TOWARDS COMBINED FORCE AND DISTANCE SENSING USING ONLY OPTICAL SENSORS TO AID IN STROKE REHABILITATION

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Abstract: Strokes are the second major cause of death worldwide, with its prevalence greatly increasing with age. The raw number of non-fatal stroke incidents is even higher, as rougly three out of four patients survive [1]. Stroke survivors struggle with various complications, including oro-fascial impairment [2]. As a direct result, the majority of stroke patients suffers from dysphagia (i.e. difficulties in swallowing) [3] and dysarthria (i.e., the inability to articulate properly) [4]. These symptoms not only tend to not improve without treatment, negatively impacting the patient's quality of life, but are also a major cause for follow-up complications such as aspiration pneumonia, malnutrition and dehydration [2]. Therapy for dysphagia mainly evolves around strengthening exercises for the tongue [5] and several devices exist for measuring the intraoral tongue pressure against the hard palate (e.g., swallowsolutions or iopimedical). For treatment of dysarthria, speech-related exercises target articulatory deficits to restore proper speech production in patients [4]. However, during these exercises, the patient's tongue is not easily visible from the outside and the difficulty for the practicing speech therapist remains to judge whether the patient is performing the exercises correctly. A viable solution to this problem is the use of optical tongue sensing methods as described in [6, 7, 8] which register the tongue movement inside the oral cavity. To aid both dysphagic *and* dysarthric patients effectively, tongue position and pressure needs to be monitored with the same device. As space inside the oral cavity is very limited, it is beneficial to combine these measurements into a single sensor type. By exploiting the effect of reflection and subscattering of infrared light on and within the human tongue, optical sensors are a viable choice.

In this paper, we therefor present the systematic approach to select and analyse several different optical sensors for their suitability. Group A consisted of analog sensors, constructed from an laser-diode, a phototransistor or a photodiode and appropriate circuitry, to convert the photocurrent into a voltage. Group B included integrated circuits, already equipped with a light source, signal processing, analog-to-digital conversion and an I2C-communication interface on a single chip. For sensor evaluation, a test station (figure 1, right) was designed and constructed, featuring a rotatable and lockable cantilever with a strain gauge attached to it. The optical sensors were placed at the end of the cantilever. When a subject pressed their tongue against the sensor, both the light signal and the tongue force could be measured simultaneously to explore the relationship between the amount of subscattered light reaching the sensor versus the applied force. For distance measurements, several simple spacer (as in [8]) could be magnetically attached on top of the sensor, to provied a fixed distance between the tongue and the sensor.
Figure 1 (left) shows the dynamic range of the most promising sensor for combined force and distance measurements up to 8 N and 30 mm. The sensor had a half power angle of 25°. While the measured signal shows very little variance for fixed distances (almost not visible in figure 1, left), the variance over the 20 consecutive force measurements is quite significant. The general trend however shows an increase in sensor signal as the applied force increases.
In the near future, the selected sensor along with its optical characteristics will be utilized in a medical device that is capable of sensing both the patients tongue pressure/force and position and to help develop patient-specific exercises for dysphagia and dysarthria therapy.

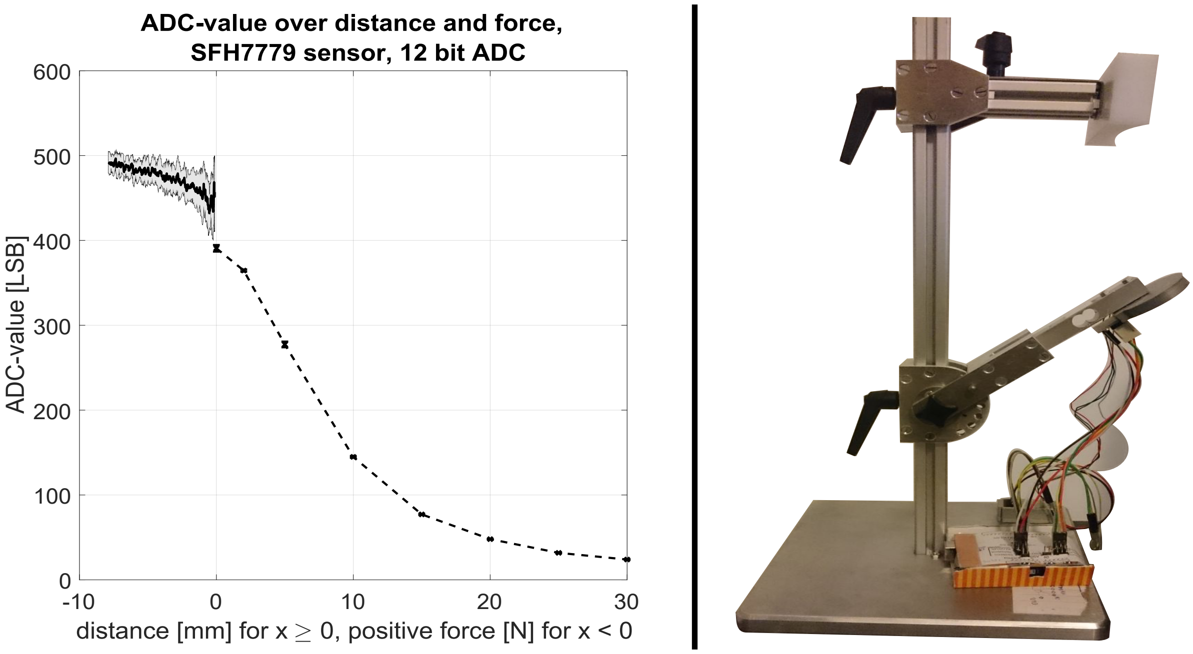

Figure 1 – Left: combined force - and distance measurements of the tongue for the selected sensor. Positive x-values are distance [mm], negative x-values are positive force [N]. Distance values are displayed as mean and standard deviation over 200 continuous samples, measured with a sampling rate of 12 Hz. Force is displayed as the moving average and standard deviation (with n = 10) over 20 repetitions of increasing the tongue force onto the sensor from 0.1 N to 8 N. Right: Test station for sensor evaluation.

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