Combining Communications and Tracking: A New Paradigm of Smartphone Games

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Abstract

The generalization trend of smartphones has brought many smartphone games into daily lives. These games are mainly dependent on the interactions on the display of the phone using finger touches. On the other hand, functions for detecting the positions and actions of the phones such as gyro-sensors have been rapidly developed over the former orientation sensors and acceleration sensors. Though it has become technologically possible to detect the users' motion via the smartphone devices and to use the phone device directly as the game device, it is hard to find the actualized cases. This paper proposes a new paradigm that includes basic frameworks and algorithms for the games combining the motion tracking and mutual communications on the smartphones and presents the details of its implementation and results.

Keywords: Smartphone, Motion tracking, Mutual communications

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1. Introduction

One of the main advantages of smartphones is various kinds of applications that are downloadable though Internet. Game applications are most popular among them and downloaded by a number of users. Most applications in smartphones are mainly dependent on the interactions on the display of the phone using finger touches[1].

New technologies such as gyro-sensors for precise tracking the positions or actions of the phone devices have been emerging. Smartphones include sensors having the levels almost same with those of Nintendo-wii and mutual communication functions such as Bluetooth. Movement recognition through accelerometer in a smartphone was also explored in recent studies [2]~[4]. These studies were mainly applied at the large scale applications such as urban street behaviors, movement pattern recognition, or map tracking. Driving style recognition using a smartphone as a sensor platform was also explored [5]. Moreover, it has been proposed to use a smartphone as a 3D input device and the concept of 3D navigation has been examined [6]. However, it has been hard to find the games or applications that recognize these positions or actions and apply for utilizing the smartphone itself as the game device while interacting between each other. Smartphones are expected to be used for the new paradigm of games between confronting users that will draw more attractions and sense of reality.

The cases that utilize the recognized positions and actions have been mainly related with the virtual reality or augmented reality technologies just including the positioning of the smartphones[7]~[10]. However, sensor-based motion recognition applications generally do not support interactive cases between participating users[11][12]. Therefore, it is required to study more on cosidering the motion tracking and mutual communications both for game appplications. Fortunately, the smartphones that are currently available support elements required to implement motion recognitions, such as acceleration sensors and orientation sensors[13]. In addition, the possibiliy of actualizing the idea looks so promising considering the study of positioning algorithm using accelerometers[14] and related studies[2]~[4]. However, the previous studies mainly cover the wide geographical range not requiring acute precision on motion tracking, that is expected to be essential in smartphone games. This presents a necessity of studying more on the motion tracking in narrower scale. In addition, there has been no study on smartphone games with mutual interactions between confronting users that are needed to hold them, sort of, on the same virtual space, requiring exchange of location information between each other. Mutual interactions including this information exchange between participating smartphone devices can be provided applying communications such as WiFi or Bluetooth embedded in them.

Even with some studies considering motion recognition based on acceleration sensors commented in the previous paragraph[2]~[4], there has been no study considering both aspects of motion tracking and mutual interactions at the same time. This issue of combining is expected to play a main role of making smartphone games have more sense of reality that will draw more interests. The lack of studies on that field leads to the necessity of designing a new paradigm of smartphone games considering these aspects together.

Therefore, this paper proposes a new paradigm of smartphone games that track the motion of the smartphone device, i.e., the x-y-z coordinates, calculated from the recognized sensor values, and exchange between devices via the inter-device communication link such as Bluetooth to be applied to the smartphone games, e.g., lightsaber showdown, western gun fight, or baseball game. The next chapter talks about the virtual space model for the games with mathematical presentations. Then the application methods of the proposed paradigm in the smartphone games are explained. The feature of the implemented result and the conclusion are lastly given.

2. Virtual Space Model for the Proposed Paradigm

For the successful development of the intended games, the target must be clarified first. This paper mainly focuses on the two aspects of the proposed paradigm, i.e., position tracking and mutual communications, for the purpose.

First, the coordinates of the current position of the smartphone device need to be considered for the position tracking. The current position of the device can be expressed as the values of x, y, z in the virtual 3-dimensional space. The initial position needs to be fixed to the starting point of the x,y,z coordinate system for reference.

According to the reference [13], the rotating angle for each direction of x, y, z can be decided using the orientation sensors in the smartphone devices. Similarly, the acceleration value for each direction of x, y, z can be decided using the acceleration sensors.

Combining the resulted angle and acceleration values, the x-y-z coordinates of the device end side can be estimated.

Let the coordinate values of initial position and the initial speed be (0, 0, 0) and 0, then the center of the device is given as $s_0 + v_0 t + \frac{1}{2}at^2$. At $t = 0$, the distance on the x-axis from the zero point and the speed of the device are assumed to be $x_0 = 0$, $u_0 = 0$. We just focus on the x-axis here for starting.

After $t = \Delta t$ elapsed, the distance from the zero point and the speed of the device are given as $x_1 = \frac{1}{2}a_1(\Delta t)^2$, $u_1 = a_1\Delta t$ where the acceleration is measured as a_1 on the x-axis.

After $t = 2\Delta t$ elapsed, the distance from the zero point and the speed of the device are given as $x_2 = x_1 + u_1\Delta t + \frac{1}{2}a_2(\Delta t)^2$, $u_2 = u_1 + a_2\Delta t$ where the acceleration is measured as a_2 on the x-axis.

After $t = 3\Delta t$ elapsed, the distance from the zero point and the speed of the device are given as $x_3 = x_2 + u_2\Delta t + \frac{1}{2}a_3(\Delta t)^2$, $u_3 = u_2 + a_3\Delta t$ where the acceleration is measured as a_3 on the x-axis.

Therefore, after $t = k\Delta t$ elapsed, the distance from the zero point is given as

$$x_k = x_{k-1} + u_{k-1}\Delta t + \frac{1}{2}a_k(\Delta t)^2 \tag{1}$$

where the speed and distance from the zero point at the next previous instant are given as u_{k-1}, x_{k-1} and the acceleration is measured as a_k on the x-axis.

Similarly, after $t = k\Delta t$ elapsed, the distance from the zero point on the y-axis is given as

$$y_k = y_{k-1} + v_{k-1}\Delta t + \frac{1}{2} b_k (\Delta t)^2 \tag{2}$$

where the speed and distance from the zero point at the next previous instant are given as v_{k-1}, y_{k-1} and the acceleration is measured as b_k on the y-axis.

The distance from the zero point on the z-axis is also given as

$$z_k = z_{k-1} + w_{k-1}\Delta t + \frac{1}{2} c_k (\Delta t)^2 \tag{3}$$

where the speed and distance from the zero point at the next previous instant are given as w_{k-1}, z_{k-1} and the acceleration is measured as c_k on the z-axis (c_k must be measured excluding the acceleration of gravity).

The location of the smartphone device, after $t = k\Delta t$ elapsed, is decided by the coordinates (x_k, y_k, z_k), only indicating the location of its center. We need the coordinates of the both ends of the device for applying the proposed game paradigm.

Let the length of the device be l, then the distance from the center to its end should be $\frac{l}{2}$. If the pitch and azimuth angles are measured as θ and φ, and the coordinates of the center are assumed as (0, 0, 0), the coordinates of the device are given as $(\pm\frac{l}{2}\sin(\alpha+\theta)\cdot\cos\varphi, \pm\frac{l}{2}\sin(\alpha+\theta)\sin\varphi, \pm\frac{l}{2}\cos(\alpha+\theta))$ where $\alpha = 90^\circ$ is applied for compensating the gap between the spheric coordinate system and the actual sensor values. The roll angle is not considered here.

From the coordinates (x_k, y_k, z_k) derived in (1)~(3), the coordinates of both ends of the device are given as:

$$x = x_k \pm \frac{l}{2}\sin(\alpha+\theta)\cdot\cos\varphi \tag{4}$$

$$y = y_k \pm \frac{l}{2}\sin(\alpha+\theta)\cdot\sin\varphi \tag{5}$$

$$z = z_k \pm \frac{l}{2}\cos(\alpha+\theta)\cdot \tag{6}$$

Now let us consider the case of intersection of two straight lines enlarged along the longitudinal axes of the device as shown in the **Fig. 1**, which are expected to be used in game applications such as light saber battles. Points A, B and C, D corresponding to each end of the device have coordinates of (4)~(6) in the **Fig. 1**.

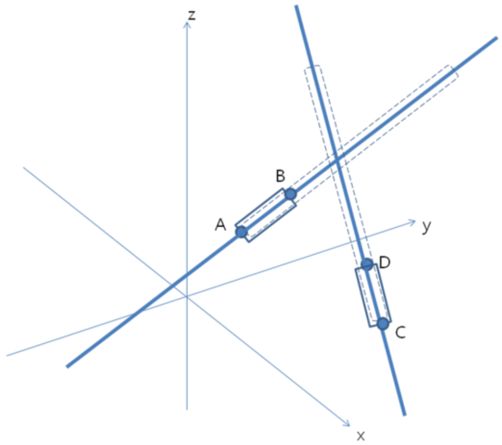


Fig.1. Intersection of two straight lines enlarged along the longitudinal axes of devices in the virtual space.

The equation of the straight line passing the points $A(x_1, y_1, z_1)$ and $B(x_2, y_2, z_2)$ is given as

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1} = \frac{z - z_1}{z_2 - z_1} = t\,. \tag{7}$$

The equation of the straight line passing the points $C(x_3, y_3, z_3)$ and $D(x_4, y_4, z_4)$ is also given as

$$\frac{x - x_3}{x_4 - x_3} = \frac{y - y_3}{y_4 - y_3} = \frac{z - z_3}{z_4 - z_3}\,. \tag{8}$$

From (7), the following equations can be written

$$x = (x_2 - x_1)t + x_1 \tag{9}$$

$$y = (y_2 - y_1)t + y_1 \tag{10}$$

$$z = (z_2 - z_1)t + z_1\,. \tag{11}$$

As *x*, *y*, *z* of (9)~(11) have same values in the equation (8) at the intersecting point, the following relation holds:

$$\frac{(x_2 - x_1)t + x_1 - x_3}{x_4 - x_3} = \frac{(y_2 - y_1)t + y_1 - y_3}{y_4 - y_3} = \frac{(z_2 - z_1)t + z_1 - z_3}{z_4 - z_3}\,. \tag{12}$$

Finally, the following equations are resulted:

$$\begin{aligned}&(x_2y_4 - x_2y_3 - x_1y_4 + x_1y_3 - x_4y_2 + x_3y_2 + x_4y_1 - x_3y_1)t \\ &= x_4y_1 - x_3y_1 - x_4y_3 - x_1y_4 + x_1y_3 + x_3y_4\end{aligned} \tag{13}$$

$$(y_2z_4 - y_2z_3 - y_1z_4 + y_1z_3 - y_4z_2 + y_3z_2 + y_4z_1 - y_3z_1)t$$

$$= y_4z_1 - y_3z_1 - y_4z_3 - y_1z_4 + y_1z_3 + y_3z_4 \tag{14}$$

$$(z_2x_4 - z_2x_3 - z_1x_4 + z_1x_3 - z_4x_2 + z_3x_2 + z_4x_1 - z_3x_1)t$$
$$= z_4x_1 - z_3x_1 - z_4x_3 - z_1x_4 + z_1x_3 + z_3x_4 \cdot \tag{15}$$

It is clear that the value of the parameter t can be calculated from (13)~(15). The sameness of the t values means the intersection of the two straight lines and the coordinates of the intersection point can be calculated from (9)~(11). If the calculated coordinates of the intersection point exceed the assumed length of the device (e.g., the length of the light saber in the light saber battle game), the intersection is to be ruled out. If it is impossible to calculate the value of the parameter t due to the zero denominator in an equation among (13)~(15), the t value can be calculated from the other equations and compared between each other for deciding whether the lines intersect or not.

3. Considerations for Practical Applications

Smartphone devices include various capabilities such as sensors and communications. Most game applications supported in the smartphones mainly focus on the phenomena appearing inside the display panels even with these capabilities. The new game paradigm based on the virtual space model proposed in this paper combines the sensors and communications inside/between devices to actualize the pseudo-realistic interactions between game users via the smartphone devices. Sports games such as baseball, table tennis, tennis, and confrontation games such as western showdown, lightsaber battle can be implemented applying the proposed paradigm.

Considering the case applied to the baseball game as shown in **Fig. 2**, the trace of the ball thrown by the pitcher can be estimated from the straight line enlarged along the direction of the device at the point where the acceleration is increased above a predefined threshold. It is also possible to determine whether the result of the match between the pitcher and batter is a possible hit or strike by checking whether the estimated trace and the straight line extended from the device of the batter side intersect or not. The more detailed result such as hit, foul, homerun can be decided by checking the angle between straight lines when they intersect. This approach also can be similarly applied to other sports games such as table tennis or tennis.

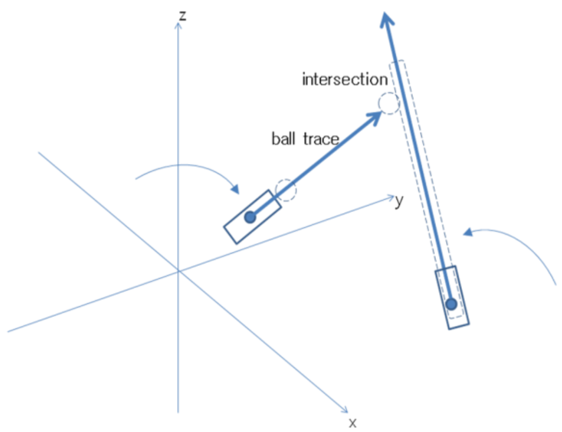


Fig.2. Intersection of two straight lines enlarged along the longitudinal axes of devices in the baseball game.

Another case of western showdown game can be applied using the proposed paradigm as shown in the **Fig. 3**. The traces of the bullets shot by the gamers can be estimated by the straght lines enlarged along the devices. The result of the showdown can be decided by checking whether the estimated traces and the body area of the counter part (estimated from the coordinates of the counter part device and the assumed area centered at the coordinates) intersect or not. This approach is similar with that of sport games already explanined. Therefore, the wetstern showdown game is expected to be implemented with ways almost same with those used in the sports games using the proposed paradigm.

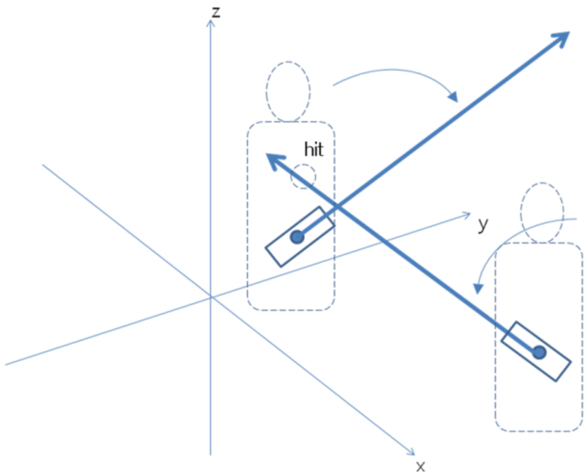


Fig.3. Intersection of two straight lines enlarged along the longitudinal axes of devices and the counter are in the western showdown game.

4. Implementation of the Games Combining Motion Tracking and Mutual Communications

The previous sections identified the mathematical model for the virtual space of the proposed game paradigm and considerations required for practical application. In addition to these, the implementation according to the proposed paradigm demands more detailed methods for combining motion tracking and mutual communications.

For actual implementation, the acceleration and orientation sensors in the smartphone devices need to be considered. Gyro-sensors are expected to be used for more precision to measure the device location but not applied here and left for further study. The acceleration sensors produce acceleration data corresponding to each movement. The location and speed of the device can be derived from the acceleration data as explained in section 2. The orientation sensors produce three angle values for each axis as shown in **Fig. 4**, i.e., *azimuth* values from 0° to 360° centered to z-axis, *pitch* values from -180° to $+180^\circ$ centered to x-axis, and *roll* values -90° to $+90^\circ$ centered to y-axis[13].

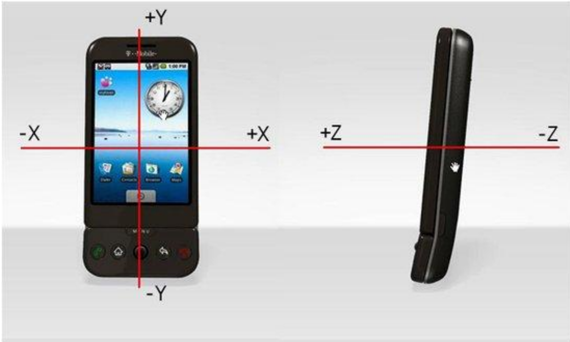


Fig.5. A smartphone with three axises.

Applying these values, the coordinates of each device will be calculated from the model of (1)~(15) of section 2. Hence, the tracking procedure can be expressed as the following algorithm:

Input:
1) The coordinates of current device location (initialized).
2) The current speed of the device at each axis (initialized).
3) The coordinates of previous device location (initialized)
4) The previous speed of the device at each axis (initialized)
5) The length of the device (constant).
6) The current time tick (initialized).
Output:
1) The intersection occurrence of two straight lines enlarged along the longitudinal axes of devices.
2) The coordinates of the intersection point.
Procedure:

```
while (until game end)
Receive sensor data.
Compute the device location coordinates.
    if this is master
    Get slave device location coordinates.
    Compute nominators and denominators for equations (13)~(15)
        if no zero denominator is found and computed values of t are equal
        An intersection is found.
        Compute the coordinates of the intersection.
        elseif one zero denominators is found and two computed values of t are equal
        An intersection is found.
        Compute the coordinates of the intersection.
        elseif two zero denominators are found and computed value of t is valid
        An intersection is found.
        Compute the coordinates of the intersection.
        else
        No intersection is found.
        endif
    if intersection is found and within the valid range
```

```
        Send the intersection status to the slave device.
        Turn on vibration motor, sound and lightening spark.
        endif
        else
        Send slave device location coordinates.
        Wait until intersection status is arrived.
        if intersection status is arrived and it occurred
        Turn on vibration motor, sound and lightening spark.
        endif
    Set the current speed and location data to the previous ones.
    Increment time tick value.
    end while
```

The mutual synchronization between smartphone devices participating in the confrontation game must be maintained by exchanging the sensor data and calculated results for providing more actual feeling to the users. Possible methods to do this include WiFi and Bluetooth communications in each device. It is required to fix one of the devices to a master and another to a slave, possibly by applying the incorporated master-slave decision function incorporated in the Bluetooth communication function. Other possible ways such as exchanging phone numbers or MAC addresses can also be applied. The required information flows for the master and slave devices are shown in **Fig. 5** and **6**.

As shown in **Fig. 5**, the locations of the master device and the slave need to be confirmed to be at the same location. Then the master retrieves sensor data from itself and the slave. The retrieved data are applied to the calculation applying the eqs. (13)~(15). The result of the calculation, i.e., the occurrence of intersection at that instant, is sent to the slave and triggers the corresponding response, i.e., vibration, flash, and sound effect.

In the procedure of the slave as shown in **Fig. 6**, the location of the slave device needs to be aligned with the master. After getting sensor data, the slave transmits them to the master for the calculation and waits. With the reception of the desired result of the calculation applying the eqs. (13)~(15), i.e., the occurrence of intersection at that instant, the corresponding response is triggered.

Before applying the proposed algorithm and information flows, it is required to verify the correctness of the proposed methods. The procedure to detect intersection between two straight lines enlarged along each device is roughly tested as shown in **Fig. 7**. Verification for tracking the position of the device has not been included in this test due to its requesting for susceptible tuning processes. Test results confirmed the correctness of the proposed algorithm and procedures. Several results from the test are shown in **Table 1**.

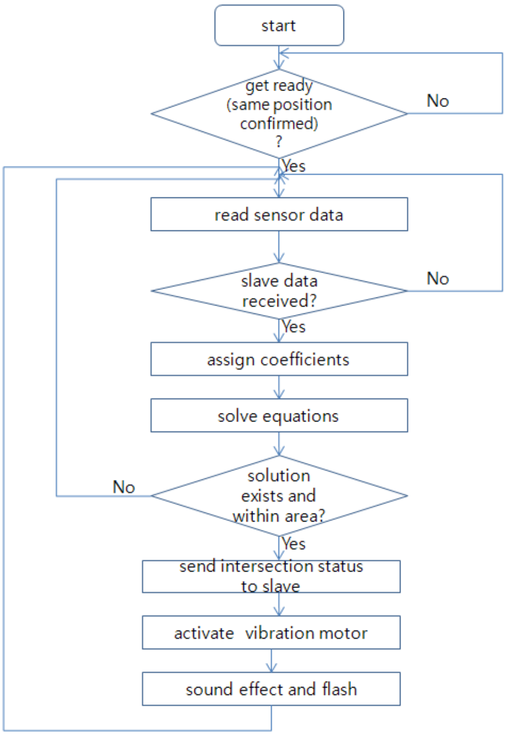


Fig.5. An Information flow for the master device.

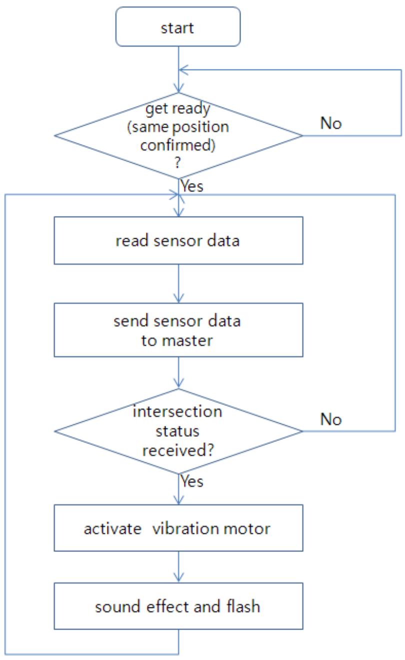


Fig.6. An Information flow for the slave device.

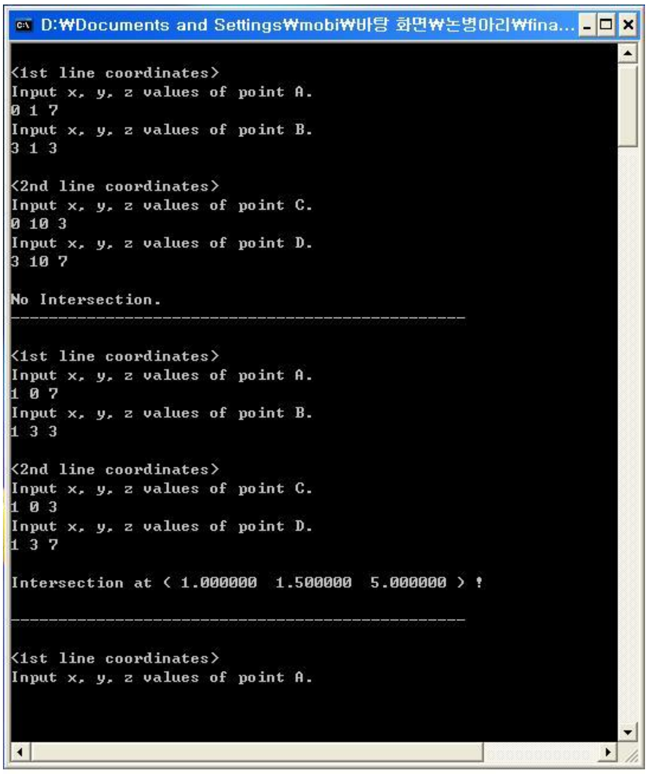


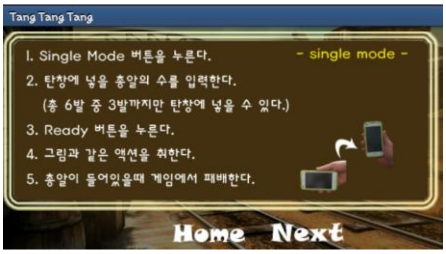
Fig.7. A screen image of the rough test for verifying the intersection algorithm.

Table 1. Results of the rough tests for verification

1st line coordinates	2nd line coordinates	Intersection
(0, 1, 7), (3, 1, 3)	(0, 10, 3), (3, 10, 7)	None
(0, 1, 7), (3, 1, 3)	(0, 1, 3), (3, 1, 7)	(1.5, 1, 5)
(1, 0, 7), (1, 3, 3)	(10, 0, 3), (10, 3, 7)	None
(1, 0, 7), (1, 3, 3)	(1, 0, 3), (1, 3, 7)	(1, 1.5, 5)
(7, 1, 0), (3, 1, 3)	(3, 10, 0), (7, 10, 3)	None
(7, 1, 0), (3, 1, 3)	(3, 1, 0), (7, 1, 3)	(5, 1, 1.5)
(1, 7, 0), (1, 3, 3)	(10, 3, 0), (10, 7, 3)	None
(1, 7, 0), (1, 3, 3)	(1, 3, 0), (1, 7, 3)	(1, 5, 1.5)
(2, 3, 6), (4, 5, 7)	(5, 3, 2), (3, 6, 8)	None
(1.7, 3.4, 5.7), (3.4, 4.9, 0.2)	(1.7, 4.9, 0.2), (3.4, 3.4, 5.7)	(2.55, 4.15, 2.95)
(1.7, 3.4, 5.7), (3.4, 4.9, 0.2)	(1.7, 4.9, 5.7), (3.4, 3.4, 5.7)	None

The proposed paradigm combining communications and tracking in smartphone games was first applied to the western showdown game, a graduation work guided by the author. **Fig. 8** shows images of its demonstrated results. The implemented game application did not reach to the intended level of position tracking methods proposed in this paper though it is based on the paradigm combining communications and motion sensing. The implemented game transforms the changing acceleration values from sensors to the gun trigger actions for showdown, while Bluetooth is used for mutual synchronization between devices. The implemented result works well for the basic functions of the confrontation game. However, it lacks of the sense of reality mailnly due to its limitation caused by unrelatedness with actual position of each edevice, expected to be resolved by including the motion tracking algorithm proposed in this paper.

(a) Image of the start screen



(b) Image of the help screen

(c) Image of the final screen

Fig.8. Demonstrated images of the graduation work.

5. Conclusion

A new paradigm for smartphone games is proposed and ways for implementation including algorithm and considerations for practical applications are explored in this paper. The proposed motion tracking algorithm based on the acceleration values from smartphone sensors were verified through rough tests for limited number of cases. The test results show the predicted output as shown in the **Fig. 7** and **Table 1** but more precise tests are required to guarantee for all different cases. In addition, the proposed paradigm combining motion tracking and mutual communications were applied to implement a smartphone game reproducing the western showdown. The implemented game application did not reach the intended level of position tracking methods proposed in this paper though it is based on the paradigm combining mutual communications and motion sensing but held out the possibilities of confrontation games with the sense of reality by combining motion tracking and mutual communications. Even with their limits, the rough tests and implementation of the western showdown game show the potential of the proposed paradigm for broadened fields of smartphone games. Therefore, the proposed paradigm could be applied to the development of various kinds of smartphone game applications that will contribute to broaden the range of the current smartphone application industry and its market.

For actual implementations, required issues such as the sensitivity of sensors, timing exactness for mutual communications, both requiring tuning processes, need to be considered in the longer phase. In addition, more research is expected to be done to improve the sense of reality in the proposed paradigm applying newer methods such as gyro-sensors, etc. More detailed issues possibly causing problems during game playing are also for further study.

References

[1] Yang Li, "Gesture Search: Random Access to Smartphone Content," *IEEE Pervasive Computing*, vol. 11, no. 1, pp. 10-13, January-March, 2012. Article (CrossRef Link).

[2] Armir Bujari, Bogdan Licar, Claudio E. Palazzi, "Movement Pattern Recognition through Smartphone's Accelerometer," in *Proc. of Consumer Communications and Networking Conference (CCNC), 2012 IEEE*, pp.502-506, January, 2012. Article (CrossRef Link).

[3] Jun Han, Emmanuel Owusu, Le T. Nguyen, Adrian Perrig, Joy Zhang, "ACComplice: Location Inference using Accelerometers on Smartphones," in *Proc. of Communication Systems and Networks (COMSNETS)*, pp.1-9, January, 2012. Article (CrossRef Link).

[4] Armir Bujari, Bogdan Licar, Claudio E. Palazzi, "Road Crossing Recognition through Smartphone's Accelerometer," in *Proc. of Wireless Days (WD), 2011 IFIP*, pp.1-3, October, 2011. Article (CrossRef Link).

[5] Derick A. Johnson and Mohan M. Trivedi, "Driving Style Recognition Using a Smartphone as a Sensor Platform," in *Proc. of 2011 14th International IEEE Conference on Intelligent Transportation Systems*, pp.1609-1615, October, 2011. Article (CrossRef Link).

[6] Henning Graf, Prof. Dr. Klaus Jung, "The Smartphone as a 3D Input Device," in *Proc. of IEEE Second International Conference on Consumer Electronics*, pp.254-257, September, 2012. Article (CrossRef Link).

[7] Eun-Gil Kim, Mi-Ryeong Yeom and Jong-Hoon Kim, "Development of Android-based Application for Measure a Space Coordinate and an Area using of Orientation Sensor," *Journal of Korea Association of Information education*, vol. 15, no. 3, pp. 439-447, August, 2011. Article (CrossRef Link).

[8] Ho-Joong Yong, Jong-Won Back and Tae-Jeong Jang, "Stereo vision based virtual reality game using position/orientation sensors and vibrotactile device," in *Proc. of HCI Society of Korea*, vol. 1, pp. 88-93, 2006. Article (CrossRef Link).

[9] Jong-Hyun Yoon and Jong-Seung Park, "Augumented Reality Game Interface Using Hand Gestures Tracking," *Journal of Korean Game Society*, vol. 6, no. 2, pp.3-12, 2006. Article (CrossRef Link).

[10] Boo-Nyon Kim, Jongho Kim and Tae-Young Kim, "A Method of Hand Recognition for Virtual Hand Control of Virtual Reality Game Environment," *Journal of Korean Game Society*, vol. 10, no. 2, pp.49-56, 2010. Article (CrossRef Link).

[11] L. Kovavisaruch, et. al., "Conserving and Promoting Thai Sword Dancing Traditions with Motion Capture and the Nintendo Wii," *Proceedings of PICMET '11*, pp. 1-5, 2011. Article (CrossRef Link).

[12] Michael Hoffman et. al., "Breaking the Status Quo: Improving 3D Gesture Recognition with Spatially Convenient Input Devices," in *Proc. of IEEE Virtual Reality Conference*, pp. 59-66, 2010. Article (CrossRef Link).

[13] "Summary on acceleration sensor values in android machines based on the coordinate system," January, 2011. Article (CrossRef Link).

[14] Kurt Seifert and Oscar Camacho, "Implementation Positioning Algorithms Using Accelerometers," *Application Note of Freescale Semiconductor*, Rev 0, AN3397, February, 2007. Article (CrossRef Link).

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