Report for determination the limits of the parameters/features for the scratch test

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1 Test Procedure

In a conveyor line for the assembly of fillers or fountain pens of a large German manufacturer, various tests on the quality of the test items (i.e. fountain pens) are carried out in order to sort out these test items that are perceived as bad during the production process and to send them to a human inspection.
One of these tests is the "scratch test", which is supposed to give an evaluation of the writing behaviour. For this purpose four test items (i.e. fountain pens) are tested simultaneously against a scratch. After these items are set in parallel onto a paper-covered glass plate, the glass plate is moved in a given pattern under them. The result is a pattern of S-shaped wavy lines, which is evaluated by further image processing (and which is not the subject here) and a part corresponding to movement one line to the left and to movement one (slightly offset) line to the right are selected.

These two movements are hereinafter referred to as the left or outward movement and the right or return movement. Compared to the experiment with a human, this described experiment is limited to only one dimensional movement. Nevertheless, such setup allows to achieve sufficient results. In particular, this is due to the sensitivity of the test system, which leads to the fact that four parallel (actually identically constructed) test locations (places where the test items are inserted) requires different limits of the parameters (which was not necessarily expected in advance).

2 Definition and computing of the parameters/ features

Each test item is supply with the accelerometers which records the data. The accelerometers are measured continuously at 25KHz per test - the test system emits a digital start signal at the beginning of both left and right movements.

This signal is used for cutting an identical sections of movement.

The data from the selected sections is transformed into the frequency domain by applying an FFT - for both left and right-hand movements. These frequency data - selection of them - is used for parameters/feature extraction:

a. Identification of the maximum in the selected section (suboptimal due to leakage effect)

b. Identification of the maximum "point energy" (here a band of adjustable width is shifted over the frequency data and the total energy of a peak is evaluated).

c. Identification of the frequency of the maximum of 1.

d. Integration of the whole spectrum.

The empirically determined sections are as follows

- The entire range (10Hz to 12500Hz) - the start at 10 Hz is intended to suppress different signal offsets of the sensors.
- The range from 500Hz to 1000Hz
- The range from 1000Hz to 1500Hz
- The range from 7500Hz to 8000Hz

Every of these four features/parameters are determined for left-hand and right-hand movements for each of four described sections. In addition, eight combined features/parameters from the sum and the distance of the fourth measuring method over all four sections are calculated. In total, there are 16 features for left-hand movement, 16 features for right-hand movement and 8 features for combined left-hand and right-hand movements.

A test item (i.e. pen) is considered to be unsatisfactory or bad, if at least one feature/parameter is judged as unacceptable. The entire system is configured using textdata that contains the limit values for all features. There are limit values for each particular type of an item (i.e. for every type of fountain pen B (wide/breit), M (medium), F (fine) and EF (extra fine). The header of the textdata contains the description of the limit value - but these are currently the same for all types of pens.

3 Determination of limit values

The limit values were determined in two meetings in cooperation with employees of three companies. In the first meeting, a sufficient number of test items were prepared and evaluated. This data were used to calculate the limit values, which were then set for the machine during the second meeting. Test items of all pen types were prepared and evaluated by both the machine and a human to check the degree of matching.

Meeting 1: For the determination of the limit values, 300 test items per each pen type were produced and evaluated as good or bad by two testers. If the testers matched, the result was used to form the limit values - if there was no match, it was not taken into account. The number was designed in such a way that at least 200 matching results of the testers were to be achieved, which was successful.

Note: Since the human testers are of course highly dependent on environmental conditions, fatigue, concentration, health, volume, individual perception, etc., it was possible to have individual cases tested. This was also done intensively with "illogical" human test results.
Between the two dates the limit values from the stored results and evaluations were created. This is currently a mostly manual process, which is carried out with the help of an Excel table (with script) for a better view of the results.

Meeting 2: For the verification of the limit values, 200 samples were produced per pen type and evaluated for good/bad by a tester. If the tester agrees with the machine, the result was adopted without further checking; if there was a difference, another human checked again and corrected if necessary.
For the B and M types a deviation of 2% and for the F and EF types a deviation of approx. 4% from mechanical scratch testing to trained testers was determined. It was agreed by all participants that the deviating test specimens were all in the border area between good and bad and that all significantly bad test specimens were detected by the scratch test.