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Technical Note

Calibration and Zeta Functions for the Wacom DTU1141b

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ABSTRACT

To accurately examine and compare Digitally Captured Signature data, the provided data channels (X, Y, F and T) need to be expressed in comparable units. The Force channel data is routinely expressed in unnormalized Pressure Levels hindering the accurate comparison between data collected from different devices. The normalization method using the Zeta Function is used to calibrate and calculate the Zeta Functions of the Wacom DTU1141b.

1. Introduction

The capturing of the handwriting movement during the execution of a signature formation and the subsequent capturing of the motion by a Digitally Captured Signature (DCS) solution is not uniform in all available solutions, but varies depending on both the software and the hardware used [1]. The motion is mainly digitized in four channels of data, X and Y for the spatial coordinates, T for time and F for force.

It has been shown [2] that the F channel values in Electromagnetic Resonance technology (EMR) solutions are actually arbitrary Pressure Level values (usually ranging from 0 to 1023), with no direct or clear correspondence to Force expressed in Newtons. It has also been shown [2] that different DCS solutions may assign the same Pressure Level value to different exercised force. It is clear that in order to perform a valid forensic examination of authenticity of DCS data captured from different solutions, a normalization step of the Force channel data needs to take place, so that the arbitrary Pressure Level values are converted in Newtons.

In this technical report we present the calibration and corresponding Zeta Functions of a Wacom DTU1141b digitizer, allowing forensic experts to normalize the Pressure Level values into Newtons and therefore proceed with comparison of these values between DCS captured with different solutions.

2. Materials and method

2.1. Calibration

The method of calculating the exercised force based on the assigned Pressure Levels has already been developed [2]; a mount is positioned over the digitizer, which is positioned over a laboratory scale. The stylus is fixed on the mount. Weight is added to the mount and the values of the weight are recorded and correlated to the Pressure Levels assigned by the DCS solution. The resulting dataset is then fitted with a 6th degree polynomial. It is known [2,3] that EMR solutions exhibit hysteresis effect and therefore two different measurements are necessary; one for ascending load (weight is increasing) and one for descending load (weight is decreasing).

For the purposes of this calibration, a new Wacom DTU1141b was used, paired with its default stylus (Wacom UP7724 stylus). Wacom Wintab data collector application (2022 edition) was used for the the collection of data points. It is noted that the Wintab data collector application provides raw Pressure Level values in the form of values from 0 to 32767, even though not all values are registered (as the actual sensitivity of Force Channel for this solution is 1024 levels).

The results are shown on Table 1, and the calibration curve on Fig. 1.

During testing it was also observed that there is interoperability between the Wacom DTU1141b digitizer and a range of Wacom styli – or

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Table 1
Calibration measurements for Wacom DTU1141b.

Software used for measurements	Wintab data collector 2022 Wacom Company Limited		
# Pressure Levels	1024 (expressed in 32bits – 32,768 levels)		
Minimum Force Threshold (Newtons)	0.25	Maximum Force Threshold (Newtons)	3.6
Ascending Load Zeta Function			
$Z_{ascending}(x) = -11171.8 + 53854.8x - 39361.5x^2 + 20839.6x^3 - 7233.7x^4 + 1402.5x^5 - 112.6x^6$			
Ascending Load Inverse Zeta Function			
$Z^{-1}_{ascending}(x) = 2.4*10^{-1} + 3.003*10^{-5}x + 1.78*10^{-9}x^2 - 4.021*10^{-13}x^3 + 3.775*10^{-17}x^4 - 1.4*10^{-21}x^5 + 1.929*10^{-26}x^6$			
Descending Load Zeta Function			
$Z_{descending}(x) = -18194.85 + 90717x - 86913.56x^2 + 50382.41x^3 - 17114.54x^4 + 3121.29x^5 - 235.66x^6$			
Descending Load Inverse Zeta Function			
$Z^{-1}_{descending}(x) = 4.584*10^{-1} - 2.02*10^{-4}x + 6.317*10^{-8}x^2 - 7.477*10^{-12}x^3 + 4.277*10^{-16}x^4 - 1.163*10^{-20}x^5 + 1.22*10^{-25}x^6$			

3rd party EMR styli that include a Wacom pressure sensor. The range of compatible styli is included in Table 2.

2.2. Normalization

The normalization of pressure level values acquired from the Wacom DTU1141b to Force in Newtons can take place by applying the inverse Zeta Functions provided in Table 1. As there are two inverse Zeta Functions provided (one for ascending and one for descending load), a criterium has to be implemented in order to choose the correct one; the criterion is the change in Pressure Level values which can be expressed by the operator ΔPL. If $\Delta PL > 0$ then the load is ascending, if $\Delta PL < 0$ then the load is descending, and if $\Delta PL = 0$ then the previous state (ascending or descending) should be kept.

Table 2
Compatible stylu for the Wacom DTU1141b.

Manufacturer	Model	Compatible with DTU1141b
Kaweco	KAWECO AL SPORT connect EMR	Yes
Lamy	LAMY AL-star black EMR pen Digital Writing	Yes
Lamy	LAMY safari twin pen all black EMR Digital Writing	Yes
Samsung	Samsung Galaxy Tab S6 Lite S Pen EJ-PP610BJEGU	Yes
Wacom	Wacom UP61089A1 pen	Yes
Wacom	Wacom UP6710 pen	Yes
Wacom	Wacom UP7724 pen (default DTU1141b Stylus)	Yes

3. Results

The calibration of the Wacom DTU1141b digitizer through the Zeta Function method provided the Zeta Functions for both ascending and descending loads. This expresses the relationship between exercised force and assigned pressure levels as well as the inverse Zeta Functions for both loads; allowing the calculation of the exercised force from the assigned Pressure Levels. The process of normalizing the values is clearly defined, and an example of how to apply the method in Python is provided, using Namirial FirmaCertaForensic's ISO standard CSV files [4] as the source of the raw data:

```
def Z_inv_A(xi):
a_0 = 0.24.
a_1 = 3.003e-5.
a_2 = 1.78e-9.
```

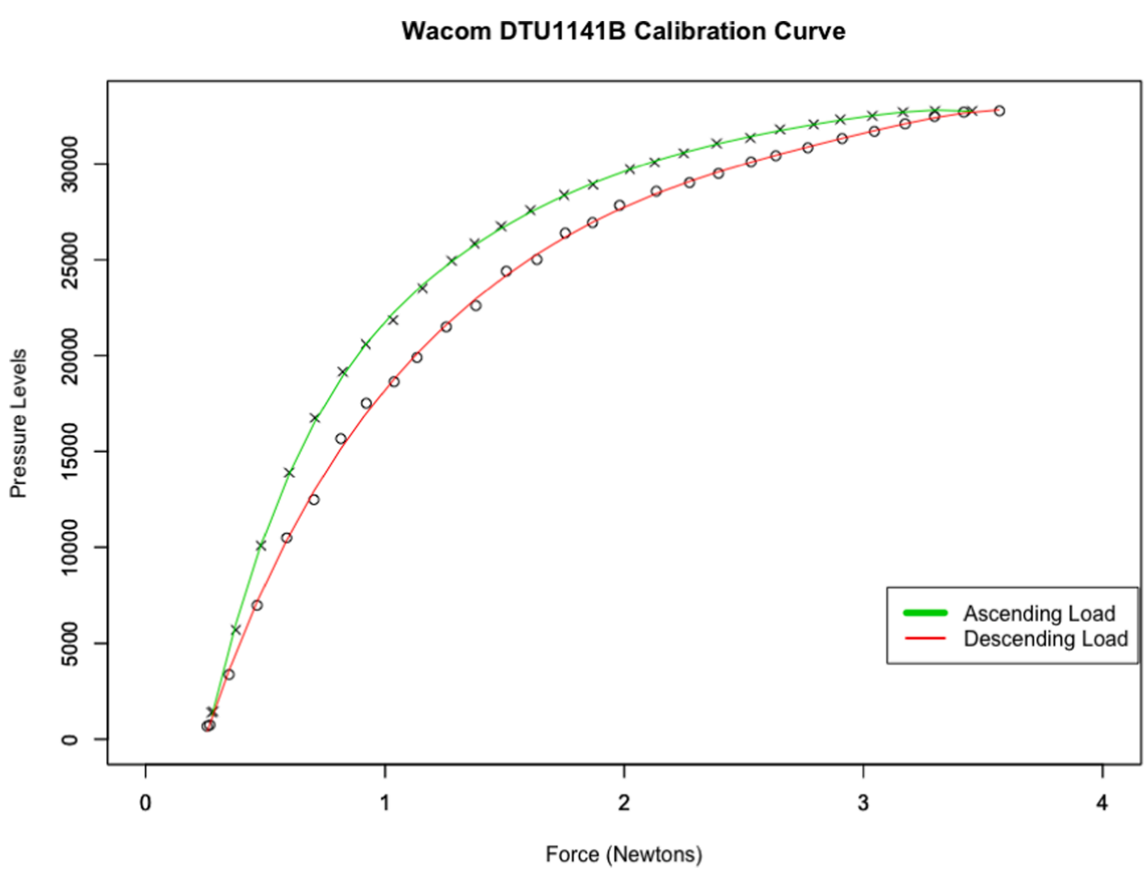

Fig. 1. Graph of the calibration curve for the Wacom DTU1141b.

```
a_3 = -4.021e-13.
a_4 = 3.775e-17.
a_5 = -1.4e-21.
a_6 = 1.929e-26.
return a_0 + a_1*xi + a_2*pow(xi,2.0) + a_3*pow(xi,3.0) + a_4*pow(xi,4.0) + a_5*pow(xi,5.0) + a_6*pow(xi,6.0).
def Z_inv_D(xi):
a_0 = 4.584e-1.
a_1 = -2.02e-4.
a_2 = 6.317e-8.
a_3 = -7.477e-12.
a_4 = 4.277e-16.
a_5 = -1.163e-20.
a_6 = 1.22e-25.
return a_0 + a_1*xi + a_2*pow(xi,2.0) + a_3*pow(xi,3.0) + a_4*pow(xi,4.0) + a_5*pow(xi,5.0) + a_6*pow(xi,6.0).
inputDataFile = 'AS'.
dataFile = open('RawData.csv').
dataReader = csv.reader(dataFile, delimiter =';').
dataCSV = list(dataReader) # this makes a list of the file to be manipulated.
print(len(dataCSV)).
# itter = 0.
# while itter < 50:
# display(dataCSV[itter]).
# itter = itter + 1.
cwd = os.getcwd() # This reads the current working folder which is the same as the notebook's.
display(cwd).
display(dataCSV[0 + 1]) # This line indicates the number of signatures.
sig_N = int(dataCSV[0 + 1][1]).
print(sig_N).
loop0 = 2.
stepL = 1.
while stepL < sig_N + 1:
#display(dataCSV[loop0 + 1]) # First line of the signature.
#display(dataCSV[loop0 + 22]) # This line indicates the number of data points in the signature.
N_max = int(dataCSV[loop0 + 22][1]).
loopEnd = loop0 + 23 + N_max.
collumNames = dataCSV[loop0 + 23] # 26th line of the file has the names of the columns.
#display(collumNames).
#display(dataCSV[loop0 + 24]) # 27th line is the first row of the table.

##########################################################################
# Here we read the different columns from the Namirial ISO standard csv file.
# the color column is just −Pressure.
# we also calculate the gradient, the 2D velocity and the Force (normilised output).
x_1 = [].
y_1 = [].
p_1 = [].
color_1 = [].
t_1 = [].
v_x = [].
v_y = [].
dP = [].
Force = [].
itter = loop0 + 24.
n = 1.
while n < N_max + 1:
x_1.append(float(dataCSV[itter][1])) # The input is in the frm of a string.
y_1.append(float(dataCSV[itter][2])) # so it needs to be converted to float.
p_1.append(float(dataCSV[itter][4])).
t_1.append(float(dataCSV[itter][3])).
color_1.append(−float(dataCSV[itter][4])).
itter = itter + 1.
n = n + 1.
step = 0.
v_x.append((x_1[step + 1]-x_1[step])/(t_1[step + 1]-t_1[step])).
v_y.append((y_1[step + 1]-y_1[step])/(t_1[step + 1]-t_1[step])).
dP.append((p_1[step + 1]-p_1[step])/(t_1[step + 1]-t_1[step])).
step = 1.
while step < len(t_1)-1:
v_x.append((x_1[step + 1]-x_1[step-1])/(t_1[step + 1]-t_1[step-1])).
v_y.append((y_1[step + 1]-y_1[step-1])/(t_1[step + 1]-t_1[step-1])).
dP.append((p_1[step + 1]-p_1[step-1])/(t_1[step + 1]-t_1[step-1])).
step = step + 1.
step = len(t_1)-1.
v_x.append((x_1[step]-x_1[step-1])/(t_1[step]-t_1[step-1])).
v_y.append((y_1[step]-y_1[step-1])/(t_1[step]-t_1[step-1])).
dP.append((p_1[step]-p_1[step-1])/(t_1[step]-t_1[step-1])).
step = 0.
while step < len(t_1):
if p_1[step] < 256:
f_1 = 0.0.
elif dP[step] > 0:
f_1 = Z_inv_A(p_1[step]).
elif dP[step]==0:
f_1 = f_1.
else:
f_1 = Z_inv_D(p_1[step]).
Force.append(f_1).
step = step + 1.

##########################################################################
# # # From the imported list we create a DataFrame object to use in the plots.
# # # each column is identified by the name given in "frame".
frame = {'t': t_1, 'x': x_1, 'y': y_1, 'P': p_1, 'color':color_1, 'v_x': v_x, 'v_y': v_y, 'grad_P': dP\, 'F_Newt': Force}.
data_frame = pd.DataFrame(data = frame, index = None, columns = None, dtype = None, copy = False).
data_frame.reset_index(drop = True, inplace = True).
#display(data_frame).
data_frame.to_csv(inputDataFile + str(stepL) + '_output.csv') # saving an output file.
```

This code is provided as a Supplementary File. An additional excel Spreadsheet is provided as a Supplementary File that provides the calculation of the Force values in Newtons if the initial Pressure Level values provided by the Wacom DTU1141b are inserted into it.

The application of this method and the calibration of the Wacom DTU1141b digitizer allows the calculation of the exercised force in Newtons and therefore makes the captured data fully compatible and comparable with such data captured from other (calibrated and normalized) DCS solutions. With these digital tools, forensic experts will be in a position to perform the normalization calculation relatively easy.

Further work is currently being carried out, calibrating more digitizers encountered in casework, in order to provide more normalized solutions for casework.

4. Author statement

Revision suggestions were taken into account and implemented, apart from 2 of the Editor's comments which are addressed.

5. Ethics statement

This paper is part of a PhD project from University of Staffordshire that has received Ethics Approval (SU_21_173).

Furthermore for this work no human or animal subjects were used.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scijus.2024.11.002.

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