A Novel Active Stylus with the Rolling Function

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Abstract
In this work, we propose a novel active stylus with the rolling function. Through the new design of the active stylus TX electrodes and the development of algorithms, the active stylus and the touch panel can provide stylus rolling behavior without needing additional active components in the stylus. We also made a prototype of an active stylus with rolling function and tested it on a touch panel.

Author Keywords
Active Stylus, Capacitive Active Stylus, Rolling Function Stylus,

1. Introduction
Capacitive touch sensors are currently the most common user interface on mobile devices. However, in certain scenarios like signing, drawing, and education, people still prefer using a stylus as an input method. Users want the writing experience with an active stylus on mobile devices to feel more like a real pen and wish to use the stylus for controlling the device. Therefore, besides the tip's position and tilt angle functions, developers are continually working to add new features to the active stylus, such as rolling detection.

As shown in Figure 1(a) & Figure 2(a), a traditional capacitive active stylus uses TX1 (tip electrode) and TX2 (ring electrode) to send signals to the panel. The sensors on touch panel detect TX1's position to determine the writing path and use TX1 and TX2's projected positions to assess the tilt angle. However, as illustrated in Figure 1(b), the panel is unable to detect the pen's rolling motion (rotation along its axis) by relying solely on the relative positions of TX1 and TX2. During rolling, TX1 and TX2's relative positions remain unchanged, making it impossible to identify the rolling direction or rolling angle.

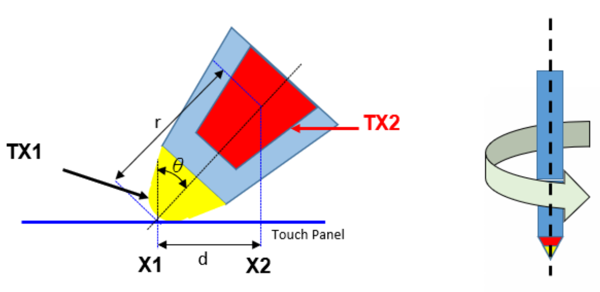

Figure 1(a). **Figure 1(b).**

Fingre 1. Triditional capacitive active stylus

2. Active Stylus with Rolling Electrodes
To give the active stylus a rolling function, we designed a new active stylus electrode that allows the panel to detect the stylus's relative electrode positions to determine its rotation angles and rotation direction. This design does not require additional active components, such as a gyroscope. It only involves making design changes to the existing electrode setup, which reduces hardware costs.

As shown in Figure 2(b), our new active stylus includes one tip electrode TX1 and two semi-ring electrodes TX2 and TX3. TX1 serves as the tip, while TX2 and TX3 serve as both ring and rolling electrodes. This new stylus with a rolling function is referred to as a "rolling stylus". The touch panel can determine the writing path by detecting TX1's position. For tilt angle calculating, TX2 and TX3 will be driven at the same time to co-work as a ring, then touch panel can calculate the tilt angle from TX1 as a tip and TX2+TX3 as a ring. Finally, TX2 and TX3 will be driven individually then the touch panel can detect whether the stylus is rotating and its rotation angles by observing the relative position changes from TX2 and TX3.

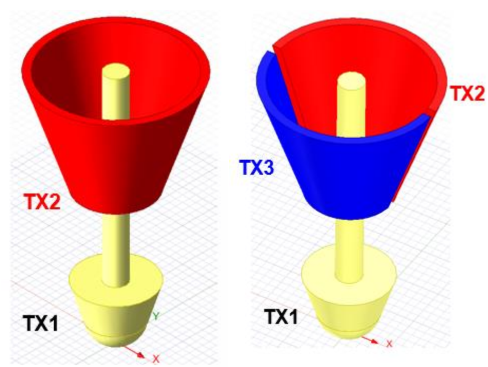

Figure 2(a). **Figure 2(b).**

Figure 2(a). Traditional active stylus with TX1 (Tip Electrode) and TX2 (Ring Electrode)
Figure 2(b). New active stylus with TX1 (Tip Electrode), TX2 and TX3 (both Ring and Rolling Electrode)

By driving TX2 and TX3 electrodes in a time-sharing method as both ring electrodes and rolling electrodes, the number of electrodes within the rolling stylus can be reduced, which simplifies the design and manufacturing complexity of the stylus. Figure 3(a) to 3(d) shows examples that how the rolling electrodes TX2 and TX3 work. We position the rolling stylus vertically on the surface of the touch panel at position (X3,Y3). The touch panel detects signals emitted by TX2 and TX3, allowing it to determine the relative coordinates of TX2 and TX3. Starting from Figure 3(a), TX2's initial position is at (X2,Y3) and TX3's initial position is at (X4,Y3). After the Rolling stylus rotates 90 degrees counterclockwise, the relative positions of TX2 and TX3 are as shown in Figure 3(b). TX2 moves from (X2,Y3) to (X3,Y2), and TX3 moves from (X4,Y3) to (X3,Y4). As the Rolling stylus continues to rotate 90 degrees counterclockwise, the relative

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positions of TX2 and TX3 change from those in Figure 3(b) to those in Figures 3(c) and 3(d), and finally return to Figure 3(a), completing a full 360-degree rotation. Based on the examples in Figure 3, we can continuously observe and record the phase position changes of TX2 and TX3 through the touch panel, thereby determining the direction and number of rotations of the active pen.

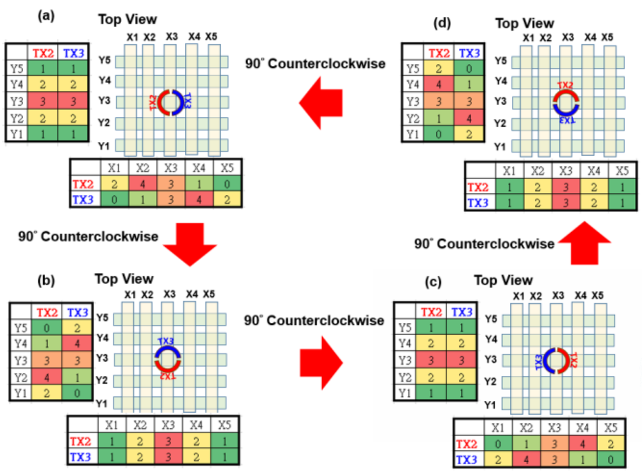


Figure 3(a)(b)(c)(d) . Signal distribution change with TX2 and TX3 rolling vertically

Figure 4(a) to 4(d) shows other examples of the rolling-function stylus horizontally on the surface of the touch panel at position (X3,Y3). Starting from Figure 4(a), TX2's initial position is at (X2,Y3) and TX3's initial position is at (X4,Y3). After the Rolling stylus rotates 90 degrees counterclockwise, the relative positions of TX2 and TX3 are as shown in Figure 3(b). Though TX2 and TX3 are at the same position (X3,Y3), because TX2 is closer to the touch panel and TX3 is farther away, the touch panel detects a higher signal from TX2 than from TX3. Through this phenomenon, we can distinguish the relative vertical position between TX2 and TX3 in Figure 4(b) and Figure 4(d). As the Rolling stylus continues to rotate 90 degrees counterclockwise, the relative positions of TX2 and TX3 change from those in Figure 4(b) to those in Figures 4(c) and 4(d), and finally return to Figure 4(a), completing a full 360-degree rotation. Based on the examples in Figure 4, we can continuously observe and record the phase position changes of TX2 and TX3 through the touch panel, thereby determining the direction and number of rotations of the active pen.

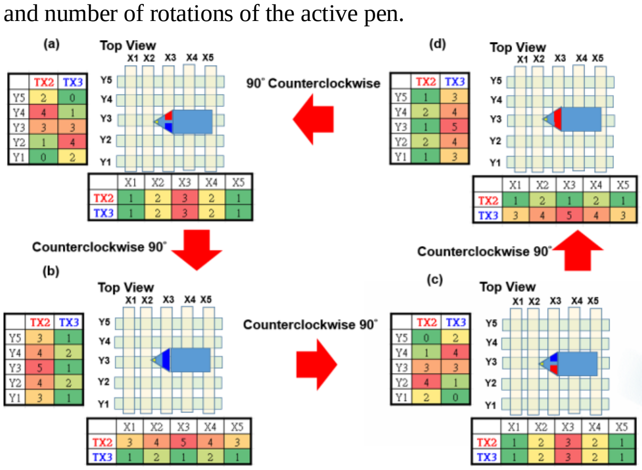


Figure 4(a)(b)(c)(d). Signal distribution change with TX2 and TX3 rolling horizontally

3. Verification with Prototype of Rolling Stylus

Thanks to the help of an active stylus manufacturer, we created a prototype of a rolling stylus, as shown in Figure 5(a) and (b). This prototype features three electrodes—TX1, TX2, and TX3—and can be programmed with software to control output signals and timing.

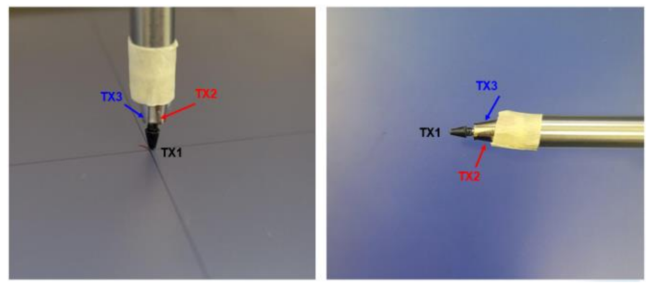


Figure 5(a). **Figure 5(b).**

Figure 5. Prototype of rolling stylus with rolling electrodes

(a) Rolling stylus is vertical on the surface of the touch panel
(b) Rolling stylus is horizontal on the surface of the touch panel

Figure 6. shows the time sequence setting of TX1, TX2 and TX3. TX1 works in frequency 1 while both TX2 and TX3 work in frequency 2. By working at different frequencies, the touch panel can distinguish TX1 from TX2 and TX3. While TX2 and TX3 work in the same frequency, we use a time-sharing method to accomplish tilt and rolling detection functions.

In T1 phase, TX2 and TX3 are driven together as a ring for tilt detection. In the T2 phase, TX2 is driven independently, while in the T3 phase, TX3 operates independently. These T2 and T3 phases are utilized for detecting rolling motion.

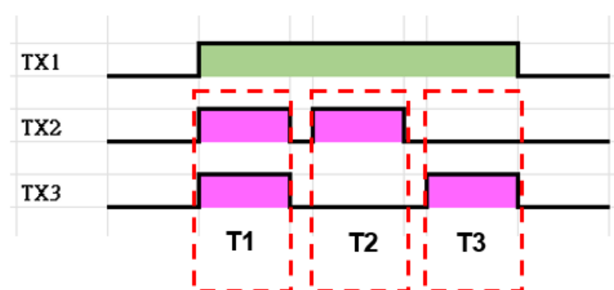


Figure 6. Time sequence of TX1, TX2 and TX3 in a rolling stylus

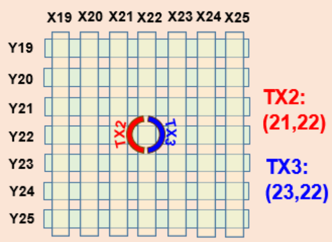
By adjusting the protocol for the touch panel and rolling stylus, and configuring the time sequence for TX1, TX2, and TX3, we performed verification on a tablet equipped with the Novatek TDDI (Touch Display Driver IC) NT36532. This was done to ensure that the rolling stylus operates as intended.

Figure 7(a) to 7(d) show the test data reported by the touch panel. We place the rolling stylus vertically on the surface of the touch panel at position (X22,Y22), as shown in Figure 5(a). Then we start with TX2 at position (X21,Y22) and TX3 at position (X23,Y22) as shown in Figure 7(a).

Each time we rotate the rolling stylus 90 degrees counterclockwise, and we record the test data. This process continues until it has turned 360 degrees and returned to the starting point. The results are shown in Figure 7(a) to 7(d). By comparing Figure 7(a) to 7(d), we can clearly observe that the signal peaks of TX2 and TX3 shift positions as the rotation angle changes. This trend is consistent with what is shown in Figure 3(a) to 3(d).

(a)

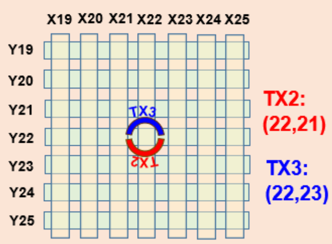
	TX2	TX3
Y19	117	109
Y20	229	232
Y21	431	444
Y22	455	465
Y23	432	458
Y24	257	244
Y25	108	72



	X19	X20	X21	X22	X23	X24	X25
TX2	188	297	631	455	100	56	33
TX3	21	47	129	389	695	345	138

(b)

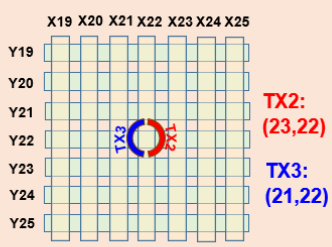
	TX2	TX3
Y19	283	44
Y20	433	96
Y21	663	191
Y22	372	517
Y23	182	688
Y24	113	341
Y25	30	172



	X19	X20	X21	X22	X23	X24	X25
TX2	55	177	389	445	399	151	53
TX3	62	203	440	473	422	141	46

(c)

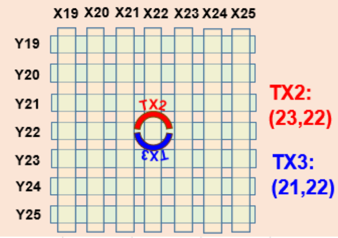
	TX2	TX3
Y19	110	96
Y20	267	255
Y21	413	408
Y22	443	476
Y23	406	448
Y24	192	222
Y25	93	87



	X19	X20	X21	X22	X23	X24	X25
TX2	14	71	150	407	700	318	199
TX3	134	334	677	447	156	67	22

(d)

	TX2	TX3
Y19	44	177
Y20	110	347
Y21	227	638
Y22	436	458
Y23	729	219
Y24	436	88
Y25	216	32



	X19	X20	X21	X22	X23	X24	X25
TX2	110	333	468	511	360	142	67
TX3	96	235	281	371	338	139	54

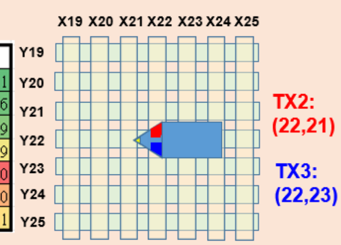
Figure 7(a)(b)(c)(d). Test data of rolling stylus placed vertically on the test tablet.

Figure 8(a) to 7(d) show the test data reported by the touch panel. We place the rolling stylus horizontally on the surface of the touch panel at position (X22,Y22), as shown in Figure 5(b). Then we start with TX2 at position (X21,Y22) and TX3 at position (X23,Y22) as shown in Figure 8(a).

Each time we rotate the rolling stylus 90 degrees counterclockwise, and we record the test data. This process continues until it has turned 360 degrees and returned to the starting point. The results are shown in Figure 8(a) to 8(d). By comparing Figure 8(a) to 8(d), we can clearly observe that the signal peaks of TX2 and TX3 shift positions as the rotation angle changes. This trend is consistent with what is shown in Figure 4(a) to 4(d). Through these tests, we can confirm that the design of the rolling electrode in prototype rolling stylus is indeed effective.

(a)

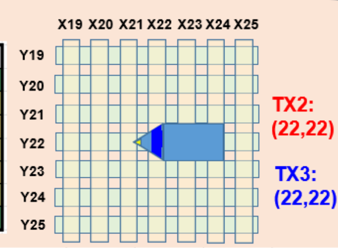
	TX2	TX3
Y19	375	11
Y20	834	36
Y21	1426	79
Y22	313	269
Y23	37	1560
Y24	17	870
Y25	10	411



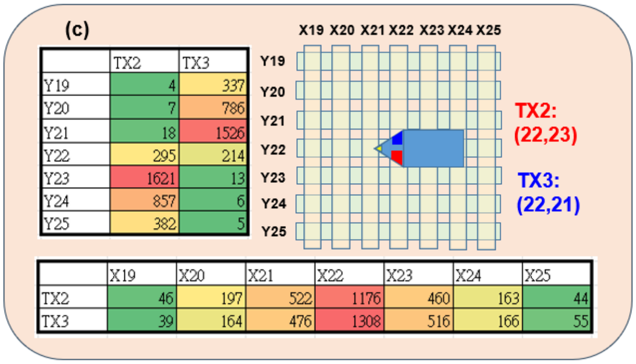
	X19	X20	X21	X22	X23	X24	X25
TX2	62	277	714	1421	774	160	54
TX3	56	257	762	1547	773	210	31

(b)

	TX2	TX3
Y19	57	11
Y20	301	148
Y21	623	278
Y22	1645	153
Y23	447	252
Y24	177	136
Y25	13	14

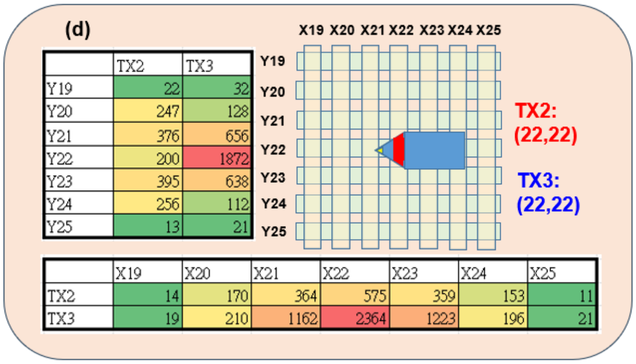


	X19	X20	X21	X22	X23	X24	X25
TX2	66	243	1188	2371	1113	166	53
TX3	31	107	331	466	306	114	26



	TX2	TX3
Y19	4	337
Y20	7	786
Y21	18	1526
Y22	295	214
Y23	1621	13
Y24	857	6
Y25	382	5

	X19	X20	X21	X22	X23	X24	X25
TX2	46	197	522	1176	460	163	44
TX3	39	164	476	1308	516	166	55



	TX2	TX3
Y19	22	32
Y20	247	128
Y21	376	656
Y22	200	1872
Y23	395	638
Y24	256	112
Y25	13	21

	X19	X20	X21	X22	X23	X24	X25
TX2	14	170	364	575	359	153	11
TX3	19	210	1162	2364	1223	196	21

Figure 8(a)(b)(c)(d). Test data of rolling stylus placed horizontally on the test tablet.

4. Algorithm and Demonstration

Based on the projection coordinates of rolling electrodes TX2 and TX3 on the XY plane in 3-dimensional space, the rolling angle is calculated using their respective projection coordinates. When considering the rolling stylus in a vertical state, we define the situation where the two projection coordinates are on the same X-axis and TX2's coordinate is greater than TX3's coordinate as a rolling angle of 0 degrees, as shown in Figure 9(a). Similarly, the situation where the two projection coordinates are on the same Y-axis and TX2's coordinate is greater than TX3's coordinate is defined as a rolling angle of 90 degrees, as shown in Figure 9(b). All other rolling angles can then be calculated using the differences in the X and Y coordinates between the two points, as shown in Figure 9(c). When accounting for the active stylus state, which usually includes azimuth and tilt angles, the same rolling angle will produce different coordinate differences, requiring angle compensation to accurately calculate the correct rolling angle.

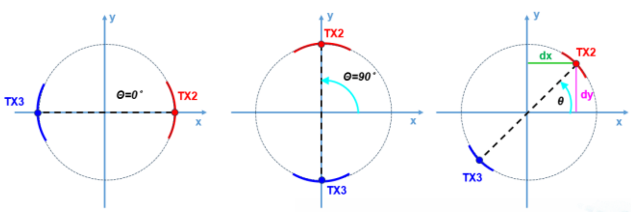


Figure 9(a). **Figure 9(b).** **Figure 9(c).**

Figure 9. Algorithm of rolling angle calculations

Figure 10 illustrates the application of the rolling stylus in a drawing software scenario. In the drawing APP, the marker has a pen nib with varying angles, resulting in lines of different thicknesses. By using the rotational control of the rolling stylus, users can adjust the angle of the pen nib. As shown in Figures 9(a) and 9(b), the cursor direction changes in response to the stylus being rotated to different angles.

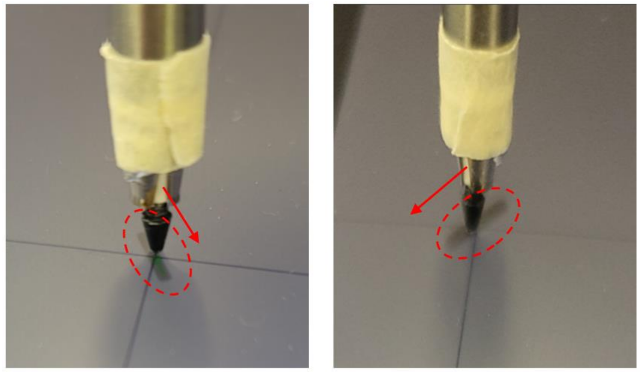


Figure 10. The rolling stylus allows users to adjust the tip direction of the marker in the app by rotating the stylus.

5. Conclusion and Impact of Research

We presented a new active stylus design featuring three TX electrodes, where TX1 serves as the tip, and TX2 and TX3 enable both tilt and rolling detection through time-sharing driving method. This rolling stylus can upgrade a tablet with Novatek TDDI (Touch Display Driver IC) product to one with rolling function without the need for additional active components, simply by updating the protocol and algorithms.

The current development is just a prototype. Further researchs are necessary for both the hardware design of the stylus and the algorithm of the touch panel.

6. Reference

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