



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF LINE WIDTH AND TYPE CONTROL OF 2D CAD  
SOFTWARE BASED ON ISO TECHNICAL DRAWING STANDARD**

**PITON NOPNAKORN**

**FK 2003 44**

**DEVELOPMENT OF LINE WIDTH AND TYPE CONTROL OF 2D CAD  
SOFTWARE BASED ON ISO TECHNICAL DRAWING STANDARD**

**By**

**PITOOON NOPNAKORN**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirements for the Degree of Master of Science**

**October 2003**



# **DEDICATION**

**To My Parents**

**One who ever shared a moment of his love and  
one who has strived patiently for their beloved children**



Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in  
fulfilment of the requirements for the degree of Master of Science

**DEVELOPMENT OF LINE WIDTH AND TYPE CONTROL OF 2D CAD  
SOFTWARE BASED ON ISO TECHNICAL DRAWING STANDARD**

By

**PITOON NOPNAKORN**

**October 2003**

**Chairman: Associate Professor Napsiah Ismail, Ph.D.**

**Faculty: Engineering**

Engineering drawing is the media of communication in manufacturing process. In order to communicate in the same graphic language in engineering, the technical drawing standard has been specified by the International Organization for Standardization (ISO).

Some commercial CAD softwares such as AutoCAD, AutoSketch and Solid Edge provided high-end ability to work whether in 3D or 2D space. Their width, length and proportion of printed lines conform to the ISO Technical Drawing Standard. But the procedures and interface to create line width and line type for simple drawing are sometime tedious and complex. The aim of this research work is to develop a 2D CAD software with emphasize on line width and line type control based on the ISO technical drawing standard for technical drawing.



The ISO 128 part 20, 21, and 24 are fundamental standard applied to the proposed software. The design of User Interface (UI) has been done in Windows XP operating system environment and Pascal-based Delphi 5 Standard as the visual programming tools. The format of drawing file was designed as the independent format, textual file, on the basis of Computer Graphics Metafile format (CGM) and Data Exchange File format (DXF). Seven drawing were printed in various line widths from 0.25 mm to 2.0 mm. Every drawing was proved the line width, length of line elements and continuous line are the same dimension as a manuscript drawing and specification in the ISO standard. The human-computer interfaces of the developed software were simplified for line width and line type control. The time taken to produce a technical drawing is less as compare to commercial softwares such as AutoCAD, AutoSketch and Solid Edge. Keystroke-level model was applied for this purpose.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**PEMBANGUNAN PENGAWALAN LEBAR DAN JENIS GARISAN PADA  
PERISIAN 2D CAD GERDASARKAN LUKISAN TEKNIK PIAWAI ISO**

Oleh

**PITON NOPNAKORN**

**Oktober 2003**

**Pengerusi: Profesor Madya Napsiah Ismail, Ph.D.**

**Fakulti: Kejuruteraan**

Lukisan kejuruteraan adalah media untuk berkomunikasi dalam proses pengeluaran. Untuk berkomunikasi menggunakan bahasa grafik yang sama dalam aspek kejuruteraan, satu piawai lukisan teknik telah ditentukan oleh International Organization for Standardization (ISO).

Sesetengah perisian CAD yang seperti AutoCAD, AutoSketch dan Solid Edge dipasarkan menyediakan kebolehan yang tinggi untuk kegunaan dalam ruang 3D atau 2D. Lebar, panjang dan nisbah garisan bagi perisian ini yang dicetak menepati piawai lukisan teknikal ISO. Tetapi prosedur serta antaramuka untuk menghasilkan kelebaran garis dan jenis garis untuk lukisan mudah kadangkala rumit dan kompleks. Kajian ini bertujuan untuk membangunkan perisian 2D dengan penekanan kepada pengawalan lebar dan jenis garisan berdasarkan lukisan teknik piawai ISO untuk lukisan teknikal.

ISO 128 bahagian 20, 21 dan 24 merupakan piawai asas yang digunakan dalam perisian yang dicadangkan. Perekaan perantaramukgan pengguna (UI) telah dibuat dalam persekitaran “Windows XP” dan piawai “Pascal-based Delphi 5” telah digunakan sebagai alat “visual programming”. Format untuk fail lukisan telah direka sebagai format tersendiri, fail “textual”, dengan basis “Computer Graphics Metafile format” (CGM) dan “Data eXchange File format” (DXF). Tujuh lukisan telah dicatat dalam berbagai lebar garisan, iaitu dari 0.25 mm sehingga 2.0 mm. Setiap lukisan telah dibuktikan dengan lebar garisan, panjang elemen garisan dan garisan bersambung yang mempunyai dimensi yang sama dengan lukisan manuskrip dan spesifikasi dalam piawai ISO. Perantaramukaan manusia-komputer untuk perisian yang telah dibangunkan telah dimudahkan bagi kawalan lebar garis dan jenis garis. Masa yang diperlukan untuk menghasilkan lukisan teknikal adalah kurang jika dibandingkan dengan perisian komersial seperti AutoCAD, AutoSketch dan Solid Edge. Model ‘Aras-keystroke’ telah digunakan untuk ini.

## ACKNOWLEDGEMENTS

I would like to acknowledge the complete support and advice given by Assoc. Prof. Dr. Napsiah Ismail, my supervisor. I would like to extend my gratitude to my co-supervisors, to Assoc. Prof. Dr. Megat Mohamad Hamdan Megat Ahmad and Assoc. Prof. Dr. Shamsuddin Sulaiman for their suggestions and encouragement.

I also would like to extend my grateful to all professional lecturers who given me the engineering wisdom during my study in the first year, Assoc. Prof. Dr. Yousif A. Khalid and Assoc. Prof. Ir. Dr. Md. Yusof Ismail.

I might not found UPM if I lost their help, Wanna Ammawath and Dr. Suttipong Pruangka. My thanks for their constant support go to my Brothers Banlue and Naresa. Thank to Kasian Tantisewee for encouragement of confidential letter. I am indebted to Gabby Setiowaty for supporting many conveniences. Thanks go to Mariam Abdul Latif, Chor Keong Seng and Kambiz Shamsi for sharing his critical time to proof my thesis and Tan Chee Fai for his comments. Unforgettable my ex-room mate Jeremy Yeak Nai Jin and Calvin Wong Hong Kiat for sharing experience of tidy and disciplinary habit.

Finally, my deepest appreciations go to my wife, daughters and son for their patience during my study.





I certify that an Examination Committee met on 3<sup>rd</sup> October 2003 to conduct the final examination of Pitoon Nopnakorn on his Master of Science thesis entitled “Development of Line Width and Type Control Of 2D CAD Software Based on ISO Technical Drawing Standard” in accordance with Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**Md. YUSOF ISMAIL, Ph.D.**

Associate Professor Ir.  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Chairman)

**NAPSIAH ISMAIL, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Member)

**MEGAT MOHAMAD HAMDAN MEGAT AHMAD, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Member)

**SHAMSUDDIN SULAIMAN, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Member)



---

**GULAM RASUL RAHMAT ALI, Ph.D.**

Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 9 JAN 2004

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Master Science

**NAPSIAH ISMAIL, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Chairman)

**MEGAT MOHAMAD HAMDAN MEGAT AHMAD, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Member)

**SHAMSUDDIN SULAIMAN, Ph.D.**

Associate Professor  
Department of Mechanical and Manufacturing Engineering  
Universiti Putra Malaysia  
(Member)



---

**AINI IDERIS, Ph.D.**  
Professor/Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 26 JAN 2004

## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



---

PITON NOPNAKORN

Date: 7 Jan 2009

## TABLE OF CONTENTS

	<b>Page</b>
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL SHEETS	viii
DECLARATION FORM	x
LIST OF TABLES	xiii
LIST OF FIGURES	xv
NOMENCLATURE	xix
 <b>CHAPTER</b>	
1 INTRODUCTION	1
1.1. Problem Statement	2
1.2. Objective	5
1.3. Thesis Scope	5
1.4. Thesis Outline	6
2 LITERATURE REVIEW	7
2.1 Computer-Aided Design	7
2.2 Graphics File Formats	8
2.2.1 Types of Graphics File Formats	9
2.2.2 Graphics File Data	10
2.2.3 Geometric Data	14
2.2.4 Vector Files	19
2.3 Drawing Exchange Format	21
2.4 Computer Graphics Metafile (CGM)	22
2.5 Application of Existing CAD	24
2.6 Standard for Exchange Data	26
2.7 ISO Standard of Drawing	27
2.7.1 Sizes and Layout of Drawing	28
2.7.2 Line	30
2.8 Software Development Process Models	31
2.9 Software Requirements Analysis	35
2.10 Object-Oriented Design	36
2.11 Programming Language	36
2.12 Software Assessment	38
2.13 Summary	39
3 METHODOLOGY	41
3.1 Programming Tools	43
3.2 Requirement Analysis	46
3.2.1 Drawing Sheet	47



3.2.2	Line Width and Line Type	48
3.2.3	Displaying Screen	52
3.2.4	Printing Resolution	52
3.2.5	Summary of Required Data	53
3.3	Procedures Analysis	55
3.3.1	Printing Process	56
3.3.2	Displaying Process	59
3.3.3	Erasing Process	61
3.3.4	Storing Process	63
3.4	Designing	66
3.5	Encoding and Testing	68
3.6	Software Assessment	68
4	RESULTS AND DISCUSSIONS	71
4.1	User Interface	72
4.1.1	Menu Bar	73
4.1.2	Drawing Sheet Control Box	77
4.1.3	Line Group Control Box	77
4.1.4	Layer Control Box	79
4.1.5	Drawing Buttons	81
4.1.6	Status Bar	88
4.2	Program Initializing	89
4.3	Line Width Setting	92
4.4	Line Drawing	94
4.5	Line Erasing	95
4.6	Printing	97
4.7	Format of Drawing File	98
4.8	Case Study	102
4.9	Line Width and Line Type Control	105
4.10	Geometric File	117
4.11	Comparison of Proposed Software and AutoCAD	120
4.12	Discussion	130
5	CONCLUSIONS AND RECOMMENDATION	133
5.1	Conclusions	133
5.2	Recommendation for Future Work	135
5.2.1	Conventional Tools for CAD System	135
5.2.2	ISO Constraints	136
	REFERENCES	138
	APPENDICES	142
	BIODATA OF THE AUTHOR	249

## LIST OF TABLES

<b>Table</b>	<b>Page</b>
1.1 Some features of commercial software	4
2.1 Sizes of trimmed and untrimmed sheets and the drawing space	28
2.2 Types of line for mechanical drawing	30
2.3 Configuration of line	31
2.4 Group of line in mechanical Drawing	31
3.1 Summary of required data	54
3.2 The summary of data requirement for printing process	57
3.3 Details of layer data	59
3.4 The summary of data requirement for displaying process	60
3.5 The summary of data requirement for erasing process	62
3.6 The summary of data requirement for storing process	64
3.7 Summary of required procedures	66
3.8 The operators of the keystroke-level model	70
4.1 Detail of layer initial data	100
4.2 Designated line width and results	113
4.3 Designated length of dashed line elements and result	115
4.4 Designated length of long dashed dotted line elements and result	116
4.5 Comparison of task unit and the execution times predicted by the keystroke-level model	121
4.6 Predicted execution times of task units for proposed software	122
4.7 Predicted execution times of task units for AutoCAD	123



4.8	Execution time in sessions of AutoCAD and proposed software	125
B.1	Dimension of symbol	148
B.2	Types of lines and applications	149
C.1	Formats of Geometry Coordinate Data	154
C.2	Specifying Attributes for CGM Formats	158
C.3	Specifying Attributes for DXF Formats	160



## LIST OF FIGURES

Figure		Page
1.1	Range of line width controller choices of <i>AutoSketch</i>	3
2.1	Graphic file structure	12
2.2	Structure of vector files	19
2.3	Dimension of drawing paper	29
2.4	Size system overview	29
2.5	Classical waterfall model	34
3.1	Work flow of methodology	41
3.2	Flow diagram of the prototype's system requirements	42
3.3	Delphi's working windows	44
3.4	Available components of Delphi version 5 Standard	45
3.5	Analysis of drawing sheet information	47
3.6	Analysis of line information	51
3.7	Analysis of displaying information	52
3.8	Analysis of printing information	53
3.9	Procedures and data flow diagram of printing process	56
3.10	Procedures and data flow diagram of displaying process	60
3.11	Procedures and data flow diagram of erasing process	62
3.12	Procedures and data flow diagram of storing process	64
3.13	Window of the project at design-time	67
3.14	Sequence of a mechanical component drawing	69



4.1	Folder tree of prototype	71
4.2	Prototype's interfaces of 2D software	72
4.3	Menu bar and pull-down menu	73
4.4	Printer setting dialog box	75
4.5	Layer and its properties displaying	76
4.6	Help dialog	76
4.7	Items of drawing sheet box, line group box and layer control box	78
4.8	Layer and its properties displaying	79
4.9	Mark dialog box and an example	82
4.10	Straight line dialog box and an example	83
4.11	Layout dialog box and an example	84
4.12	Arc dialog box and an example	84
4.13	Circle dialog box and an example	85
4.14	Ellipse dialog box and an example	86
4.15	Rectangle dialog box and an example	87
4.16	Polygon dialog box and an example	87
4.17	Text dialog box and an example	88
4.18	Status bar	89
4.19	Flow chart of program initializing	90
4.20	Acquisition of current line width variable	93
4.21	Acquisition of pen width variable and length of line configuration	93
4.22	Flow chart of line drawing algorithm	96
4.23	Line erasing algorithm	97



4.24	Flow chart of printing algorithm	98
4.25	Format of drawing file	100
4.26	Drawing of the component (Hasting, 1975)	103
4.27	Front view drawing	104
4.28	Top view drawing	104
4.29	Actual size printed drawing in 0.25 mm group of line width	106
4.30	Actual size printed drawing in 0.35 mm group of line width	107
4.31	Actual size printed drawing in 0.5 mm group of line width	108
4.32	Actual size printed drawing in 0.7 mm group of line width	109
4.33	Actual size printed drawing in 1 mm group of line width	110
4.34	Actual size printed drawing in 1.4 mm group of line width	111
4.35	Actual size printed drawing in 2 mm group of line width	112
4.36	Description and Attribute section of geometric file	117
4.37	“DwgControl” section of geometric file	118
4.38	“Entity” section of geometric file	119
4.39	Proposed software drawing with 0.5 mm and 0.25 mm line width	126
4.40	AutoCAD drawing with 0.5 mm and 0.25 mm line width	127
4.41	Proposed software drawing with 1 mm and 0.5 mm line width	128
4.42	AutoCAD drawing with 1 mm and 0.5 mm line width	129
B.1	Graphical symbols for orthographic representations:	148
B.2	Dimension of dashed line	151
B.3	Application of dashed line	151
B.4	Dimension of long dashed dotted line	152
B.5	Application of long dashed dotted line	152



B.6	Dimension of long dashed double-dotted line	153
B.7	Application of long dashed double-dotted line	153
E.1	Printer setting dialog box	165
E.2	Straight line input dialog	167



## NOMENCLATURE

2D	2 dimensions space
3D	3 dimensions space
ADA	A computer language derived from Pascal, used primarily by the military.
ANSI	The American National Standards Institute
ASCII	American Standard Code for Information Interchange
B-reps	Boundary representation
Bézier Curve	A curve that is calculated mathematically to connect separate points in smooth, free-form curves and surfaces of the type needed for illustration programs and CAD models.
Bitmap	A graphics file format which store, manipulate, and represent images as rows and columns of tiny dots.
BSI	British Standards Institution
CAD	Computer-Aided Design
CGM	Computer Graphics Metafile: a file format for the storage and retrieval of picture information.
CRT	Cathode-Ray Tube, an electron tube, or evacuated glass container
CSG	Constructive Solid Geometry
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardization)
dpi	Dot Per Inch
DXF	Data Exchange File
HCI	Human-Computer Interface
IGES	Initial Graphics Exchange Standard
ISO	The International Organization for Standardization



JISC	Japanese Industrial Standard Committee
MIT	The Massachusetts Institute of Technology
Modula-2	Language that emphasizes modular programming. High-level language based on Pascal, characterized by lack of standard functions and procedures.
RAD	Rapid Application Development
Raster Graphics	A method of generating graphics in which images are stored as multitudes of small, independently controlled dots (pixels) arranged in rows and columns.
SAGE	Semi-Automatic Ground Environment
STEP	Standard for the Exchange of Product Model Data
SDPM	Software Development Process Model
Vector Graphics	A method of generating images that uses mathematical descriptions to determine the position, length, and direction in which lines are to be drawn.

## **CHAPTER 1**

### **INTRODUCTION**

Engineering drawing is the main method of communication between all persons concerned with design and manufacture of components (Boundy, 1980). Its main role functions as a graphic language transmitting ideas from the draughtsman or designer to the end user, management and professional engineering staff for carrying out engineering projects. The technical drawing standards have been issued with the implementation of the International Organization for Standardization (ISO). They are presented as technical drawing according to the international manufacturing language of engineering in most countries.

Generally, most of the countries that are rich in industrial manufacturing technology also established official agency that approves and develops standards. The American National Standards Institute (ANSI), British Standards Institution (BSI), Deutsches Institut für Normung e.V. (DIN, the German Institute for Standardization), and Japanese Industrial Standard Committee (JISC) are examples of standard agencies found in the United States of America, Britain, Germany and Japan respectively. ANSI and BSI implemented the Imperial unit for their standard while DIN and JISC implemented the Metrics system. As the role of predominant industrial countries, some of their standards are adopted as ISO international standards in



the Metric system, for example, the unit for length is measured in millimeter (mm).

Among the ISO standards, mechanical engineering drawing is standardized in various aspects including the size and layout of drawing sheets, application styles, representation of drawing elements and application in CAD system.

### **1.1 Problem Statement**

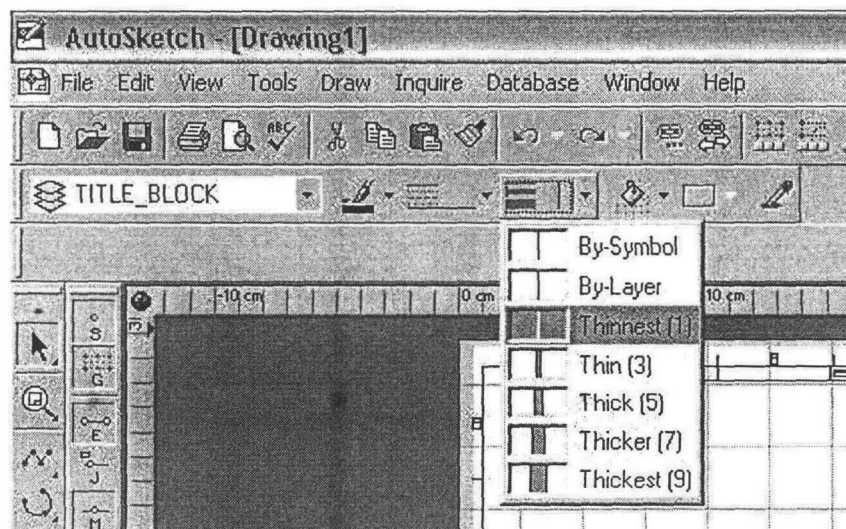
Generally, ISO mechanical engineering drawing comprised of continuous line and non-continuous line. Non-continuous lines are the lines that are drawn with the combination of line element such as gap, dot, dash and long dash. These lines are called dashed line, long dashed dotted line and long dashed double dotted line. They can be made in any size of the width that specified by ISO. However, the lengths of line elements are proportioned to line width.

Recently, the commercial CAD software products in the market, such as *AutoCAD* and *AutoSketch* of *AutoDesk* and *Solid edge* of *Unigraphics Solutions Inc* usually support both American standards and ISO standards to software. Their efficiency line widths, line types and line proportions control, can be used to create drawings in different ways.

For controlling the line width and line type in the drawing process and modifying process, AutoCAD requires six steps for drawing process and two

steps for modifying process. In drawing process consists of the steps as loading line types, creating layers, setting line type, setting line weight, drawing the line and editing line proportion in the object properties. However, in modifying process consists of line weight and line proportion editing.

Meanwhile, *AutoSketch Release7*, which is developed for fast and accurate 2D drawing, comprises of the tools to control the line properties that almost the same as AutoCAD approaches, such as layer controller, line style controller and line width controller. Although it provides some tools for setting line width and line type, but line width and proportion of line element are not as ISO standard because the line width control component is not provided the real number value, as seen in Figure 1.1.



**Figure 1.1:** Range of line width controller choices of *AutoSketch*



*Solid edge* is one of the software products for high performance 3D modeling. In version 11, *Draft* module is used for creating the drawing in 2D mode. It embraces two standards, ANSI and ISO. Although it provided the control of line type and width, but the tool for controlling the line element proportion is excluded. Thus, the length of line elements is not proportioned to the line width as specified in the ISO standard.

In conclusion, the *Draft* module which is comprised of the tools to control line width and line type as designated by ISO except for the line elements proportion which is uncontrollable. As *AutoSketch*, it has not provided sufficient precise component to set line width. AutoCAD is an automatic version of CAD software product that can create the drawing as the ISO line constraints. However, its complex procedures are arisen, especially in modifying process. Some features of commercial software are shown in Table 1.1.

Table 1.1: Some features of commercial software

Features	AutoCAD	AutoSketch	Solid edge
Allocate line width as designated in ISO	Yes	No	Yes
Create line type as designate in ISO	Yes	Yes	Yes
Proportionate line elements to line width as designated in ISO	Yes	No	No
Support 3D	Yes	No	Yes
Price	RM14,000 to RM18,000	RM400 to RM700	Not Available