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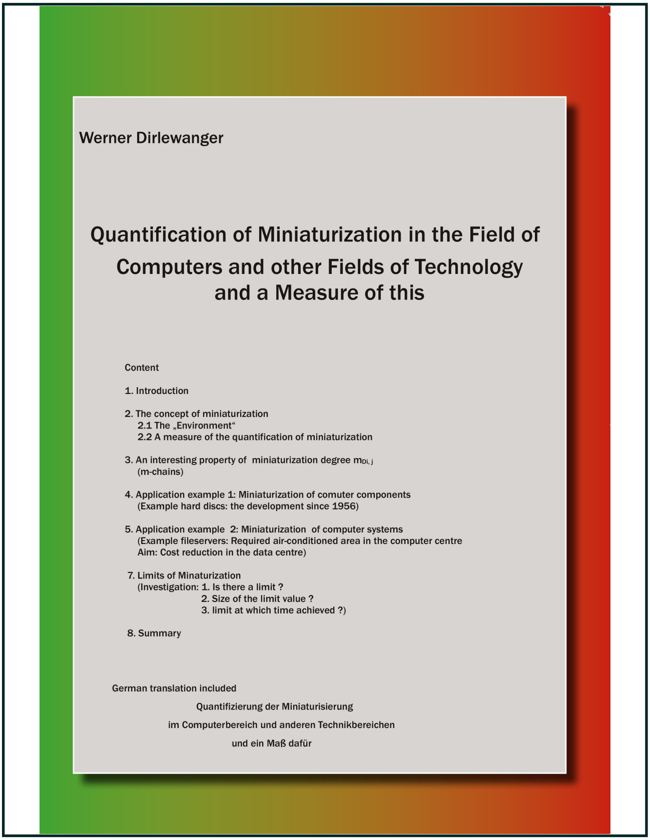
# Quantification of Miniaturization in the Field of Computers and other Fields of Technology and a Measure of this

*Quantifizierung der Miniaturisierung im Computerbereich und anderen Technikbereichen und ein Maß dafür*

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# 1. Introduction

In various technical fields it can be observed that younger versions of the respectively used technical devices or components thereof always have smaller spatial dimensions and this with the same or even better performance. Examples: mobile phone, smartphone, watches, medical devices, computers. This phenomenon is called "miniaturization". It can be "strong", "medium" or "weak" or possibly not at all.

These are emotional classifications that sometimes help. However, they are not qualified for technical and economic considerations. What is needed is a quantified and reproducible description of the strength of miniaturization for the particular case.

In the context of an intensive literature research, the term "miniaturization" was first sought. No concrete definition could be found in the German language area. The term appears in many places, but its use is always intuitive. For the Anglo-Saxon form, namely "miniaturization", a definition was found, see [1]. Miniaturization is described there as: "Trend to manufacture mechanical, optical and electronic products and devices in ever smaller form". A definition for the quantification of the miniaturization was found nowhere

However, in order to be able to analyse the effects of miniaturization and to present them quantitatively, a tool to describe the properties indispensable. In the following, such a tool is proposed, its definition explained and its application described. It is simple, understandable and good to handle. It can be applied to a wide range of systems and devices as well as individual device components. Although the need for this tool arised from computer problems, its applicability is not limited to this. It can also be applied to many miniaturization questions in other areas of technology.

# 2. The concept of miniaturization

## 2.1 The "Environment"

In order to deal with miniaturization, the type of the devices, products, etc. to be investigated must first be defined, i.e. the object type. Example: Disc storage drives for computers.

The term miniaturization includes the word "smaller" and thus a comparison. Therefore, a reference system has to be defined. In the example is it a hard disc specified by its technical data or, alternatively, by manufacturer and type.

Furthermore, the miniaturization criterion must be defined. This is, generally speaking, the "space requirement" of the object. The meaning of "space requirement" must be made more concrete in individual cases. In the example "hard disc drive" is "the space requirement" the spatial volume of the hard disk drive.

There are many characteristics, with which the object appears externally ( for instance response time, power consumption, weight, storage capacity and so on). The following definition has to be made. Chose one, but not more: "object characteristic".

The "environment" of a miniaturization consideration therefore consists of the following data:

- Object type ... ...... (in the example: hard disk drives)
- Number of objects examined in the study, as well as listing with detailed description of each object (In the example: drive type ABC, manufacturer XYZ)
- Name of the object intended to serve as a reference system.
- Miniaturization criterion V (in the example: space requirement)
- Object characteristic C (in the example: memory capacity)

# 2.2 A measure of the quantification of miniaturization

How to quantify whether and to what extent miniaturization occurs? For this purpose, the following variables are defined:

"Space requirement" V
"Object characteristic" C
"Relative space requirement" $p_{rel}$

V is the space occupied by the object. In the example, V is the volume of a hard disk.V is to be understood as an abstract quantity, since V does not necessarily have to be a volume specification. If, for example, a miniaturization investigation is to take place in the problem circle of printed circuits, then the occupied area of the circuit board is the object of the consideration, and not the volume. V is then a surface area and has a corresponding dimension, e.g. "$cm^2$". V could also be a length specification, eg the length of the cables for system cabling in the data centre. In the example of hard disk storage, the value of V can be easily determined: Firstly the hard disc dimensions are determined. Then the width (in cm) times the length (in cm) times the height (in cm) gives the value of V (in ccm) for this hard disc.

The object characteristic C indicates the functional size of the object. In the example, C is the storage capacity of the disc (in MB). However, if, for example, printed circuits are considered for I / O modules, then C could be the number of interfaces to I / O devices that the board has. One more example: computing systems for online operation are considered. Then, C could be the maximum number of users that the computer can serve simultaneously. Of course, such a number always refers to a very precisely described user behaviour ("computer centre work load").

The size V, the (absolute) space requirement, as well as the object characteristic C thus are defined. In the context of miniaturization, it is desirable to have a variable which describes the space requirement independent of C.

These is found by the quotient of (absolute) space requirement and the object parameter C. This is the "relative space requirement" $p_{rel}$ of the object:

$$p_{rel} = V / C \qquad (1)$$

Example: The hard disc has the dimensions: width = 10 cm, length = 15 cm, The hard disk has a capacity of 260 MB. Their relative space consumption $p_{rel}$ is therefore the same

300 ccm / 260 MB = 1.153846 ccm per MB.

To illustrate $p_{rel}$, one can also consider the reciprocal 1 / $p_{rel}$. In the present example, this value has the value:

260 MB / 300 ccm = 0.86666 MB per ccm.

This value can be interpreted as a memory density. $p_{rel}$ has the meaning of an inverse memory density.

In general, several objects are to be investigated in a miniaturization study. The number of objects, including the reference system, is denoted by N. Each object is assigned a number, also to the reference system. In principle, the reference system can obtain each of the N numbers. As will be explained later, however, it is recommended to give the reference system the number “1”. Even if only a single object is to be investigated, a reference system must be defined. N thus has at least the value 2. As will be explained later, it may be necessary to appoint another of the N objects to the reference system instead of the originally selected reference system. However, the old and the new reference system still remain a member of the set of N objects.

The variables for the quantitative description of the miniaturization refer to a particular one of the N "objects". The variables will therefore get an index i. The index indicates the "object".

$$p_{rel} = p_{rel\ i} \quad \text{and} \quad V = V_i \quad \text{and} \quad C = C_i \qquad (2a), (2b), (2c)$$

Equation (1) then is as follows:

$$p_{rel\ i} = V_i / C_i \qquad i = 1,2,.....,N \qquad (3)$$

The reference value, which makes it possible to classify the values of preli , is the relative space requirement of the reference system:

$$p_{REF} = V_{REF} / C_{REF} \qquad (4)$$

$V_{REF}$ is the space requirement of the reference system and $C_{REF}$ is its storage capacity. $P_{REF}$ is provided with an index j. The index specifies which one of the N objects is used as the reference system (it is generally object no. 1).

So is:

$$p_{REF} = p_{REF\,j} \quad \text{and} \quad V_{REF} = V_j \quad \text{and} \quad C_{REF} = C_j \qquad (5a, 5b, 5c)$$

Equation (4) then is as follows:

$$P_{REFj} = V_j / C_j \qquad (6)$$

j is the number of the reference object.

If we now form the quotient of the relative space consumption $p_{rel\ i}$ of an object i under consideration and the relative space consumption of the reference system j , a meaningful value for the description of miniaturization arises. It is the

"Miniaturization degree" $m_D$ .

$m_D$ gets 2 indices, i and j.

$$m_{D\,i,\,j} = p_{rel\,i} \;/\; p_{rel\,j} \qquad (7)$$

This is then "the degree of miniaturization of the object i" referring to the object j.

$m_{Di,j}$ compares the normalized space consumption of the object i with the normalized space consumption of the reference system j. The normalization refers to the object characteristic variable C. $m_{Di,j}$ is a standardized value for the quantitative description of miniaturization.

The usual procedure is as follows: Determine which object should be the reference system. Its number gives the value of j. Then set i = 1, then i = 2, ...., i = N. Thus obtains the miniaturization degree values for the objects in the order of their numbering.