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RESEARCH ARTICLE

Measuring Height of an Object using Accelerometer and Camera in iOS and Android Devices

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Abstract— The height of object can be determined by using inch tapes, angles of elevation and basic trigonometry. Everything listed can be replaced by using standard smart phones having accelerometer, GPS receiver, network connectivity and camera. The research deals with calculation of height of an object by converting data received from the sensors.

Keywords— iOS, Android, accelerometer, height of object, geometry

I. INTRODUCTION

Google's **Android** and Apple's **iOS** are operating systems used primarily in mobile technology, such as smart phones and tablets. Android, which is Linux-based and partly open source, is more PC-like than iOS, in that its interface and basic features are generally more customizable from top to bottom. However, iOS' uniform design elements are sometimes seen as being more user-friendly.

TABLE I
DIFFERENCE BETWEEN ANDROID AND IOS DEVICES [1]

	Android	**iOS**
Company/Developer	Google	Apple Inc
OS family	Linux	OS X, UNIX
Initial release	September 23, 2008	July 29, 2007

Programmed in	C, C++, java	C, C++, Objective-C
Source model	Open source	Closed, with open source components
Latest stable release (May 2014)	Android 4.4 Kitkat (October, 2013)	7.1 (March 10, 2014)

A. iOS

iOS, previously iPhone OS is a mobile operating system developed by Apple Inc. and distributed exclusively for Apple hardware. powering iPhone, iPad, iPod Touch, and Apple TV. It's UI is based on the concept of direct manipulation, using multi-touch gestures such as swipe tap, pinch and reverse pinch. It is a closed source software and is only available in select apple devices.[2]

B. Android

Android is an Operating System which is based on Linux kernel. It's UI is based on direct manipulation using touch inputs like pinching, swiping and tapping. Applications are able to send notifications to the user to inform them about relevant information, such as emails and text messages. Android's source code is available under open source licenses. In terms of security and privacy applications in android run in a sandbox, which is an isolated area of the system that does not have access to the rest of the system's resources. Permissions are explicitly granted by the user when an application is installed. While installing an application, Play Store displays all permissions required by application to work. The sandboxing and permissions system reduces the impact of vulnerabilities and bugs present in applications, but developer confusion and limited documentation has resulted in applications routinely requesting unnecessary permissions, reducing its effectiveness. [3]

C. Accelerometer

The accelerometer measures acceleration i.e. acceleration due to movement and acceleration due to gravity. When the device is stable, the accelerometer returns just accelerometer due to gravity. Accelerometers in different kinds of smart phones return different values. For example in iPhone, it returns g values, 1 g means 1*9.81 m/s^2 and in android phones, it returns values with SI units m/s^2.

D. iPhone

Each acceleration event includes simultaneous acceleration readings along the three axes of the device, as shown in Figure 1. Referenced from [4],[5]

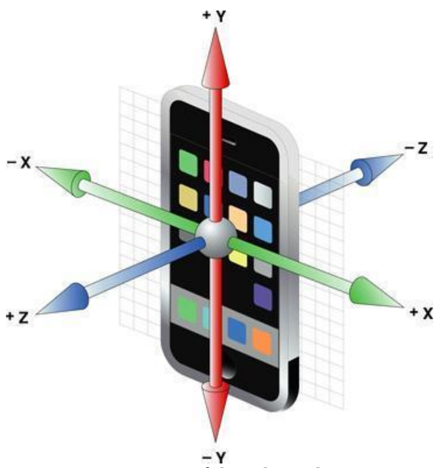


Fig. 1 Orientation of the iPhone device axes

The device accelerometer reports values for each axis in units of g-force, where a value of 1.0 represents acceleration of about +1 g along a given axis. When a device is laying still with its back on a horizontal surface, each acceleration event has approximately the following values:

E. Android Phones

The axes are as same as iPhone accelerometer axes

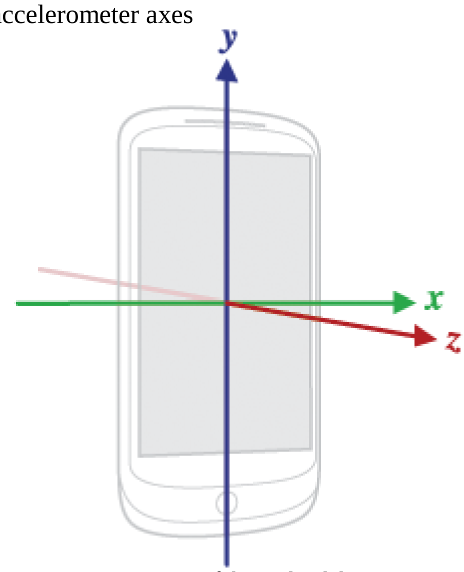


Fig. 2 Orientation of the Android device axes

Sensor.TYPE_ACCELEROMETER:[6]

All values are in SI units (m/s^2)

The sensor measures resultant acceleration (A) which is acceleration due to gravity and acceleration due to movement. Conceptually, it does so by measuring forces applied to the sensor itself (Fs) using the relation:

A = -g - ∑F / mass

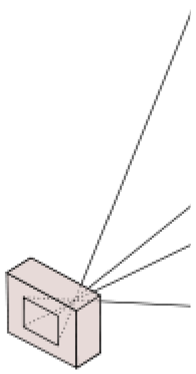
When the device is kept on a table the accelerometer reads a magnitude of **g** = 9.81 m/s^2.

Referenced from [6],[7][8]

F. Camera

Camera is used to pin point the foot and the top of the object, the foot being at the ground level. A small cross is placed at the centre of the screen with respect to the camera such that it is relationally at the centre of the camera. It is done so that the angle of view of camera is 0 degrees. so that the line of sight is perpendicular to Z axis of mobile device.

In photography, angle of view describes the angular range that is imaged by a camera. It is used interchangeably with "field of view".



x: 0

y: 0

z: -1

Fig. 3 A camera's angle of view can be measured horizontally, vertically, or diagonally.[9]

II. PROPOSED SOLUTION

- **The phone is always kept in portrait mode.**
- **For android phones the accelerometer readings has to be divided by 9.81 for angle calculations.**
- **Unit of angle used in calculation is degrees**

A. Finding height H of device

Height is entered as height of user and then, H is calculated by subtracting 4 to 5 inches as this is the height of device a normal user hold the device.

B. Finding distance between device and the object.

H=Height entered - 4 inches...(1)

1) *Device Alignment:* Through the camera, the user aligns the device's angle to the point at which the object touches the ground level.

Note: The ground level is the level at which the user is standing.

The accelerometer gives the values which is converted into angles for further calculations.

2) *Calculations:*

$\theta=|\sin^{-1}(\text{value of accelerometer w.r.t. Y axis})|$ .... (2)
$\varphi=90°-\theta=|\sin^{-1}(\text{value of accelerometer w.r.t. Z axis})|$ .... (3)
$H/D=\tan\varphi$
Therefore, $D=H\cot\varphi$ .... (4)

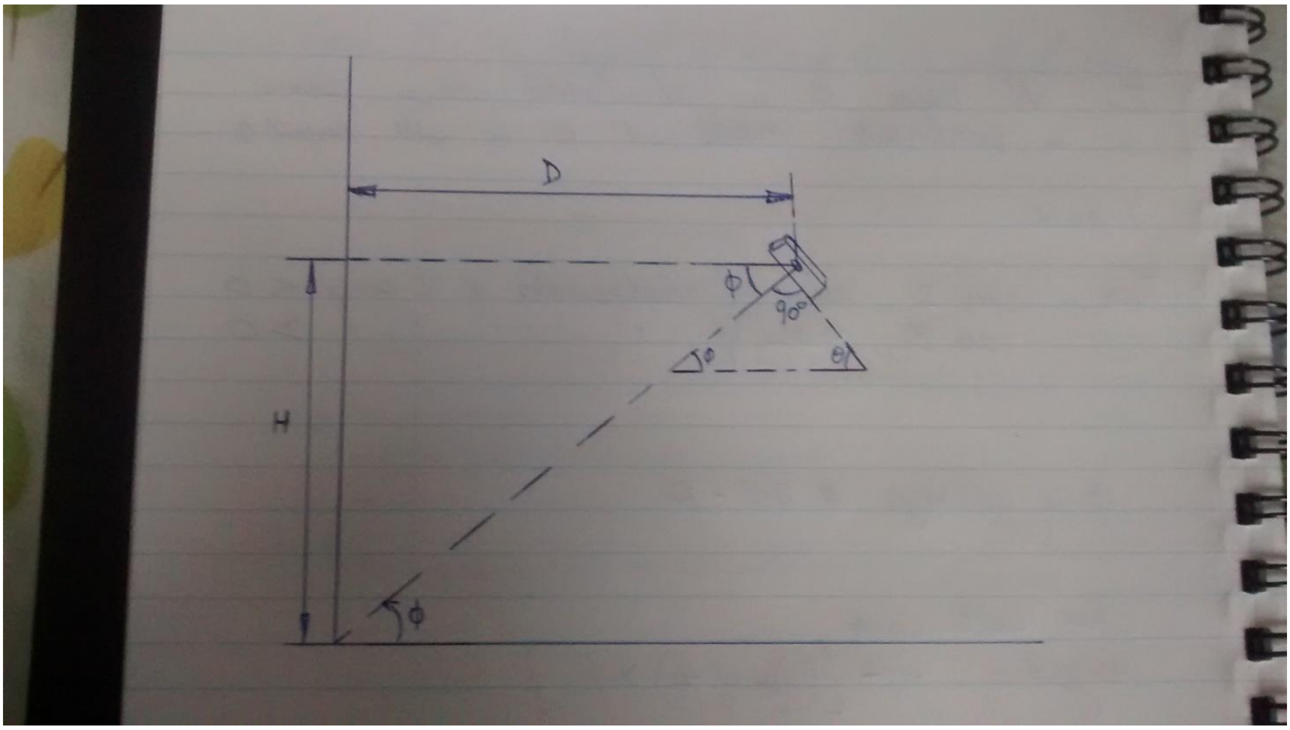


Fig. 4 Calculating distance from the device

TABLE II
DESCRIPTION OF SYMBOLS USED ABOVE

S.no.	Symbol	Description
1.	**D**	**Distance of user(mobile device) from the object which is being calculated by using H and φ.**
2.	**H**	**Height of user's device which is 4 inches less than the height of user.**
3.	**θ**	**Angle of bent which is calculated using accelerometer of the device.**
4.	**φ**	**Angle of depression which is calculated by taking complementary from angle of bent.**

C. Finding height of object

- Aim at the top of the object by looking in from the camera
- There are 2 cases out of which 1 may arise

1) Case : When object's height is less than height at which device is held

- Distance D has been calculated

$\theta_1=\sin^{-1}|(\text{value of accelerometer w.r.t. Y axis})|$ .... (5)

$\varphi_1=|90°-\theta_1| =\sin^{-1}|(\text{value of accelerometer w.r.t. Z axis})|$ ....(6)

$h_1/D=\tan \varphi_1$ .... (7)

$h_1=D \tan \varphi_1$ .... (8)

Therefore $h_2=H - h_1$ .... (9)

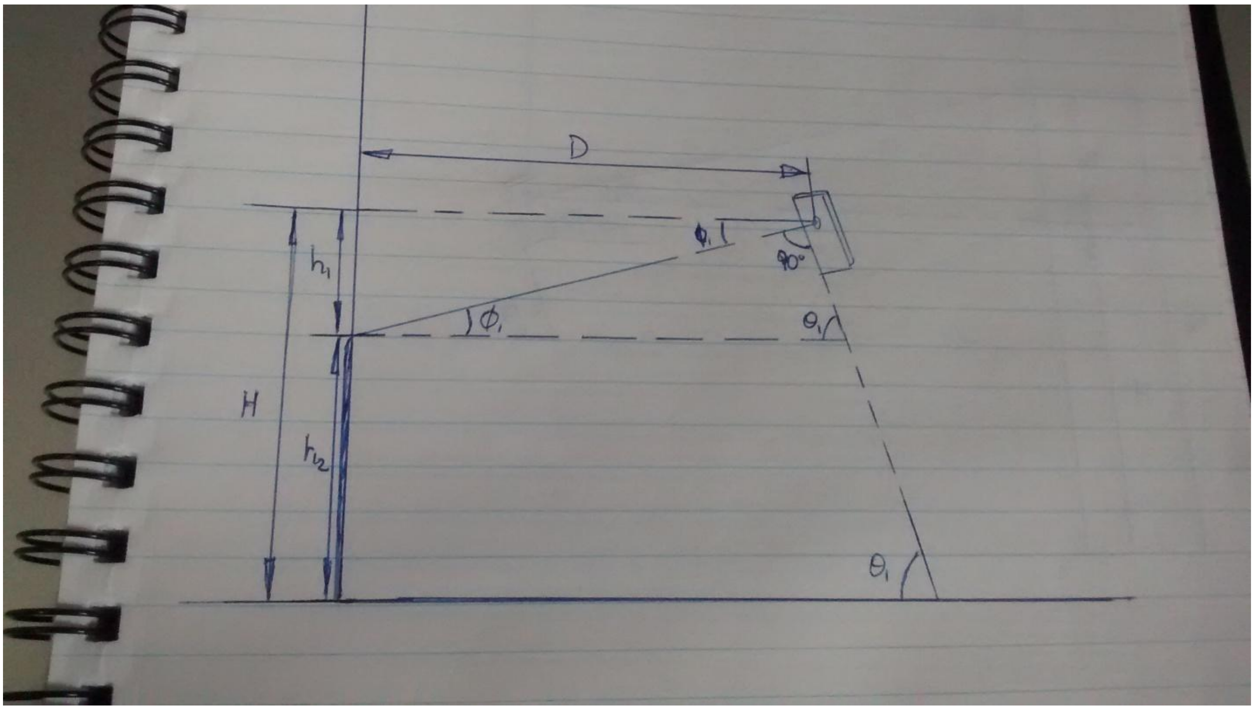


Fig. 5 Calculating height of object when it is less than that of device

TABLE III
DESCRIPTION OF SYMBOLS USED ABOVE

S.no.	Symbol	Description
1.	**D**	**Distance of user(mobile device) from the object which has been calculated**
2.	**H**	**Height of user's device which is 4 inches less than the height of user.**
3.	**θ_1**	**Angle of bent which is calculated using accelerometer of the device.**
4.	**φ_1**	**Angle of depression which is calculated by taking complementary from angle of bent.**
5.	**h_1**	**Height calculated from the top of the object to the height of the mobile device using distance D and angle φ_1**
6.	**h_2**	**Height of the object(required) calculated by subtracting h_1 from H**

2) Case : When object's height is greater than height at which device is held

- Distance D has been calculated

$\theta_3=\sin^{-1}$|(value of accelerometer w.r.t. Y axis)|.. (10)

$90°+\varphi_3=180°-\theta_3$

$\varphi_3=90°-\theta_3=\sin^{-1}$|(value of accelerometer w.r.t. Z axis)| .... (11)

$h_3/D=\tan\varphi_3$ .... (12)

$h_3=D\tan\varphi_3$ .... (13)

Therefore $h_4=H + h_3$ .... (14)

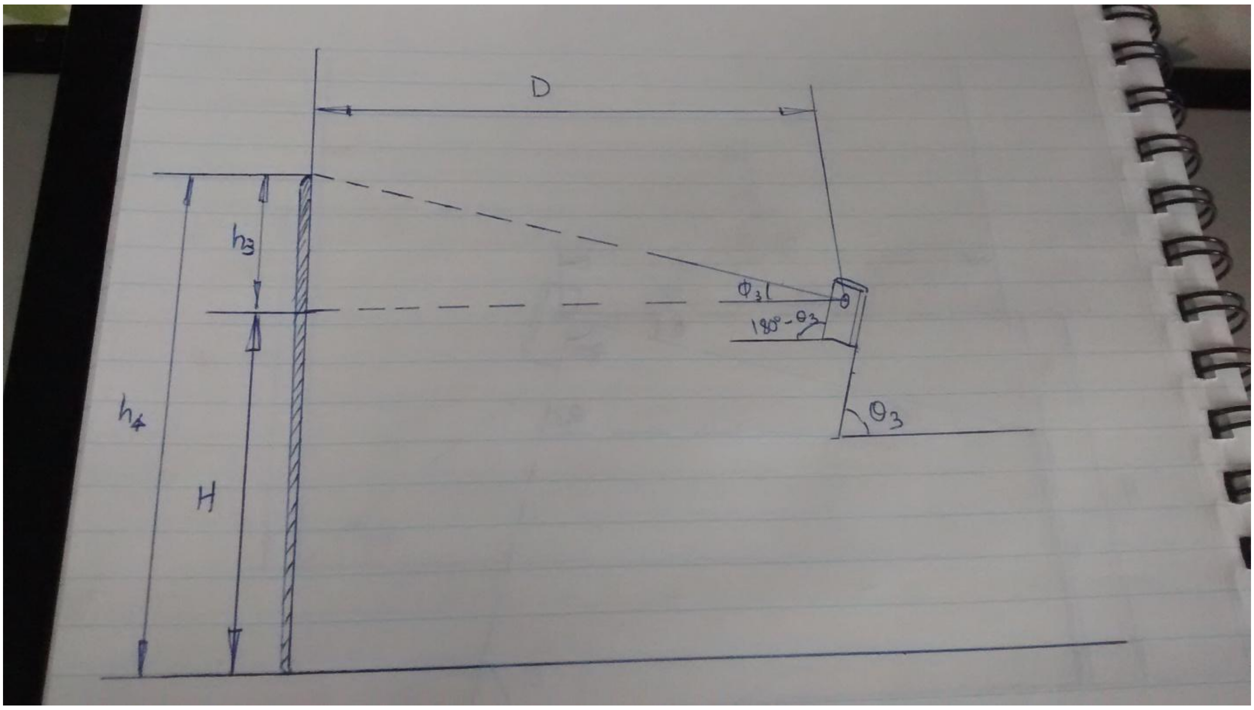


Fig. 6 Calculating height of object when it is greater than that of device

In both cases θ is calculated when phone is in portrait mode and θ is wrt Y axis and φ is wrt Z axis.

TABLE IV
DESCRIPTION OF SYMBOLS USED ABOVE

S.no.	Symbol	Description
1.	**D**	**Distance of user(mobile device) from the object which has been calculated**
2.	**H**	**Height of user's device which is 4 inches less than the height of user.**
3.	θ_3	**Angle of bent which is calculated using accelerometer of the device.**
4.	φ_3	**Angle of elevation which is calculated by taking supplementary from angle of bent.**
5.	h_3	**Height calculated from the height of device to the top of the object using distance D and angle** φ_3
6.	h_4	**Height of the object(required) calculated by adding** h_3 **and H**

Explanation and reasoning to proposed solution

- The phone is always kept in portrait mode for simplicity in the solution; the axis changes when the phone's mode is changed from portrait to landscape mode.
- For android phones the accelerometer readings has to be divided by 9.81 for angle calculations as android phones give readings in m/s^2 and the needed value should lie from -1 to 1 so as to take the sine inverse for angle calculations.
- Unit of angle used in calculation is degrees just for easier explanations.

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