References

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On-Line Classification of Sleep Stages with a Lab Computer[1])

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A few methods for automatic sleep classification were suggested recently. Mostly, these programs need to be run on medium size or large data processing systems, because the discrimination of the sleep stages is achieved by means of time and storage consuming algorithms.

But as far as we know programs for the determination of the sleep stages W, R, 1, 2, 3, 4, and MT that can be run on lab computers do not exist. We have developed a program for the determination of sleep stages for an IBM system 1130 that is part of our lab equipment.

Figure 1 is a survey of the experimental and data processing set. The program processes data of one EEG-channel, suitably derived from the C4–A1 or C3–A2 points. The analog data are transferred to an analog-digital-converter, and then the digitized EEG-data are filtered and preprocessed.

The first step is the extraction of the local minima and maxima of the series of filtered EEG-data. A digitized EEG signal of 30 sec contains 60 000 bits of information under the conditions of our converting device[2]).

The corresponding series of minima and maxima contains about 3000 bits of information.

[1]) Supported in part by the Deutsche Forschungsgemeinschaft (DFG).
[2]) Time steps: 5 m/sec, amplitude resolution: 10 bit.

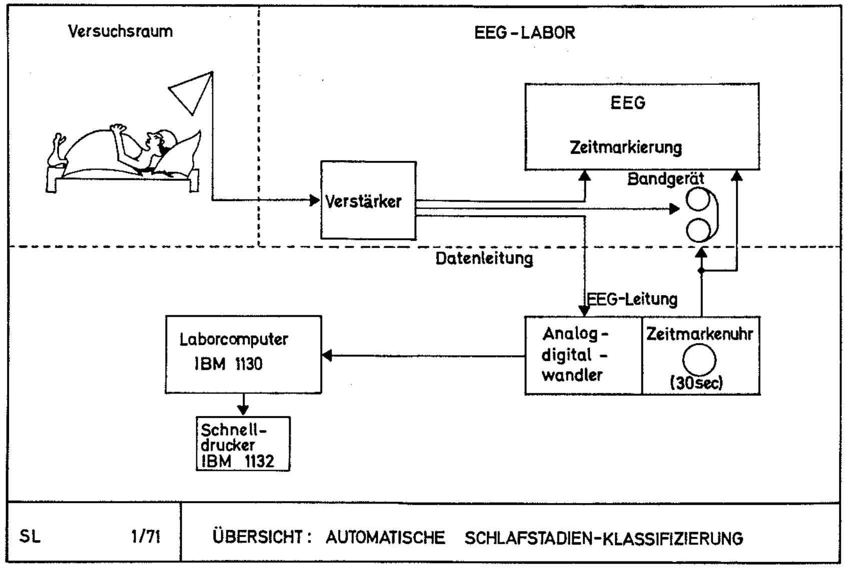

Fig. 1

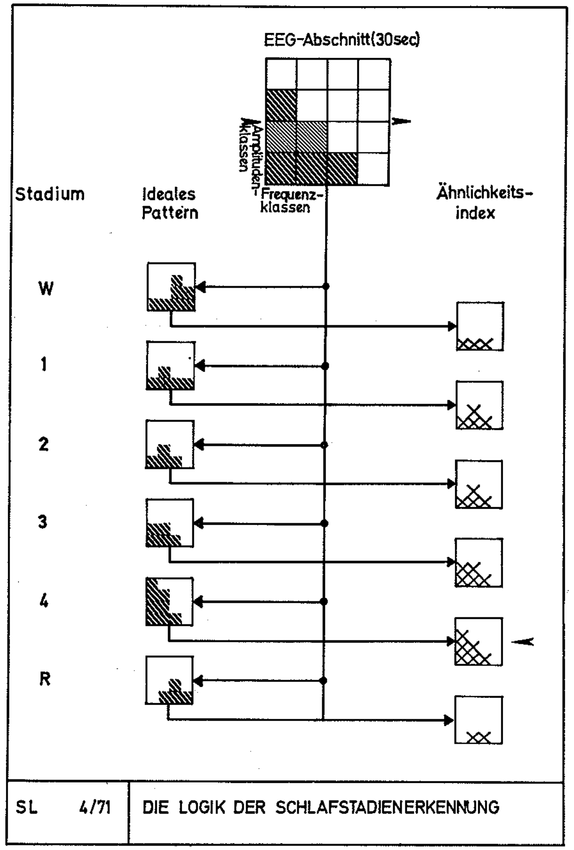

Fig. 2

The following steps of processing perform as well a reduction of information to achieve the extraction of characteristic features of the pattern. At the moment we compute the joint interval-amplitude-distribution of the local extrema in 30 sec EEG sections. The distribution is computed in terms of interval-amplitude classes that can be defined by variable parameters of the programs. For a distribution table with 6×7 classes that we use presently, the information is about 300 bits.

The following program step is an adaptive algorithm. In its learning phase parameters are determined that enable the program to detect the sleep stages in real-time in the run phase.

The learning phase is performed after a night of accustoming the proband to the lab situation. Besides the EEG-data the computer is fed with information about the visual classification of the sleep stages by sleep scientist. From these data a norm-matrix is computed for each of the sleep stages.

The information of such a norm-matrix is about 100 bits. In the run phase the determination of the sleep stages is performed by a comparison of the interval-amplitude tables with the experimental data and the norm-matrices.

A simple method is for instance the class-by-class comparison of the data- and norm-matrices and the computation of the number of hits (see figure 2). In general, this problem can be solved by the principles of table comparison.

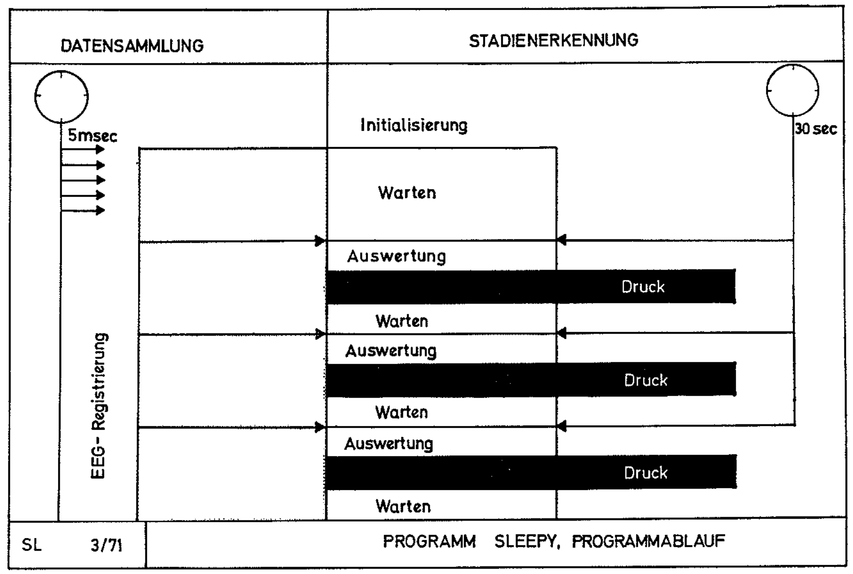

Fig. 3

The final information which is requested for discriminating the sleep stages is 3 bits.

Figure 3 shows the steps of the data collection (background program) and the sleep stage classification (foreground program). The first tests of the programs ended up with a rate of agreement between the visual and automatic classification of more than 80 %.

The program described here has the following advantages over other programs:

1. The program is a simple algorithm that can be run on-line on a little lab computer.
2. All intermediate results mentioned here are printed by the program, therefore it fits very well into experimental sets of the process control type.
3. The program is adaptive, the adaption is performed intrainidividually in the learning phase.