Automatic Dementia Diagnosis based on a digital Clock Drawing Test

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Dementia describes an irreversible neurodegenerative syndrome of different diseases. During the progression of this incurable disease, different parts of the brain are affected causing cognitive impairment and gradually reducing the quality of life. Thus, it is very important to conduct an early diagnosis of dementia to counteract the syndrome.

The diagnosis of dementia consists of an interview with an acquittanced person assigning the outcome of the medical consultation to a scale, for example the Reisberg scale [1] and the evaluation of a Clock Drawing Test. Up to date, there are many different modifications of the Clock Drawing Test, sometimes containing subjective criteria for the evaluation, for example, in the fourth grade of the Shulman scoring “moderately poor spacing” [2]. Therefore, the evaluation of the same test by different specialists may result in different scores.
By digitizing the Clock Drawing Test all criteria are quantified, allowing a very accurate evaluation and reproducible score, meaning that the same test will always have the same score. Further on, different parameters can be acquired by the digitized test, which are nearly impossible to acquire by the traditional pen and paper based tests. These parameters, which reflect the cognitive ability of the patient, are, for example, the time interval between strokes, the time interval for drawing specific strokes, the total time for finishing the test, the size of the strokes compared to the clock size, etcetera [3].

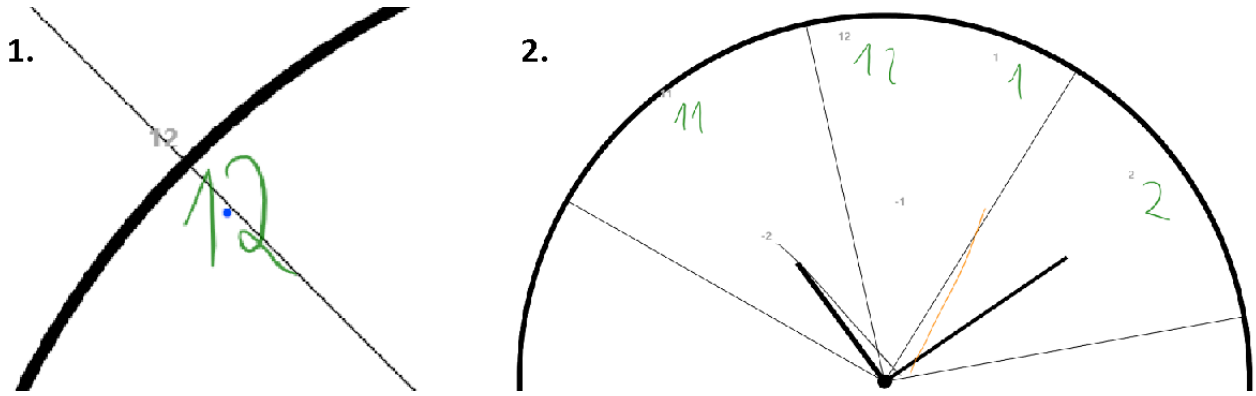

Fig. 1: Precise evaluation of quantified criteria. 1. The mass point of the digit 12 being outside of the puffer zone. 2. The inclination of the drawn minute hand being too steep.

The Clock Drawing Test "C-GADT", developed by the St. Marien-Hospital Hamm, consists of seven quantified criteria and is suitable for digitization. The first four criteria analyze the placement of the drawn anchor digits 12, 3, 6 and 9 in a 45° puffer zone to the left and right of the ideal position. The fifth criteria analyses if the patient did draw exactly the digits of 1-12. The sixth and seventh criteria analyze the placement and inclination of the drawn hands in a puffer zone of 24° to the left and right of the drawn digit 2 and/or 11. A total maximum score of 10 points can be achieved, the first four criteria giving each one point and the last three giving each two points. The digitized test was executed on a Surface Pro 4 Tablet-PC using the active pen technology for digitizing the strokes.

In this Bachelor thesis, a small trial with 12 patients was conducted. To ensure the statistical accuracy, a database of 152 Clock Drawing Tests was analyzed. 12 tests being drawn by the patients; 40 tests being created by a medical expert in the field of dementia [(2)], who also provided 100 scans of real tests, which were traced in the digitized Clock Drawing Test. The following aspects have been evaluated in this thesis: 1. The frequency of occurrence of each C-GADT point was counted and the ratio of each point was calculated to determine the complexity of each criteria for the patients; 2. If a fully automatic solution or an assistance system is more viable and 3. Frequent source of errors.

1. The digit 12 was drawn in 82.2%, the digit 3 in 66.4%, the digit 6 in 67.1% and the digit 9 in 59.2% of the cases. Therefore, the anchor digits were placed correctly in an average of 68.7% of the tests. The more complex criteria, the exact drawing of the digits were fulfilled in 33.5% of the cases and the placement of the hour hand were drawn in 34.2% of the tests. The last and most complex cognitive criteria, the placement of the minute hand, was drawn in 19.7% of the cases.

2. 35 of the 152 tests were evaluated fully automatically by the digital test and 117 of the 152 needed to be corrected at least once. Thus, an assistance system is more viable, because the evaluation of Clock Drawing Tests turns out being too variable for a full automatic solution.

3. The two most prominent sources of errors were 86 times, that a drawn stroke was not converted to the right number and/or not converted to a number at all. This happened because the used library was not optimized for detecting only numbers but also handwritten text. In 39 times, no stroke was automatically assigned to a drawn hand. By now, both problems were improved. A "Nearest Neighbor Algorithm" defines the closest stroke to the mass point of the programmatically created line. After that, the inclination and bound check is conducted. The clustering of drawn strokes occurs now more in an x-axis rather than in a radius. Thus, unwanted strokes are not combined and the detection of the numbers is improved.

In this thesis, a tool for accurate evaluation of Clock Drawing Tests is presented resulting in reproducible scores. The digitized test provides the possibility to analyze time- and size-related parameters. Creating statistical analysis of this values and video sequences of the Clock Drawing Tests may provide a powerful tool for long-time evaluation of the health development of patients suffering a dementia disease, but also for the evaluation of the quality and effectiveness of different treatments.

References

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