



Cairo University

# 3D SOLID CAD APPLICATION ON ANDROID HANDHELD DEVICES FOR FASTER AND MOBILE DESIGN SOLUTION

By

Mohamed Ahmed Metwalli ElSharawy

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
MASTER OF SCIENCE  
In  
Mechanical Design and Production Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2015

# 3D SOLID CAD APPLICATION ON ANDROID HANDHELD DEVICES FOR FASTER AND MOBILE DESIGN SOLUTION

By

Mohamed Ahmed Metwalli ElSharawy

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
MASTER OF SCIENCE  
in  
Mechanical Design and Production Engineering

Under the Supervision of

Sayed M. Metwalli

Professor of Mechanical Design  
Mechanical Design and Production Engineering  
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2015

# 3D SOLID CAD APPLICATION ON ANDROID HANDHELD DEVICES FOR FASTER AND MOBILE DESIGN SOLUTION

By

Mohamed Ahmed Metwalli ElSharawy

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
MASTER OF SCIENCE  
In  
Mechanical Design and Production Engineering

Approved by the  
Examining Committee

---

Prof. Dr. Sayed M. Metwalli, Thesis Main Advisor

---

Prof. Dr. Ahmed A. El Zoghby, Internal Examiner

---

Prof. Dr. Roger W. Mayne, External Examiner

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
2015

**Engineer's Name:** Mohamed Ahmed Metwalli ElSharawy  
**Date of Birth:** 23 / 01 / 1986  
**Nationality:** Egyptian  
**E-mail:** melsharawy@gmail.com  
**Phone:** +201223238198  
**Address:** 6 Awlad El Sheikh ElSharawy St.  
Mansouria , Haram ,  
Giza, Egypt.  
**Registration Date:** 1 / 10 / 2008  
**Awarding Date:** 31 / 03 / 2015  
**Degree:** Master of Science  
**Department:** Mechanical Design and Production Engineering



**Supervisors:**  
Prof. Dr. Sayed M. Metwalli

**Examiners:**  
Prof. Dr. Sayed M. Metwalli (Thesis main advisor)  
Prof. Dr. Ahmed A. El Zoghby (Internal examiner)  
Prof. Dr. Roger W. Mayne (External examiner)

**Title of Thesis:**

3D Solid CAD Application on Android Handheld Devices for Faster and Enhanced Design

**Key Words:**

3D – Solid – CAD – Computer Aided Design– Android – Apps

**Summary:**

Handheld mobile applications (apps) are growing massively in both function and mobility. This is due to the increasing variety of mobile operating systems (Android, iOS, RIM, Windows ...etc.), technological advancement in the handheld computing power and the fact that these apps are mobile and can be used literally everywhere. With the growing need, one has to have more live-design tools offering on the spot solutions that meet more of the instant (Rapid Prototyping) technologies growing e.g. 3D Printing, Real-Time Construction/Maintenance...etc.

Scientific communities cannot be disengaged from the above stated facts there had to be a research about what are the available offered engineering solid computer-aided-design apps that can offer the same level of details and design capabilities as the ones offered on personal computers. Android OS offers what is needed in terms of popularity across different platforms, manufacturers, users and developers; in addition to being an open-source coded OS. In this thesis two sections are covered. First is the analysis for the Android platform and answering the following questions: What are available 2D/3D modeling apps on Google-Play (Android Market)? Can these apps be used in true design applications? What are these apps offering i.e. solid or surface modeling? What is the difference between both? What is missing in the market and how to close the engineering-need gap available? In the second section a solid 3D CAD app that is designed and programmed (from the point-of-view of this work) that offers

the needed CAD app capabilities, tools and options in order to serve the higher purpose of having a real-time tool to design with on the fly. The app name is chosen to be (3Droid). It is a 3D solid modeling CAD application that functions on all Android handheld devices; which enables full 3D solid modeling with just the fingertips of the user enabling a real-time design solution.

## **Acknowledgments**

I acknowledge hereby all the professors and teachers that have taught me during my undergraduate and graduate school at Faculty of engineering, Cairo University. For all the motivation and scientific knowledge that they gave me without selflessly.

I would like to specially acknowledge my professor and mentor Prof. Sayed M. Metwalli. For all his teaching efforts during my undergraduate and graduate studies. For all the guidance and motivation to complete this thesis with all life distractions around. Thank You!

# **Dedication**

I wish to dedicate this thesis to my loveable parents, caring wife and joyful daughter.

# Table of Contents

<b>ACKNOWLEDGMENTS .....</b>	<b>I</b>
<b>DEDICATION.....</b>	<b>II</b>
<b>TABLE OF CONTENTS.....</b>	<b>III</b>
<b>LIST OF TABLES .....</b>	<b>V</b>
<b>LIST OF FIGURES .....</b>	<b>VI</b>
<b>NOMENCLATURE .....</b>	<b>X</b>
<b>ABSTRACT.....</b>	<b>XI</b>
<b>CHAPTER 1 : INTRODUCTION .....</b>	<b>12</b>
1.1.    APPS IN OUR LIVES .....	12
1.2.    COMPUTING POWER IN OUR HANDS .....	13
1.3.    THE POWER OF MOBILITY.....	16
1.4.    ENGINEERING NEED FOR LIVE DESIGN TOOLS.....	17
1.5.    WHY ANDROID? .....	17
1.6.    PROGRAMMING ON ANDROID.....	19
1.7.    OPENGL Vs. OPENGL ES .....	20
1.8.    ORGANIZATION OF THE THESIS .....	21
<b>CHAPTER 2 : BACKGROUND LITERATURE AND PREVIOUS WORK.....</b>	<b>23</b>
2.1.    TYPE 1 - 2D CAD .....	23
2.2.    TYPE 2 - 3D FILE VIEWERS .....	23
2.3.    TYPE 3 - 3D PART LIBRARY SYSTEMS .....	25
2.4.    TYPE 4 - PRIMITIVE SURFACE MODELING .....	26
2.5.    TYPE 5 - FREEFORM SURFACE SCULPTING .....	29
2.6.    CONCLUDING REMARKS.....	30
<b>CHAPTER 3 : ANDROID SOLID CAD APP DEVELOPMENT.....</b>	<b>32</b>
3.1.    PROGRAM AN ANDROID SOLID CAD APP .....	32
3.2.    EARLY CONCEPT AND DESIGN LAYOUT.....	32
3.3.    APP MATHEMATICAL BACKGROUND .....	84
3.3.1.    SKETCH: LINE MATHEMATICAL REPRESENTATION .....	84
3.3.2.    SKETCH: PLANE MATHEMATICAL REPRESENTATION .....	85
3.3.3.    SKETCH: CIRCLE MATHEMATICAL REPRESENTATION.....	86
3.3.4.    SKETCH: B-SPLINE MATHEMATICAL REPRESENTATION.....	88
3.3.5.    CREATE: EXTRUDE MATHEMATICAL REPRESENTATION .....	90
3.3.6.    CREATE: REVOLVE MATHEMATICAL REPRESENTATION .....	91
3.4.    APP ARCHITECTURE & CODE LOGIC .....	92
3.5.    APP FINAL DESIGN.....	96



<b>CHAPTER 4 : APP DESIGN APPLICATIONS AND VERIFICATION.....</b>	<b>102</b>
4.1. APP DESIGN APPLICATIONS .....	102
4.1.1. DRAWING A CUBE ON 3DROID .....	102
4.1.2. DRAWING A CYLINDER ON 3DROID .....	103
4.1.3. DRAWING A HOLLOW CYLINDER ON 3DROID .....	104
4.1.4. DRAWING A FRUIT BOWL ON 3DROID.....	105
4.1.5. DRAWING A BOLT ON 3DROID .....	106
4.1.6. CONSTRUCTING A BUTTERFLY VALVE ON 3DROID.....	107
4.1.7. DRAWING A CHAIR ON 3DROID.....	111
4.1.8. DRAWING A DIRECTIONAL VAVLE ON 3DROID .....	113
4.2. VERIFYING CAD MODELS .....	116
4.2.1. CAD SOFTWARE VERIFICATION METHOD .....	116
4.2.2. 3D PRINTING VERIFICATION METHOD .....	118
<b>CHAPTER 5 : CONCLUSION.....</b>	<b>126</b>
<b>REFERENCES .....</b>	<b>127</b>
<b>APPENDIX A: 3DROID APP .....</b>	<b>130</b>

## List of Tables

Table 1 - AGC Vs. iPhone-5S .....	14
Table 2 - HP Computer Product Line-Up Comparison .....	15
Table 3 - Main Handheld Operating Systems in Comparison.....	18
Table 4 - Android Programming Tools .....	19
Table 5 - OpenGL vs. OpenGL-ES .....	20

## List of Figures

Figure 1 - Apps used by an average girl in a single day.....	13
Figure 2 – A variety of sizes for handheld devices .....	19
Figure 3 - Google-Play Logo [2] .....	23
Figure 4: SimLab – Type 2.....	24
Figure 5: STLView – Type 2.....	24
Figure 6: Graphite – Type 2 .....	25
Figure 7 : Glovius – Type 3.....	25
Figure 8 : iGus – Type 3.....	26
Figure 9: Sketcher 3D – Type 4 .....	26
Figure 10: om3DCAD – Type 4.....	27
Figure 11: AutoDesk – Type 4 .....	27
Figure 12: Buf3D Lego – Type 4 (LEGO shapes are the primitive geometry used) .....	28
Figure 13: Quibsm – Type 4.....	28
Figure 14 : 3D Model Player – Type 4.....	29
Figure 15 - Surface Modeling Representation.....	29
Figure 16 : d3D Sculptor – Type 5 .....	30
Figure 17 : TrueSculpt – Type 5.....	30
Figure 18 - 3Droid App Concept Splash Screen 1 (University Name) .....	34
Figure 19 - 3Droid App Concept Splash Screen 2 (App Name) .....	34
Figure 20 - 3Droid App Concept Main App Menu .....	35
Figure 21 - 3Droid App Concept Draw Part Command clicked .....	35
Figure 22 - 3Droid App 3D Drawing Canvas .....	36
Figure 23 - 3Droid App tap to select a Sketch function.....	36
Figure 24 - 3Droid App showing available sketch options .....	37
Figure 25 - 3Droid App Select Plane to Sketch on .....	38
Figure 26 - 3Droid App showing the selected plane to draw a sketch on .....	38
Figure 27 - 3Droid App drawing a Circle .....	39
Figure 28 - 3Droid App showing Circle editing possibility .....	39
Figure 29 - 3Droid App Polygon 1 <sup>st</sup> point start selecting.....	40
Figure 30 - 3Droid App Polygon 2 <sup>nd</sup> point drawing.....	40
Figure 31 - 3Droid App Polygon 3 <sup>rd</sup> point selecting .....	41
Figure 32 - 3Droid App Polygon 4th point selecting .....	41
Figure 33 - 3Droid App Polygon drawing ends by clicking the Line button.....	42
Figure 34 - 3Droid App showing possible trim option.....	42
Figure 35 - 3Droid App Concept to confirm Trim action .....	43
Figure 36 - 3Droid App showing trimmed sketch.....	43
Figure 37 - 3Droid App click the (Sketch) button again to end sketching.....	44
Figure 38 - 3Droid App sketch turns grey to indicate that it is un-editable .....	44
Figure 39 - 3Droid App clicking on the (Create) button .....	45
Figure 40-- 3Droid App selecting the sketch for (Extrude Feature) .....	45
Figure 41 - 3Droid App to extrude the sketch (Extrude Feature).....	46
Figure 42 - 3Droid App Clicking Create button to extrude (Extrude Feature) .....	46
Figure 43 - 3Droid App click Create to end (Extrude Feature).....	47
Figure 44 - 3Droid App sketching on the created part .....	48
Figure 45 - 3Droid App selecting the surface on the part to sketch on .....	48
Figure 46 - 3Droid App Face selected.....	49

Figure 47 - 3Droid App drawing a circle on Part - Face .....	49
Figure 48 - 3Droid App completing the sketch .....	50
Figure 49 - 3Droid App Part with added sketch on .....	50
Figure 50 - 3Droid App press Create to utilize the sketch .....	51
Figure 51 - 3Droid App Create Menu Appears .....	51
Figure 52 - 3Droid App Cut Feature selected and sketch picked .....	52
Figure 53 - 3Droid App Cut depth entered .....	52
Figure 54 - 3Droid App Concept Cut done in part .....	53
Figure 55 - 3Droid App Click on Isometric to change the camera view .....	53
Figure 56 - 3Droid App selecting the view from menu .....	54
Figure 57 - 3Droid App top view orthographic view selected .....	54
Figure 58 - 3Droid App Top View Illustrated .....	55
Figure 59 - 3Droid App Clicking return to exit and save .....	55
Figure 60 - 3Droid App Save option appears .....	56
Figure 61 - 3Droid App click Yes to Save .....	56
Figure 62 - 3Droid App choose directory to save part .....	57
Figure 63 - 3Droid App Main Menu and Draw part selected .....	58
Figure 64 - 3Droid App sketch menu opened .....	58
Figure 65 - 3Droid App choose Plane to sketch on .....	59
Figure 66 - 3Droid App Concept Plane selected (Top) Plane .....	59
Figure 67 - 3Droid App Plane highlights when selected .....	60
Figure 68 - 3Droid App sketching on the selected plane a B-Spline point 1 to 4 .....	60
Figure 69 - 3Droid App sketching on the selected plane a B-Spline point 1 to 4 .....	61
Figure 70 - 3Droid App sketching on the selected plane a B-Spline point 1 to 4 .....	61
Figure 71 - 3Droid App sketching on the selected plane a B-Spline point 1 to 4 .....	62
Figure 72 - 3Droid App sketching on the selected plane a B-Spline point 1 to 4 .....	62
Figure 73 - 3Droid App finalize B-Spline Sketch .....	63
Figure 74 - 3Droid App Select another plane to sketch on .....	63
Figure 75 - 3Droid App Select the front plane .....	64
Figure 76 - 3Droid App draw a circle on the front plane .....	64
Figure 77 - 3Droid App enter circle data .....	65
Figure 78 - 3Droid App enter circle data .....	65
Figure 79 - 3Droid App Finalize Circle .....	66
Figure 80 - 3Droid App finalize sketching .....	66
Figure 81 - 3Droid App close sketch menu .....	67
Figure 82 - 3Droid App Concept Illustrated .....	67
Figure 83 - 3Droid App Create part with sketches .....	68
Figure 84 - 3Droid App select sweep .....	68
Figure 85 - 3Droid App select the curves to sweep profile and path .....	69
Figure 86 - 3Droid App profile to sweep selected .....	69
Figure 87 - 3Droid App path to sweep selected .....	70
Figure 88 - 3Droid App sweep by clicking again on sweep button .....	70
Figure 89 - 3Droid App Sweep generated .....	71
Figure 90 - 3Droid App click return to save (as previously illustrated) .....	71
Figure 91 - 3Droid App New part to draw .....	72
Figure 92 - 3Droid App empty canvas .....	72
Figure 93 - 3Droid App sketch selected .....	73
Figure 94 - 3Droid App plane selection .....	73
Figure 95 - 3Droid App front plane selected .....	74
Figure 96 - 3Droid App B-spline to draw with .....	74

Figure 97 - 3Droid App sketch B-spline with points from 1 to 4.....	75
Figure 98 - 3Droid App sketch B-spline with points from 1 to 4.....	75
Figure 99 - 3Droid App sketch B-spline with points from 1 to 4.....	76
Figure 100 - 3Droid App sketch B-spline with points from 1 to 4.....	76
Figure 101 - 3Droid App sketch B-spline with points from 1 to 4 and finalize.....	77
Figure 102 - 3Droid App finalize B-Spline.....	77
Figure 103 - 3Droid App close contour with a polygon tool with 3 points.....	78
Figure 104 - 3Droid App close contour with a polygon tool with 3 points.....	78
Figure 105 - 3Droid App close contour with a polygon tool with 3 points.....	79
Figure 106 - 3Droid App finalize the polygon tool.....	79
Figure 107 - 3Droid App sketch finalization.....	80
Figure 108 - 3Droid App Concept Illustrated.....	80
Figure 109 - 3Droid App create menu selected.....	81
Figure 110 - 3Droid App Revolve feature selected.....	81
Figure 111 - 3Droid App curve to revolve selected.....	82
Figure 112 - 3Droid App axis to revolve across is defined and the revolve angle.....	82
Figure 113 - 3Droid App click Revolve to perform operation.....	83
Figure 114 - 3Droid App Revolved part is generated.....	83
Figure 116 - Line defined by two points P1 and P2.....	84
Figure 115 - SketchLine3D Class: Line Drawing Code.....	84
Figure 117 - Plane surface ( <i>S</i> ) defined by three points P1, P2 & P3.....	85
Figure 118 - SketchPlane Class: Plane Drawing Codes.....	85
Figure 119 - SketchPlane Class: Plane Variables.....	86
Figure 120 - Planar Circle Representation.....	86
Figure 121 - Parametric Circle Representation.....	87
Figure 123 - SketchCircle3D Class: Circle Variables.....	87
Figure 122 - SketchCircle3D Class: Circle Drawing Code.....	87
Figure 124 - B-Spline Mathematical Model Illustrated [46].....	88
Figure 125 - Difference between curve approximation and interpolation [42].....	89
Figure 126 - SketchSpline3D Class: Spline Variables.....	89
Figure 127 - Extrude Cylinder Example.....	90
Figure 128 - Revolve Process Illustration.....	91
Figure 129 - Revolve of a Line about the Z-Axis.....	91
Figure 130 - Revolve Parametric Graphical Representation.....	92
Figure 131 - 3Droid App Architecture.....	93
Figure 132 - 3Droid Sketch Select Operation.....	93
Figure 133 - 3Droid Create Line Operation.....	94
Figure 134 - 3Droid Create Circle Operation.....	94
Figure 135 - Circle Segmental Resolution Spectrum.....	95
Figure 136 - 3Droid Extrude Operation.....	95
Figure 137 - 3Droid Revolve Operation.....	96
Figure 138 - 3Droid Final Design showing the splash screen 1.....	97
Figure 139 - App name Splash Screen 2.....	98
Figure 140 - Initial Selection Screen - App Main Menu.....	98
Figure 141 - App drawing canvas with drawing tools menu bar.....	99
Figure 142 - App Selected Icons Graphics.....	100
Figure 143 - App Tool Properties Menus Graphics.....	100
Figure 144 - Standard Gestures Touch-Screen Devices.....	101
Figure 145 - Drawing a 20mmX20mmX20mm Cube on 3Droid.....	102
Figure 146 - Drawing a 50mmX50mm Cylinder on 3Droid.....	103

Figure 147 - Drawing a 50mmX50mm Cylinder on 3Droid.....	103
Figure 148 - Using the Polygon (Line) tool and Revolve to create a hollow cylinder.	104
Figure 149 - Using the Polygon (Line) tool and Revolve to create a hollow cylinder.	104
Figure 150 - Using the B-Spline tool to create a fruit bowl section.....	105
Figure 151 - Using the B-Spline tool and the Revolve to create a fruit bowl .....	105
Figure 152 - Using the Polygon (Line) tool to create a bolt section .....	106
Figure 153 - Using the Polygon (Line) tool and Revolve to create a bolt.....	106
Figure 154 - Using 3Droid to create a body section of butterfly valve (step 1 of 8) ...	107
Figure 155 - Using 3Droid to revolve a butterfly valve section (step 2 of 8) .....	107
Figure 156 - Using 3Droid to create a butterfly valve body ball section (step 3 of 8).	108
Figure 157 -Using 3Droid to revolve a butterfly valve body ball section (step 4 of 8)	108
Figure 158 - Using 3Droid to revolve the valve body ball section (step 5 of 8).....	109
Figure 159 - Using 3Droid to create a butterfly valve neck section (step 6 of 8) .....	109
Figure 160 - Using 3Droid to revolve butterfly valve neck section (step 7 of 8).....	110
Figure 161 - Using 3Droid to create a butterfly valve Hand (step 8 of 8) .....	110
Figure 162 - Using 3Droid to create a chair (1 of 4).....	111
Figure 163- Using 3Droid to create a chair (2 of 4).....	111
Figure 164- Using 3Droid to create a chair (3 of 4).....	112
Figure 165 - Using 3Droid to create a chair (4 of 4).....	112
Figure 166 - Using 3Droid to create a directional valve 1/6 .....	113
Figure 167 - Using 3Droid to create a directional valve 2/6 .....	113
Figure 168 - Using 3Droid to create a directional valve 3/6 .....	114
Figure 169 - Using 3Droid to create a directional valve 4/6 .....	114
Figure 170 - Using 3Droid to create a directional valve 5/6 .....	115
Figure - Using 3Droid to create a directional valve 6/6 171 .....	115
Figure 172 - 3Droid 20mmX20mmX20mm drawn cube .....	117
Figure 173 - CAD Verification with SolidWorks .....	117
Figure 174 - 3Droid 50mmX50mm drawn cylinder.....	118
Figure 175 - 3D Printing Verification with Makerware Model Slicing Software.....	119
Figure 176 - 3D Printer Verification Process Illustration .....	119
Figure 177 - 3D Printer Verification Process Close-up.....	120
Figure 178 - 3D Printer Verification Process other Close-up view.....	120
Figure 179 - 3D Printing Verification Process of a cylinder.....	121
Figure 180 - 3D Printing Verification Process further printing a cylinder.....	121
Figure 181 - 3D Printing Verification Process printing the cylinder .....	122
Figure 182 - 3D Printing Verification Process final printed cylinder .....	122
Figure 183 - 3D Printing Verification Process final cylinder.....	123
Figure 184 - 3D Printing Verification Process Illustration .....	123
Figure 185 - 3D Printing Verification Process of number of surfaces on cylinder .....	124
Figure 186 - 3D Printing Verification Process by measuring cylinder radius .....	125
Figure 187 - 3D Printing Verification Process by measuring cylinder length .....	125

# Nomenclature

## SYMBOLS

P: Geometric Point  
L: Geometric Line / Length  
x: X-Axis Coordinate Value  
y: Y-Axis Coordinate Value  
z: Z-Axis Coordinate Value  
S: Geometric Planar Surface  
 $r$ : Circle Radius  
 $\alpha, \beta$ : Circle Center Coordinates  
 $\theta$ : Angle  
A, B, C: Constants  
t: Incremental Value

## ABBREVIATIONS

CAD: Computer Aided Design  
APP: Application; common term for software that runs on a mobile device  
3Droid: Solid CAD app developed through this thesis  
SDK: Software development kit  
ADT: Android Development Tools  
AVD: Android Virtual Device  
JDK/E: Java Development Kit/Environment  
OS: Operating System  
RP: Rapid Prototyping  
OSS: Open-source software  
PC: Personal Computer  
CNC: Computer Numerical Control  
STL: Stereo-Lithography; 3D CAD file format  
OBJ: Object; 3D CAD file format  
DXF: Drawing Exchange Format; 3D CAD file format  
IDE: Integrated development environment  
OOP: Object Oriented Programming  
SDK: Software Development Kit  
API: Application Programming Interface  
GLUT: OpenGL Utility Toolkit  
GLU: OpenGL Utility Library  
GPU: Graphics Processing Unit  
EGL: is an API that manages the interface between Khronos renderers (OpenGL-ES, OpenGL or OpenVG) and the native platform windowing system  
Piecewise function: Any function that is defined by a multiple of other sub-functions