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FEASIBILITY OF SMART-TEXTILES FOR VEHICLE-EXTERIOR: IMPACT OF DISTURBANCES

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ABSTRACT

There are many challenges when using Smart-Textile controls with conductive yarn in daily activities involving vehicle exteriors. To test its general feasibility, disruptive factors like keys, rings, or skin care products as well as sensor knitting densities and -sizes need to be accounted for, in its day-to-day use. To investigate the influences of those disruptive factors and variables, multiple test series are concluded within a constructed test environment. The tests provide pre-defined distances between a finger and a Smart-Textile button, to research differences in the reactivity of the sensor. The results show that the use of the Smart-Textile with disruptive factors and changing variables can be challenging to implement due to interferences with the expected signals but can be accounted for when installed properly. Furthermore, the results provide a more advanced understanding of common influences with regards to the individual factors intensities and the following actual returned signals. Through those results, suitable configurations, and limitations for Smart-Textile sensors in vehicle exteriors can be derived.

KEYWORDS

Smart-Textile, Capacitive Sensor, Vehicle Exteriors, Disturbing Factors, Variables, Feasibility.

INTRODUCTION

One of the greatest and long-lasting challenges in the E-Mobility sector is the distance a vehicle can reach [1]. To minimize this hurdle, studies are conducted to use light weighted materials such as the use of textiles in the vehicle cabin, especially for electric light weighted vehicles, to decrease the overall weight and therefore increasing the reach of those vehicles [2]. Textiles are not only versatile in its material compositions, but also in its functions when combined with electrical components [3]. The results are defined as Smart-Textiles. The area of applications for Smart-Textiles are extensive and offer many options of implementation for the use in vehicle exteriors, including the Smart-Textile button for example, which might be used to open or close vehicle doors [2,4]. The main goal of this work is to investigate the feasibility of Smart-Textiles for vehicle exterior by identifying possible disruptive factors or daily usage. The tests are performed in this work to show possible deviating signals. One possibility to construct a textile sensor is by knitting a circular area from electric conductive yarn and use it as a capacitive sensor. The sensor operates with the change of the electrical field. When calibrated correctly, conductive materials such as human skin, a finger for example, can trigger electric signals by approaching and/or touching the yarn. When sensing the finger, the sensor will send an electrical signal to a processing unit, which can convert it and activate pre-defined actions. Disruptive factors, in this study, are defined as those which might be carried when interacting with the sensor. Especially, those which might interfere with this desired signal and therefore change the behavior of the system are of great interest. Those disruptive factors will be tested by wearing or holding them while using the sensor. The test will examine if deviations in the reaction of the sensor occur, due to their conductive properties.

Those factors include watches, rings, or smartphones. Other disturbances, which cover the expected sensed object e.g., body lotion or glove covered finger, might trigger differences in the measurement as well and therefore will also be tested. Other challenges of this specific operating principle need to be accounted for, which include the area covered by yarn and its knitting density.

TECHNICAL REALIZATION AND METHODICAL APPROACH

In order to investigate the influences, a test environment was set up in which controlled finger spacings were used to test the effects of different disruptors and variables. The focus is on day-to-day user and their possible carried items, when operating the sensor in their vehicle exterior. Those include items which can disturb the sensors readings. Bodylotion, Gloves, Phones, Rings and Smartwatches, which are commonly carried items are tested to understand and optimize capacitive Smart-Textile sensors for the light weighted vehicle industry. The tested variables consist of different sensor sizes and knitting densities. Figure 1 shows the systems setup of the test series. The test is performed, as shown in Figure 1, by placing a piece of conductive textile into a 3D printed holding device (top). This guarantees repetitive test criteria in dependence of the tested distances and the centering of the textile.

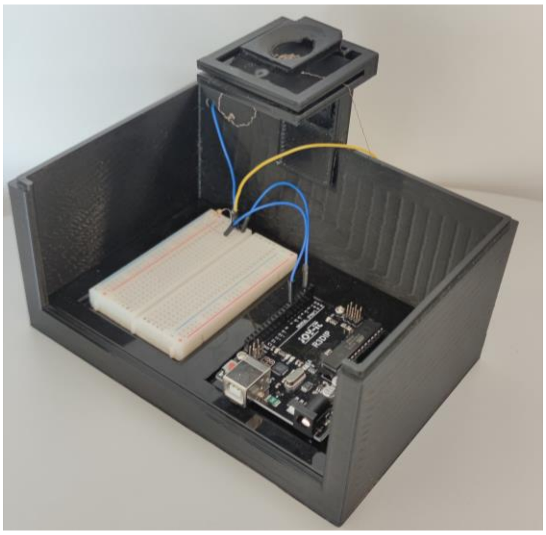

Figure 1. Testing Environment.

Above, the testing environment includes an additional finger rest with an oval cutout, which provides repetitive centering of the middle finger and placing the fingertip in the same position for each run. The 3D printed holding portion and finger rest can be adjusted in height, for optimization of the return signal, if necessary. After inserting the sensor, a maximal distance of 11.5 mm is chosen for the fingertip, since the reaction of the sensor is at its most stable in this position. To standardize the approach of the finger to the holding device, all finger are spread to its full extend, unless gripping an item is necessary. All tests are performed at a steady temperature of 21 °C +/- 2 °C. An Arduino Uno Rev3 is connected to a 1 MΩ resistor and to the conductive yarn, which is knitted on another textile in a circular pattern, thus a touch surface is created and an approach- and touch-sensitive area is provided, the so-called Smart-Textile button. The tested sensor has a stitch distance of 2,5 mm, consists of 364 stitches and a has an overall diameter of 30 mm. The Arduino is running on a combination of the Capacitive Sensing Library, and a self-written control portion. In every test run, the middle finger is placed onto the finger rest until a stable return signal is detected. When the sensor is triggered, the processing unit returns a value in arbitrary units. The program consist of a send pin and a receive pin. It toggles the send pin into a new state and measures the time to the receive pins state change and returns the variables value in an arbitrary unit [5]. To achieve repetitive results, the distance between the sensor and the finger remain constant, while the disturbance factors are tested. Since the sensor recieves small permanent flactuating errors, due to environmental influences, 20 return values are averaged, for better visualization of the return values. To increase the consistancy of the returned values and deviating effects due to changes in the finger placement, tests are repeated 30 times, each. The steady state value, before approaching the sensor, showed a reading of 4 with a tolerance of +/- 2. The changed values are collected and compared to a reference, to gain an understanding of the range of feasibility to use Smart-Textiles in the vehicle exterior. To generate the reference value, the sensor readings are collected by placing a finger on the finger rest without any disturbance factors. After all data from each disturbance factor is tested, another test is performed with a sensor diameter of 15 mm, a stich distance of 1,5 mm and a total of 157 stitches. Those values are compared to the reference sensor. All readings are visualized in Figure 2 in a Boxplot Diagram. The Boxplot Diagram presents distributions of the readings in three quartiles. Quartile 1 represents the 25th percentile, quartile 2 represents the median and quartile 3 shows the 75th precentile. It presents the distribution of the readings, while visualizing the entire data pool. If values differ too much of the median readings, they are labled as outliers and get trimmed to enhance accuracy [6]. Afterwards the results compared to the bigger sensor are discussed to lay the groundwork of the optimization for sensor designs in the vehicle exterior and to open new possibilities to further studies.

RESULTS AND DISCUSSION

The results of the test series show that influences can occur due to disturbing items. To evaluate the results, the median of the bare hand test is used as a reference for desired sensor readings. Following, this median as well as the average is approximately 60 and is therefore used as the reference, while the other values are compared as percentages to this reference. In Figure 2 this reference is highlited with a black line. Figure also 2 shows the median percentage in comparison to the return values reference on the Y-Axis, while the different tests are distributed on the X-Axis.

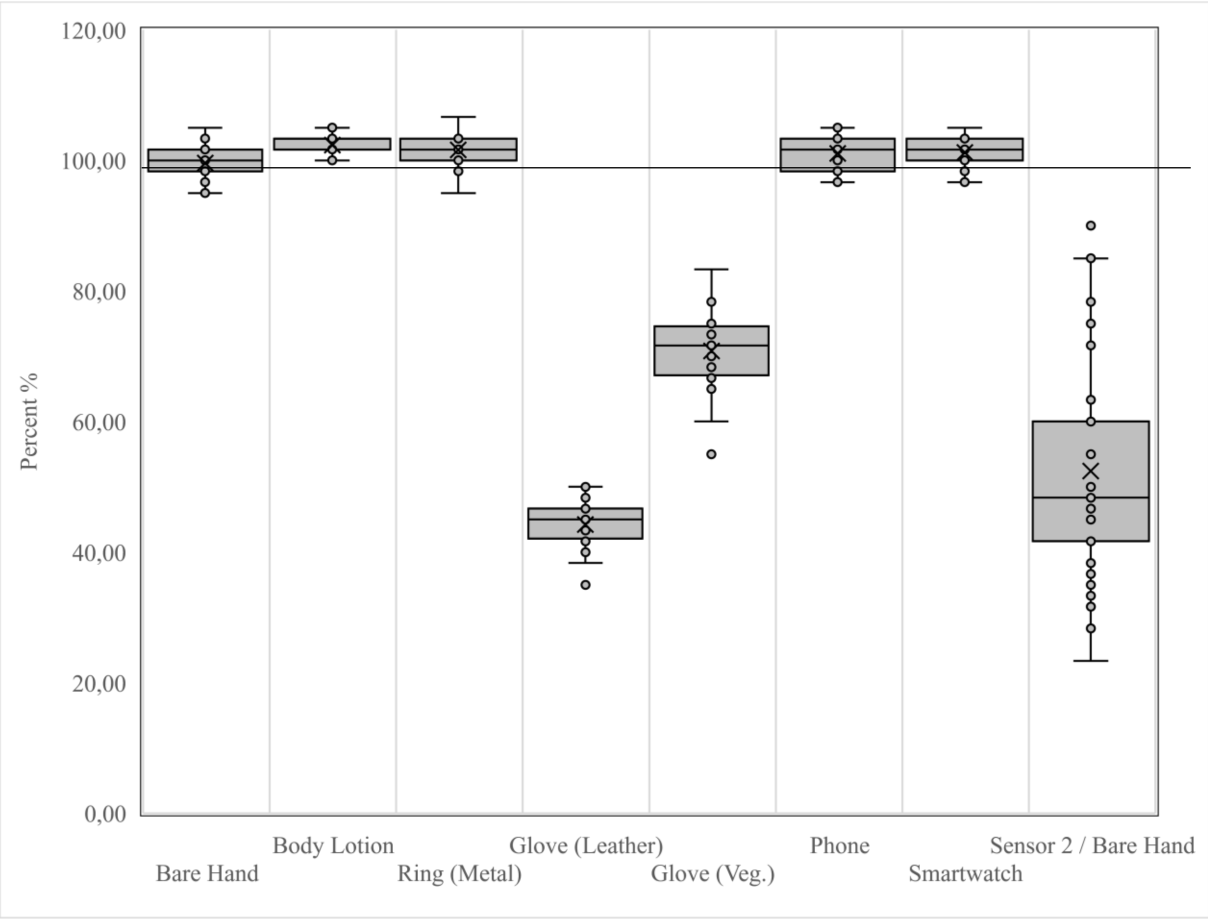

Figure 43. Differences in Sensor Reactions between Reference and Disturbing Factors.

The bodylotion (103,33 %), ring (101,67 %), phone (101,67 %) and smartwatch (101,67 %) show a max. deviation of 3,33 %. Due to the high sensitivity of the sensor, this can be caused by small deviations in the finger placement and are therefore neglected in this study. The gloves show a drastical deviation, with a median reactivity of 45,00 % for leather and an average of 71,67 % for the vegetarian glove. The sensor reacts the least, when gloves are used. The gloves separate the finger from the sensor by the thickness of its material. With the leather gloves being thicker than the vegetarian gloves, the reduction in reactivity is followed. To test a difference between sensors of different sizes and knitting densities, another sensor is tested in the same test environment. The readings of the second tested sensor consist of a great range in values, with a median of 47.50 %, a lower quartile of 23.33 % and an upper quartile of 85.00 % compared to the reference. Therefore, the interquartile range (IQR) is equal to 61,67 %, which is comparetively large in comparison to the reference IQR of 10 % and is therefore, in this study, defined as unstable. While the sensors are able to detect changes of the fingers covered by gloves, the thickness of the gloves and the following problematic placement in the oval finger rest result in a relatively great increase of distance, and therefore lessens the reactivity of the sensor. Eventhough the gloves show great differences in reactivity, the sensor is still able to detect those and additionally can differentiate between naked finger and finger covered in gloves.

CONCLUSION

This study exaimes the basic feasibility of Smart-Textile sensors by providing sensor readings of a capacitive sensor test with different disturbing factors. Many day-to-day items are tested, to find changes in sensor reactivities. Eight different tests are conducted, with seven focusing on disturbing factors and one on a different size and knitting density. The results show that many disturbing factors do not influence the sensor in a way to cause problematic interactions with Smart-Textile sensors. Gloves prevent the sensor for optimal readings, due to an increased distance, but are still sensed. Since the other disturbing factors have little to no effect on the sensor reading, the functionality of the sensor in the day-to-day use is not compromized. This study shows, that direct accessible Smart-Textile sensors are feasible for the use in vehicle exteriors. Future studies could provide a flat non-conductive material to create a specific distance between sensor and finger, while providing a more consistant finger placement. Further studies consist of the specific changes in sensor readings, due to size and knitting densities, which have proven effects on the sensor readings by testing the second sensor. The optimization of the sensor sensitivity ranges, where the sensor will accept the values as a human interaction to activate a door-opening sequence, are also of great interest for future studies. To further study the usability of Smart-Textiles in vehicle exteriors, the difference in sizes, knitting density as well as the textile the sensor is stitched on should be reviewed to gain further information, how those variables may influence sensor readings.

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Presenter Biography

Fabian Edel started 2015 working at the Institute of Human Factors and Technology Management IAT of Stuttgart University. Since January 2017 Fabian Edel works at the Fraunhofer Institute of Industrial Engineering (IAO) as a researcher. Mr. Edel's main competences are micro-mobility and the fuzzy front end of the innovation process.

Nico Lübbe studies Mechanical Engineering M. Sc. at the University of Stuttgart and works as a student research assistant at the Fraunhofer Institute for Industrial Engineering (IAO) since November 2020. Today, he excels in the development of Smart-Textile Sensors with the focus on capacitive Smart-Textile sensors.