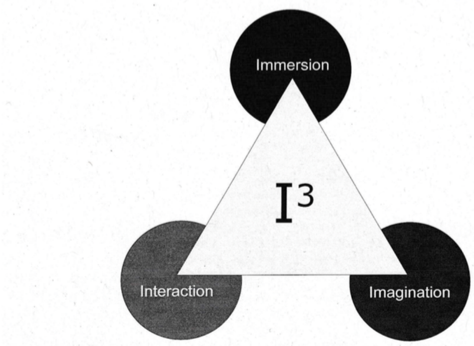



Figure 1.42 Virtual reality – immersion – interaction – imagination – $I^3$ [1.3]

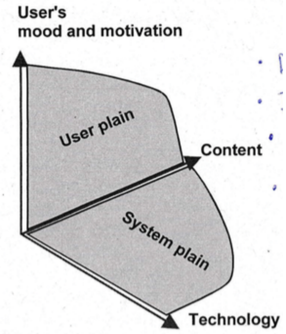



Figure 1.43 Definition of "Immersion"

### Interaction

- **interplay of information, action and reaction.**
- describes the effect of computer generated models onto the **human perception channels.**
- continuous: continuous interaction with the virtual environment **(low delay)**
- reaction: every movement of the user causes a reaction in VR (note: difference with movies)
- generation / modification of geometry displayed, visual, acoustic, haptic, olfactory, and physical properties (e.g. collision, material prop., torque, DOF ...)of virtual object (copy or supplement real object)
- interactivity: ability of the system to allow a user's interaction, while the application is running. Special hardwares are needed.
- interaction facility
  - Passive: the user sees, hears and feel. (e.g. "Back to the Future" ride of Universal Studios)
  - Exploratory: the user can explore the virtual env.
  - Interactive: the user explores the env, and interacts with the virtual objects also modify the env.

### Immersion

- Goal: to create the **"Sense of Presence" (SOP)** i.e. subjective impression of the user to be integrated in a fictive environment, which is not physically present.
- SOP focusing on...
  - Natural interaction
  - Interface to the computer is in the background
  - Higher information density is possible
  - More efficient access to complex data
- User plain vs. System plain: interaction of both plains is the main purpose of supporting tech. Immersion is to map both plains onto each other.

### Virtual Environment

- for interactivity, powerful computers are needed.

- sub-categories of virtual env.
  - Reality driven virtual env.: generated model could also exist in reality
  - Scaled virtual env.: computer generated which exists in reality, but can only be understood and explained by the user who applies the virtual model.
  - Distant virtual env.: computer generated which represent a model of the real would cannot be explored out of distance or security reasons.
  - Imaginative virtual env.: computer generated only come from the user's imagination.
  - Informative virtual env.: visualize abstract data.
- another sub-categories of virtual env.
  - desktop virtual env.
  - immersive virtual env.
  - augmented virtual env.
  - telepresence virtual env.

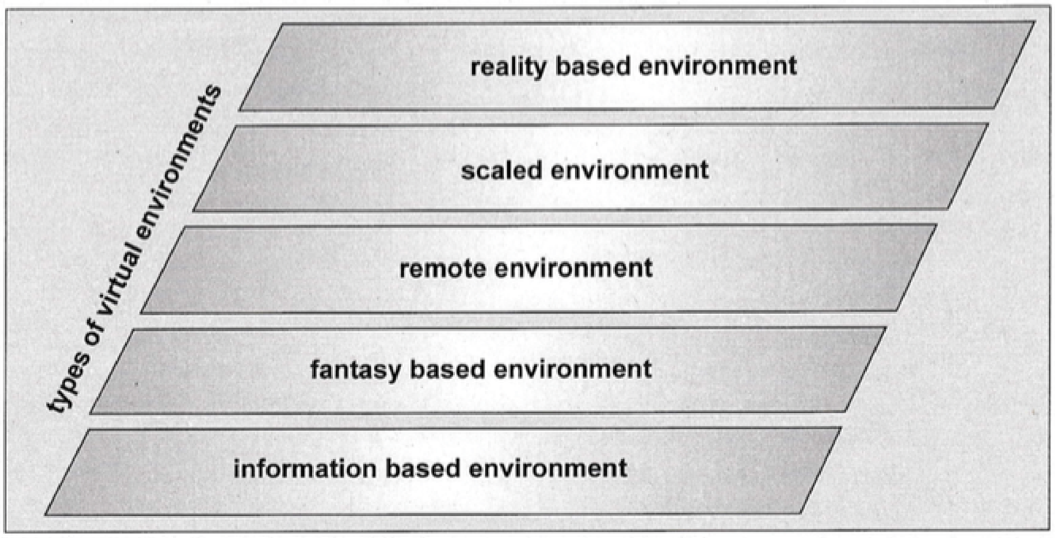



Figure 1.44 The different kinds of virtual environments

**Summary**

Virtual (VR) is a computer fictive world, which is characterized by the fact, that it can address **the perception channels** of the human user via interfaces. The user registers these sensations and answers by certain **reactions**. These reactions are registered by **the virtual environment** and cause corresponding reactions of the system. In order to complete the illusion of a new virtual reality, **only sensations from VR and not from reality can reach the user.** Thus, the user feels **completely immersed** in the virtual environment, which temporarily replaces reality. VR has to respond **fast and correctly** (corresponding to the defined rules) to the actions of the user.

### 1.3.4. The Benefit of VR for industry

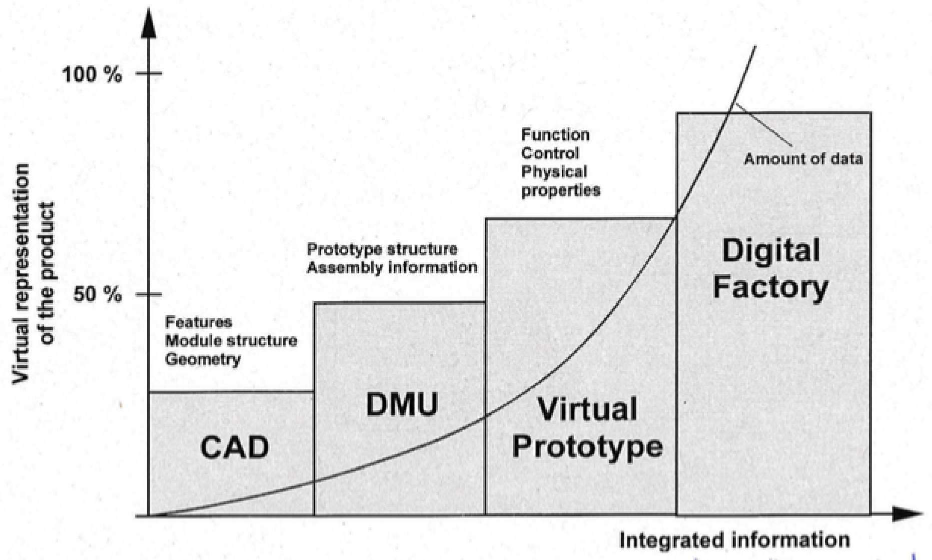
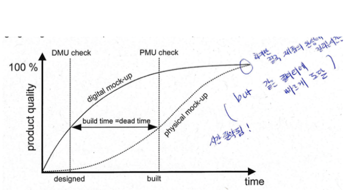



**Figure 1.45** Increase of data during the product life cycle (use of VR in industry)

- complexity of today's product → huge amount of data.
- product life cycle vs. data
  - CAD: module geometry
  - DMU(Digital Mock-up): assembly verification, collision detection and tolerance analysis
  - Virtual prototype: physical properties (function simulation and software simulation)
  - Digital factory: design and manufacturing process are considered
- prototyping process up to now (physical mock-up)
  - Digital proto → geometrical proto → functional proto → technical proto
- now, VR is used for prototyping by DMU. (alternative of physical mock-up)
  - **reach same quality of product in less time.** (Figure 1.47)
  - **design modification iteration is much smaller and faster**: time & cost-saving
    → much closer to ideal development process (Figure 1.48 and 1.49)
  - all digital data gathered can be used later for other purposes (e.g. for the sales process)
  - visualization of data: creative teamwork (idea generation)



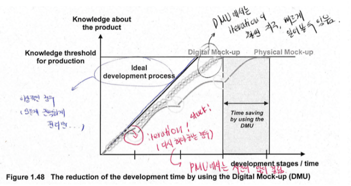




Figure 1.48 The reduction of the development time by using the Digital Mock-up (DMU)

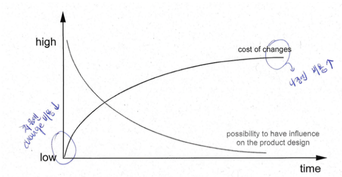



Figure 1.49 Cost of changes and the possibility of changes

**VR in product development process**

- FMEA (Failure Mode and Effectiveness Analysis): visualization of geometry → detect possible failures, show the required details to all persons simultaneously.
- Access control: check accessibility to important point. (e.g. screw connections, connectors...: Figure 1.51)
- Kinematic verification: collision check w/o building (physical) proto.
- Design review: general design review. (geometrical proto)
- Crash simulation: automotive sector. Deformation process can be visualized.

**VR in Later production phases**

- User training: for complex products, person can handle the product have to be taught in parallel. (e.g. escape from the plant in emergency)
- Product presentation: important part of the sales process. (e.g. Motor show)
- Assembly/service instruction: VR offers techniques and algorithms, which can drastically reduce the amount of data for complex geometries. (less powerful computer for visualization can be used.)

**Digital product and services for user**

- the structures of the digital product are optimized for the computer, not for the access by the user directly.
- improvement of the interaction between the user and the digital product is a main requirement
- The user uses special **services** that allow him the access to the processes based on the digital product:
    - visualize: content of the digital product or parts of it are visualized to the user. (graphical / text-based)
    - simulate: unknown behavior will be simulated
    - archive: all data about the product allows having instantaneous access to them
    - document: documentation of a product or the processes (graphical / text-based)
    - transfer: content of the digital product or excerpts of it are transferred over a network in a digital form
    - present: excerpts of the digital product were extracted, processed and displayed. (optical aspects are in the focus of interest)
    - integrate: excerpts of the digital product are integrated into the database.

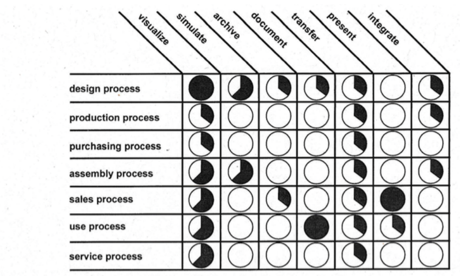


Figure 1.55 The importance of virtual reality in the product development process

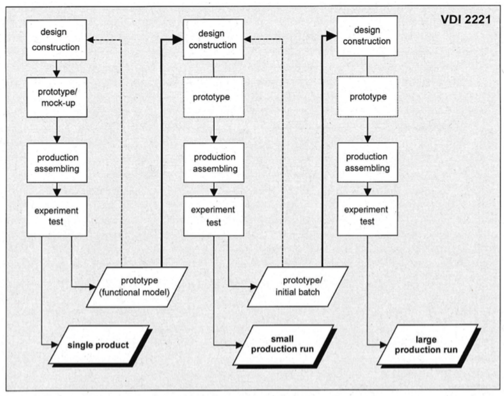


Figure 1.56 Product manufacturing process for different numbers of units – use of prototypes

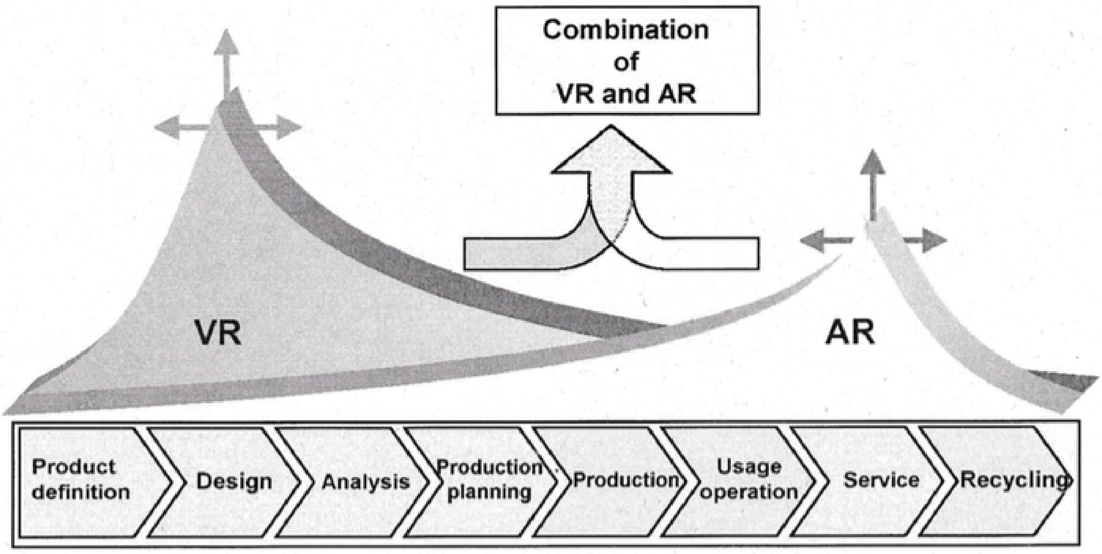
**Real Prototypes and Mock-ups**

- It is usual to pass the process several times and to create functional prototypes and initial batches.
- Benefit of using digital mock-ups (e.g. CAD, CAE)
  - Communication: team works (e.g. marketing team $\leftrightarrow$ designer $\leftrightarrow$ process engineer)
  - Documentation of the state-of-the-art: review the state-of-the-art of the product under development. (know-how reached so far and reduces uncertainties)
  - Integration platform: integration of sub-systems.
  - Documentation of development steps (milestones): this can ensure the overall development goal can be achieved within a realistic time.
- New visualization technologies is to replace the physical proto.
- VR allows the generation of synthetical environments in the computer for a realistic simulation of a design or construction.
- Digital mock-ups is in the dramatic reduction of development itme, the higher product quality, and the reduction of cost for changes.

- Note: classification of prototypes
  - design proto: verification of the conceptual design concerning optical, esthetical, ergonomic requirements (not mechanical properties)
  - geometrical proto: verification of dimensional, tolerances, and fits. (not material)
  - functional proto: verification of mechanical, electrical, acoustical properties.
  - technical proto: all functional.

**Usage of VR and AR in the product development process**

- VR - mainly at the beginning of the product's life cycle
- AR - increasing importance in the later stages
- (the amount of VR decreasing) = (the amount of AR increasing)
- Note: at the present time, VR is a slight dominance. It's difficult to synchronize the real and the virtual object in time and position. (AR is much challenging)


Combination
of
VR and AR
VR
AR
Product
definition
Design
Analysis
Production
planning
Production
Usage
operation
Service
Recycling