

Jože Duhovnik · Ivan Demšar
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Space Modeling with SolidWorks and NX

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Preface

This book is for the reader who wants to acquire new engineering skills related to concrete, complex solutions through the modeling of objects in 3D space. Anyone who has ever dealt with modeling, or just simple drawing, soon finds out that the straightforward examples from exercises are easily repeatable. However, there are few such examples in real-life. Therefore, we have decided to offer a better and more detailed presentation of the complex shapes and problems associated with the modeling of real objects. Based on our years of experience with a large number of people through graduate and master's study programs we have decided to opt for the gradual acquisition of knowledge, which leaves it well grounded in the student.

The extent of the material exceeds that required for regular study. However, there are a couple of universities that deal in detail with such basic knowledge, the basic language of engineers, i.e., the ability to present new products and ideas. Our cooperation with industry, various institutes, and our long experience in designing products with various complexities have resulted in a wide range of examples compared to regular monographs. We leave the readers to form their own opinions about the large number of presented examples.

We should point out that the transferring of dimensions and details to technical documentation represents the pinnacle of modeling. Of course, anybody dealing with the quality and perfection of products is aware of this. Should the readers find that the presented knowledge about detailed modeling and the special forms of technical language are both new and interesting, and that they are able to generalize and use it confidently, we will derive great satisfaction.

During the Bologna reforms, our colleagues suggested that in the first semester students should acquire new knowledge about descriptive geometry and technical drawing. In the second semester, this knowledge is upgraded with skills related to space modeling. At the end of the semester, the students are made familiar with transferring a shape to the high-quality representation of a product by means of technical documentation. Our 8 years of experience has shown that in later stages—in machine elements, energy systems, and manufacturing engineering courses—students can easily present their ideas using complex models. This was a proof of our intention to also include knowledge about the high-quality presentation of ideas in the 3D environment in a new profile of engineering competences.

Developing methods and the complexity of models for industrial design, for example, requires familiarity with free-form surfaces, which will be the next

logical step after the content of this book. We believe that the presented systematics will allow both students and their teachers to easily recognize the upgrade to their existing knowledge. This belief was also confirmed by our staff engineers, who were willing to attend special courses to upgrade these skills, mainly in 2D space.

The hand-sketching chapter was taken from the book “Engineering Graphics,” where a co-author is Prof. Milan Kljajin from Strossmayer University (Osijek, Croatia). He confirmed that we were able to use this content. We would like to express many thanks to him for this permission. Our book would be incomplete without this chapter.

A book of this size cannot be written by a single author. A substantial contribution to its final form came from a team of Ph.D. students, Damijan Zorko and Pavel Tomšič. Mateja Maffi, Simon Demšar, and Paul McGuinness took care of the translation and proofreading, and the technical editing was carried out by Janez Krek. They all deserve sincere gratitude for their tolerance and patience.

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Contents

1	Introduction	1
1.1	Arranging Rooms for the Study of Modelling	3
1.2	Development and Design Process and Engineering Graphics	4
2	Technical Freehand Sketching	15
2.1	Sketching Basics	15
2.2	CAD and Technical Freehand Drawing	17
2.3	Basic Rules of Freehand Drawing	18
2.3.1	Material, Sketching Tools	18
2.3.2	Sketching Straight Lines	20
2.3.3	Sketching Curved Lines	29
2.4	CAD and Technical Freehand Sketching	34
2.4.1	Procedural Sketching	36
2.4.2	Stroke Sketching	42
2.5	Sketching Spatial Drawings	42
2.5.1	Presenting a Half Cross-Section	43
3	3D Modelling	49
3.1	Topological Elements in a 3D Modeller	50
3.1.1	Point	51
3.1.2	Edge	53
3.1.3	Loop	54
3.1.4	Surface	55
3.1.5	Volume	55
3.2	Presenting 3D Models	56
3.2.1	Wireframe Model	56
3.2.2	Surface Model	57
3.2.3	Volume (Solid) Model	58
3.3	Geometric Transformations	63
3.3.1	Translation	64
3.3.2	Rotation	65

3.3.3	Scaling	66
3.3.4	Mirroring.	67
3.3.5	Perspective Projection.	68
4	3D-Modelling Software Packages	71
4.1	Introduction	71
4.2	SolidWorks	72
4.2.1	Menu Bar	72
4.2.2	Command Manager and Toolbars.	73
4.2.3	Heads-Up View Toolbar	73
4.2.4	Manager Window.	74
4.2.5	Task Pane	77
4.2.6	Status Bar	78
4.2.7	Graphic Area	78
4.2.8	SolidWorks Options	80
4.3	Siemens NX PLM	83
4.3.1	Introductory Window	83
4.3.2	Manipulating the View in the Graphic Window	85
4.3.3	Ribbon Bar	85
4.3.4	Top Border Bar	87
4.3.5	Resource Bar	88
4.3.6	Radial Tool Bar/Shortcut.	89
4.3.7	Keyboard Shortcuts.	92
4.3.8	NX Options	94
4.3.9	Application Tab	94
4.3.10	Synchronous Modelling.	94
4.3.11	Command Finder	95
5	Extrusion	97
5.1	Manufacturing Technology	97
5.2	Modelling Prismatic Objects	99
5.2.1	Object Formation in Space	100
5.2.2	Basic Sketches on the Basic Plane	101
5.2.3	Extrusion of a Basic Sketch on a Plane Into Space.	103
5.2.4	The Formation of Complex Shapes and Details Using Extrusions	105
5.3	Modelling in SolidWorks.	108
5.3.1	Basic Form	108
5.3.2	Cut-Out on the Front Top Part.	111
5.3.3	Cone Cut-Out 30 × 10 mm on the Back Top Part	111
5.3.4	Groove Modelling 8 × 4 mm.	112
5.3.5	Creation of Through Holes $\phi 8.5$ mm	113

5.3.6	Slot Modelling $\phi 13 \times 20$ mm	113
5.3.7	Grove Modelling 25×8 mm on the Bottom Part	114
5.3.8	Final Model	114
5.4	Modelling in NX	116
5.4.1	The Creation of a Model	116
5.4.2	The Positioning of an Object in Space	116
5.4.3	Basic Sketch	118
5.4.4	The Creation of a Basic Sketch	119
5.4.5	Cut-Out on the Front Part of the Model	120
5.4.6	Prismatic Cut-Out 30×10 mm on the Top Upper Part	122
5.4.7	Modelling of a Small Groove 8×4 mm on the Bottom of the Cone Cut Out	122
5.4.8	Modelling of Through Holes $\phi 8.5$ mm on the Basic Sketch	123
5.4.9	Modelling of a Slot $\phi 13 \times 20$ mm	125
5.4.10	Modelling of a Special Groove 25×8 mm	125
5.4.11	Final Model	127
5.5	Examples	129
6	Revolving	135
6.1	Manufacturing Technology	135
6.2	Modelling of Axisymmetric Models	136
6.2.1	Positioning of an Object in Space	137
6.2.2	Positioning of the Basic Sketch	137
6.3	Modelling in Solid Works	141
6.3.1	Basic Shaft Form	141
6.3.2	Formation of Centre Bores	143
6.3.3	Formation of the Retaining Ring Grooves	144
6.3.4	Formation of the Keyseats	145
6.3.5	Edge Filleting and Chamfering	148
6.3.6	Final Model	148
6.4	Modelling in NX	149
6.4.1	Positioning of an Object in Space	149
6.4.2	Formation of a Base Sketch in the Plane XC–YC	150
6.4.3	Revolving into Space	150
6.4.4	Modelling a Centre Bore	151
6.4.5	Modelling of the Retaining Ring Groove	154
6.4.6	Modelling a Keyseat	156
6.5	Examples	161

7	Sweep	167
7.1	Manufacturing Technology	167
7.2	Modelling Products with Constant Cross-Sections	169
7.2.1	Positioning an Object in Space.	170
7.2.2	Creating a Base Sketch	170
7.2.3	Sweep	170
7.3	Modelling in SolidWorks.	173
7.3.1	Creating a Guide Curve.	173
7.3.2	Setting a Cross-Section profile.	174
7.3.3	Curve Sweep	174
7.3.4	Shape Complementing	176
7.3.5	Final Model.	176
7.4	Modelling in NX	178
7.4.1	Creating the Guide Curve	179
7.4.2	Creating a Cross-Section Profile.	180
7.4.3	Complementing the Technological Shape	180
7.5	Examples.	184
8	Loft-Transition.	191
8.1	Manufacturing Technology and Use	191
8.2	Modelling Objects with a Variable Cross-Section.	193
8.2.1	Placing an Object in Space	193
8.2.2	Creating a Base Sketch	194
8.2.3	Transition in Space.	194
8.3	Modelling in SolidWorks.	196
8.3.1	Positioning the Cross-Sections	196
8.3.2	Forming a Transition in Space	196
8.3.3	Creating the Inlet Part of the Casing.	197
8.3.4	Creating the Shell.	200
8.3.5	Adding the Central Part.	201
8.3.6	Adding the Guide-Vane Blades	202
8.3.7	Completing the Shape and the Final model	204
8.4	Modelling in NX	204
8.4.1	Setting the Main Cross-Sections for Loft-Transition	204
8.4.2	Creating the Guide Curve and Orienting the Curves of the Cross-Sections	204
8.4.3	Creating a Transition Through Cross-Sections by Means of the Guide Curve	209
8.4.4	Completing the Shape.	209
8.5	Examples.	217

9	Supplementing the Shape	221
9.1	Manufacturing Technology and Use	221
9.2	Auxiliary Shapes in the Modelling Process	222
9.2.1	Fillet	223
9.2.2	Chamfer	224
9.2.3	Shelling	225
9.2.4	Ribs	226
9.2.5	Draft	226
9.2.6	Patterning Geometric Entities (Pattern)	228
9.2.7	Mirroring Geometric Entities (Mirror)	229
9.3	Modelling in SolidWorks	229
9.3.1	A Base Model	231
9.3.2	Reinforcing Ribs	233
9.3.3	Attachment Holes	234
9.3.4	Draft	236
9.3.5	Fillet	236
9.3.6	Final Model	237
9.4	Modelling in NX	240
9.4.1	Creating a Rough Model	240
9.4.2	Chamfer	240
9.4.3	Carving the Cover (Shell)	240
9.4.4	Patterning Geometric Entities (Pattern)	243
9.4.5	Rib Modelling (Rib)	244
9.4.6	Mirroring About a Plane (Mirror)	245
9.4.7	Creating Bores (Bore-Hole)	246
9.4.8	Draft Modelling (Draft)	246
9.4.9	Adding Detailed Edge Blends	250
9.5	Examples	254
10	Welding a Construction	259
10.1	Manufacturing Technology and Use	260
10.2	Modelling Welded Constructions	261
10.2.1	Modelling Welded-Beam Constructions	261
10.2.2	Modelling Other Welded Constructions and Marking Welded Assemblies	264
10.3	Modelling in SolidWorks	267
10.3.1	Creation of the System Structure: Skeleton	267
10.3.2	Profile Formating Through Skeleton	267
10.3.3	Extrusion in Space	270
10.3.4	End-Forming Profiles	271
10.3.5	Welds Modelling	271

10.3.6	Cut List of Individual Parts of a Welded Construction	273
10.3.7	Final Model of the Welded Construction of a Chair	273
10.4	Modelling in NX	274
10.4.1	Creation of the System Structure: Skeleton	274
10.4.2	Formation of a Standard Profile	276
10.4.3	Extrusion of Profiles in a Skeleton Structure	279
10.4.4	End Formation of the Profiles	282
10.5	Examples.	293
11	Sheet-Metal Bending.	297
11.1	Manufacturing Technology and Use	298
11.2	Modelling Sheet-Metal Products.	299
11.2.1	Definition of the Material's Parameters.	300
11.2.2	Methods of Modelling Sheet-Metal Products	300
11.2.3	Features and Settings	301
11.2.4	Setting Bent Edges	304
11.2.5	Modelling Sheet-Metal Products.	305
11.3	Modelling in SolidWorks.	306
11.3.1	Creating the Base Shape	306
11.3.2	Adding Edge Flanges	308
11.3.3	Completing the Shape	312
11.3.4	Unfolding the Sheet Metal and Cutting	313
11.3.5	Final model	316
11.4	Modelling in NX	317
11.4.1	Selecting a Module for Modelling Sheet-Metal Products	317
11.4.2	Creating the Base Shape	318
11.4.3	Adding Edge Reinforcements.	320
11.4.4	Completing the Shape	325
11.4.5	Flat Surface of the Sheet-Metal Product's Final Shape	328
11.5	Examples.	332
12	Modelling Physical Models and Parameterization	335
12.1	Measuring Physical Models	336
12.2	Base Model	339
12.2.1	Screw Parameterization.	341
12.2.2	Bearing Parameterization.	344
12.3	Modelling in SolidWorks.	344
12.3.1	Rough Shape	344
12.3.2	Detailed Shape.	345

12.3.3	Parameterization	347
12.3.4	Generation of a Configuration	348
12.4	Modelling in NX	351
12.4.1	Creation of a Rough Shape of the Model	351
12.4.2	Formation of a Detailed Shape of the Model	353
12.4.3	Formation of the Generator of Parts	359
12.5	Examples.	364
13	Assemblies	367
13.1	Technology	367
13.2	Modelling Assemblies.	371
13.2.1	Assembly Structure.	371
13.2.2	Bottom-Up Building of an Assembly	371
13.2.3	Top-Down Building of an Assembly.	372
13.2.4	Relations Between the Components in an Assembly	373
13.3	Modelling in SolidWorks.	374
13.3.1	Preparing Components	374
13.3.2	Assembly: Bottom-Up Design Technique	377
13.3.3	Modelling a Housing in the Top-Down Technique	383
13.3.4	Final Assembly Model	388
13.3.5	Exploded View	388
13.4	Modelling in NX	388
13.4.1	Bottom-Up Method.	388
13.4.2	Top-Down Method	398
13.5	Examples.	409
14	Technical Documentation (Drawing)	413
14.1	Assembling Drawing.	413
14.2	Manufacturing Drawing.	418
14.3	Modelling in SolidWorks.	419
14.3.1	Drawing Sheet Format	419
14.3.2	Views	421
14.3.3	Dimensioning.	427
14.3.4	Marks in the Figure	428
14.3.5	The Title Block of the Drawing	432
14.4	Modelling in NX	434
14.4.1	Format and the Title Block of the Drawing	435
14.4.2	Defining Views of 3D Objects.	437
14.4.3	Break-Out View	441
14.4.4	Creating Details (Detail View).	443
14.4.5	Dimensioning.	443

14.4.6	Tolerances and Matings.	445
14.4.7	Miscellaneous Marks in the Drawing	445
14.5	Examples.	451
15	Modellers and Technical Documentation	455
15.1	The Size of Written Text and Dimensions.	455
15.2	Automated Dimensioning	456
15.3	Labelling Cross-Sections	459
15.4	Hatching	468
15.5	Presenting the Section Planes of Axes and Screws	472
15.6	Parts List.	477
References	489

Chapter 1

Introduction

Abstract Various layouts are presented for the working places in a classroom that allow communications between the tutor and the students. This is followed by a presentation of the different forms of engineering graphics that are subject to changes in the Research and Development (R&D) process. This R&D process includes three loops in the research and strategic parts, and a golden loop in the development phase. The developments of the graphic expression from the sketch to the working documentation are specified, and directly connected with the phases of the R&D process.

A knowledge and understanding of space and its dimensions are important for both engineers and designers. Some people are born with a talent to understand space, objects and their distribution, while others can learn it. However, such a talent must be developed, which makes learning about and understanding the concept of space vital, even for the most talented of individuals. Learning provides a solid basis for a detailed study of space, particularly the systematic organization of space. Excellence in terms of knowledge is acquired through constant training and the resulting improvement. Should engineers or designers not learn about the fundamental forms of expression, such as a sketch on a piece of paper and/or a digitised model on a screen, they will gradually lose the ability to present their ideas with clarity.

Without training, they forget that it would be better to replace their gesticulating and gobbledygook with a pencil and paper in their hands. Of course, instead of a pencil, it is often enough to take a piece of clay brick, and some concrete or a rock for the writing surface. With a sketch it only takes a few lines to present our thoughts clearly. At first sight, this method of presentation might seem too rough to create new ideas; however, it is a fact that an initial idea is often presented with very rough concepts. An idea that originates in the abstract, conceptual world of an engineer represents creativity that is later reflected in the real-world environment. This is the virtue of having an engineering understanding of the world, as each line, each thought, expressed by a sketch, provides the reliability of connections. Together with numerical proofs it provides the possibility for modern man to be able to live in

tall buildings and to travel by aeroplanes, trains and ships. It is difficult to imagine a person using a flat in a skyscraper or flying in aeroplanes with a feeling that the skyscraper might fall apart or the aeroplane might not take off because, in such a technical system, an object would not have been specified in all the required details.

The objective of a space-modelling course is to acquire the practical engineering and designer skills to express 3D shapes and the necessary variations by assorted means of expression. The exercises during this course provide training that will reinforce an individual's knowledge. The course is suitable for the first year, second semester of a university study programme, in order to provide a student of technology or design with the fundamental knowledge of expressing and specifying a shape in space, similar to the need for a solid basis in mathematics, physics, materials science.

It is possible to gain an understanding of space modelling immediately after gaining the basics of descriptive geometry and technical documentation. The lectures and exercises take place weekly. They are structured in such a way that the students upgrade their knowledge from simple objects to complex models. The whole course of exercises includes three interactive knowledge assessments. Such a course of exercises requires quality software and computer equipment. Special attention has been paid to this area as it is not possible to acquire high-quality knowledge without high-quality hardware and software. Good computing equipment provides a good response during the use of individual routines, while high-quality software provides reliability for the performance of the modelling.

Particular knowledge is presented through examples of characteristic shapes and features. Each characteristic shape is presented with a short introduction, followed by presenting the use of the feature in the manufacturing process. General description is presented, which is useful for all modelling software. In the next two sub-chapters we describe modelling with SolidWorks software, which is more user-friendly for beginners. This is followed by NX, which belongs to the area of advanced modelling software. Our objective is not to teach the routines for a particular software package, i.e., SolidWorks or NX in our case, but to teach the modelling philosophy with the use of features from different shapes that are more or less the same for all modelling software. The differences between the different modelling-software packages lie mainly in the user interfaces.

In preparing the work programme for basic modelling we have included all the necessary skills, knowledge and findings that complement the need for acquiring a comprehensive knowledge of solid-body modelling. Table 1.1 shows the topics that a student at a good university will cover (2 h per week) and the knowledge that he or she can acquire with additional study and training at home after 30 h of exercises.

From the presented programme it is clear that there is a special emphasis on the individuality of the exercises. This means that it is not appropriate for two students to do the exercises behind a single screen or on one computer. It goes without saying that the structure of the classroom and the software for systematic exercises require a special approach, i.e., a special architecture for the room. High-quality software, integrated into a unit, is also vital.

Table 1.1 The topics and the order of tutorials for space modelling

Exercise no.	Topic covered during exercises	Note
1.	Role and meaning of modelling for engineering	Introductory tutorial, Boolean algebra, sketching
2.	Making a sketch and extrude	
3.	Making a sketch and revolve	
4.	Auxiliary shapes of modelling	Fillet, chamfer
5.	Assessment—combined models	
6.	Complex shapes—sweep, loft	Sweep, loft
7.	Welded structures	
8.	Sheet-metal products	
9.	Measuring a physical model, digitising, parameterisation	
10.	Assessment—physical models	
11.	Assemblies of structures with models—bottom-up technique	
12.	Assemblies of structures with models—top-down technique	
13.	Documentation—assembly drawing	
14.	Documentation—working drawing	
15.	Assessment—examples as finished units	Seminar work

1.1 Arranging Rooms for the Study of Modelling

Organizing a suitable room for a small group is an important task. Exercises can only be performed well if at least one assistant (a leader and an assistant, who could be a student from a higher grade) is available for every 6–8 students. A suitable group has between 12 and 16 students. With two experts in the room for an accelerated interaction with the students, the access to the students should be fast. This is achieved by providing at least 60–70 cm of space behind the seats for the expert to gain access to each student.

Larger classrooms with up to 30 places are possible; however, the work then slows down significantly, despite having up to twice as many experts. In this case there are four experts in each classroom (and three in special cases). The classroom plan for 16 places is shown in Fig. 1.1. A classroom with 32 places is shown in Fig. 1.2. In the case that the classroom is narrower and longer, the plan can be designed in accordance with the template in Fig. 1.3.

Because a programme-integrated environment is vital for a quick response and good communications with the students, it is shown on its own in Fig. 1.4. The concept involves a joint server with 16 working places and the main specifications of the hardware that were available on the market between 2010 and 2014.

Fig. 1.1 Classroom plan for 16 working places and connections

1.2 Development and Design Process and Engineering Graphics

Engineering uses different demonstration techniques: writing (describing), mathematical formulae (equations) and drawing (sketching, modelling). Writing is a matter of general human education, whereas mathematical formulae are a way to use equations in order to describe natural phenomena. Engineering drawing is used to show nature in space. Artistic drawing, on the other hand, serves a different purpose. The latter describes things as realistically and as clearly as possible, whereas engineering drawing in its final form yields a plan. This plan should be as clear to as many users of different cultures and skills as possible, and was the basis for the introduction of the standards for engineering expression, i.e., technical drawing. Such engineering expression through drawing is generally referred to as engineering graphics.

The more sophisticated is a product, the more detailed is the knowledge of engineering graphics that needs to be applied. While thinking, in the abstract world, when a rough, immaterialized idea is emerging, we should begin with a freehand sketch. Freehand sketching uses specific techniques and requires a certain level of knowledge. The techniques of freehand drawing are based on manual dexterity, and on refined motoric functions of the hands and fingers. For this reason it is vital to learn

Fig. 1.2 Classroom plan for 32 working places and connections

freehand-drawing techniques so that our records will be clear and unambiguous, in a similar way to clear writing.

Unskilled engineers, not using a sophisticated freehand-drawing technique, will express themselves with a lower quality. It is difficult for them to articulate an idea; it is difficult to place it in space. With freehand-drawing techniques it is vital to take account of the abilities in proportional ratios, in both details and dimensions.

As engineers, we develop and study how to make people's lives in their surroundings easier in practical terms. And so, developing the world, we think how to work smoothly in a process that allows us to materialize an idea with a product in the form of an object. In this view we have developed different approaches and procedures, one of them being the R&D process. In this process, individual phases are specified. They are then processed consecutively, depending on the expected results of the task during each phase. As a rule, they are not limited in terms of detailed analyses and researches in a particular phase, nor by going back to the previous phase for further information. The R&D process is known as iterative, supplementing and generally based on the decisions of the team or its decision makers. What to expect as a result in each phase is specified in descriptive, analytical-mathematical, and graphic forms. Generally, there are several forms of R&D processes as well as different methods

Fig. 1.3 Classroom plan for 32 working places and connections (an extended classroom with a screen of the same size)

of processing. In this book we will elaborate on one that was developed in both theory and during work on projects. The model is not limited to a traditional industrial product. It is generalized and includes all the necessary synergy of knowledge. The R&D procedure was first published by Duhovnik [7] as the Golden Loop in the Design & Development process in 2003 at TU Delft and University of Wroclaw. It was then supplemented with early-phase research on the technology of processes [12] that a product should provide (Fig. 1.5).

At this point the focus will be on the main parts of the R&D process. More information and a more detailed explanation are available in the literature.

The innovative loop is of key importance for recognizing a problem and placing it in space. In the innovation loop we specify the task, the requirements and the wishes that play a part in defining a problem or a technological process (e.g., cutting

Fig. 1.4 Network lecture room with hardware capabilities

bread, lifting a liquid and taking it into the mouth—a spoon is intended for the same process in both Chinese and European cuisines). All rough starting points are generally supported by rough sketches, rough models (Plasticine, real models made out of wood or virtual—digitised). Together with specifying the shape of an expected object, its function—described by parameters—should also be defined. However, not all parameters are of the same importance. The important parameters are identified by means of various methods. They are called the winning parameters. The winning parameter of each function is the one that significantly affects the fulfilment of a particular function, so it is called the winning parameter of the main function (it can be physical, chemical, biological, etc.).

The system-engineering loop places an expected result (innovation, a high-quality product)—vital for the materialization of a product—logically into space and time. An innovation that is not system-defined in the engineering, general, social environments, generally receives no response from the market or users, which keeps such an invention at the level of a hobby.

The application research loop is important in order to define the parameters that provide an optimum choice of function in the material, the conceptual and the user's

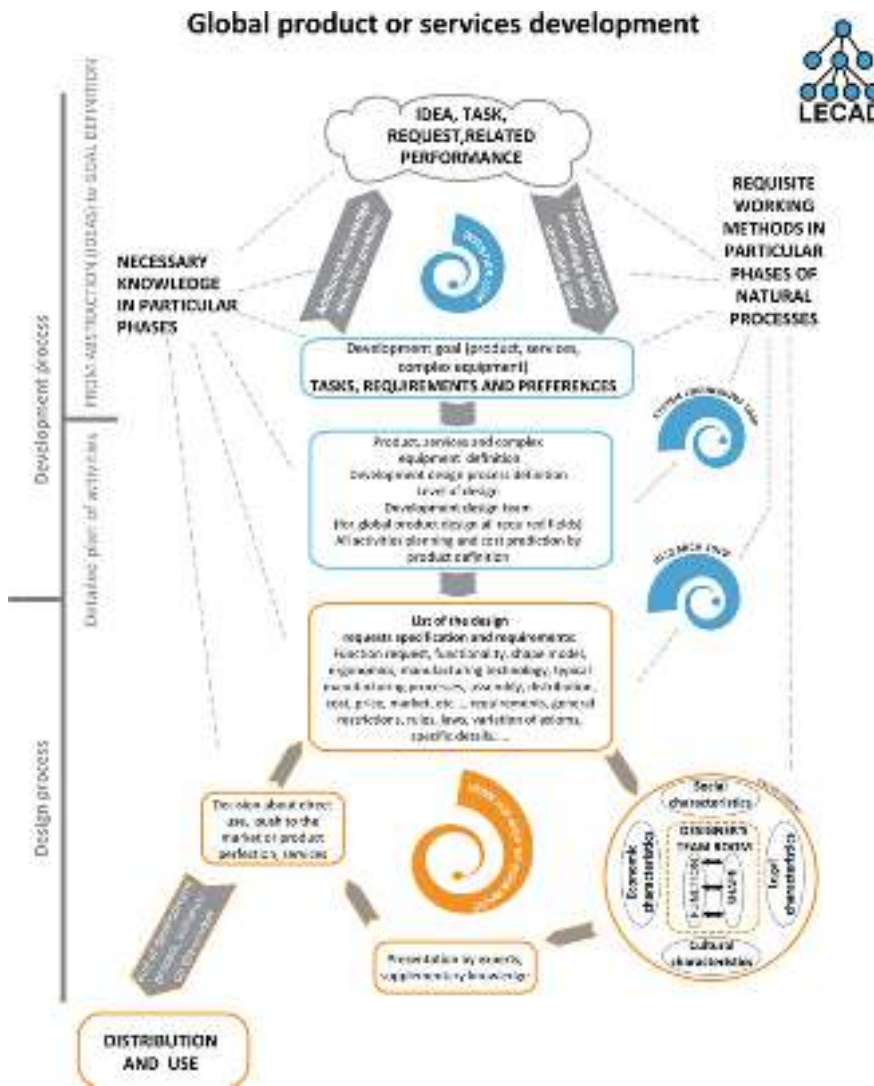


Fig. 1.5 The R&D process includes four loops [12]

environment. Fundamental and application researches are in tune with and of vital importance for the development of mankind. Supported by engineering solutions, they are the key to the reliable, high-quality and long-term development of mankind. Any deviation from the integrity and the connection between fundamental and application researches is a clear sign of the level of the development of a particular environment.

The golden loop in the development process defines a product in all its details, supplements fundamental researches for all key parameters that define the details and quality materialization of a product. These are referred to as application researches, and they are vital for defining the perfection of a product. Without detailed application researches—dealing with the interaction between the basic process and the material environment—a product cannot be sustainably and well placed in space and time. It was for this reason that it was termed the “golden loop”.

With such a recognized R&D process it makes sense to determine the role of engineering graphics. It is up to the engineer to choose the forms of engineering graphics to be used during the individual phases of the R&D process.

At the beginning of development, man expressed quantity in the form of analogue notes and tried to reproduce them. However, there has always been a desire to digitise analogue records. Therefore, besides text digitising (in the form of ASCII code) at an accelerating rate due to its simplicity, there were increasing attempts to digitise the notes. At first, dot recognition was used; however, high-quality records take up a lot of memory. Together with dot recording, there were also attempts to describe sketches with vectors. Vector graphics found their way into engineering sketching, and recording specific shapes, including free, random areas, takes up significantly less memory.

Vector expressions are presented in various books and form the basis for the development of mathematical relations in all modelling software, including SolidWorks and NX. For reasons of simplicity and accessibility for a larger number of users, this book expresses engineering shapes using commands that will become standard in the communications between man (the user) and computer. The mathematical basics will be briefly presented in the third chapter. In engineering graphics it is our objective to quickly acquire a digitised record of a developing product, which is then translated into other types of analyses and simulations. So, we will skip transferring shapes from one software package to another, e.g., from modelling software into FEMs (finite-element methods), CFD (computational fluid dynamics) or Moldflow (Simulation Moldflow software provides simulation tools for injection-mould design, plastic-part design, and the injection-moulding design process).

A sketch should be digitised as soon as possible and presented in 2D or 3D space. When we have rough, less-accurate data in the sketch, the product model (Fig. 1.6) is rough, too.

We can then proceed to a rough product model, or a wooden model, clay, hard polystyrene or Plasticine. In this case, 2D or 3D scanners are used to capture their dimensions, which are then transferred into modelling software in a digital form (Fig. 1.7).

Prior to the system engineering loop we need and expect to develop significant engineering details with rough calculations of the loads and deformations. Text and mathematical equations are generally used to describe the functions for such analyses. For shapes, it is a freehand sketch or sketching in a digital model. With modelling software, there are different approaches to sketching detailed shapes, which are then logically introduced into the basic digitised model. A shape, presented with a model, forms the basis to establish a link between the function and the shape in the research

Fig. 1.6 Engineering graphics in the R&D process for the four characteristic loops

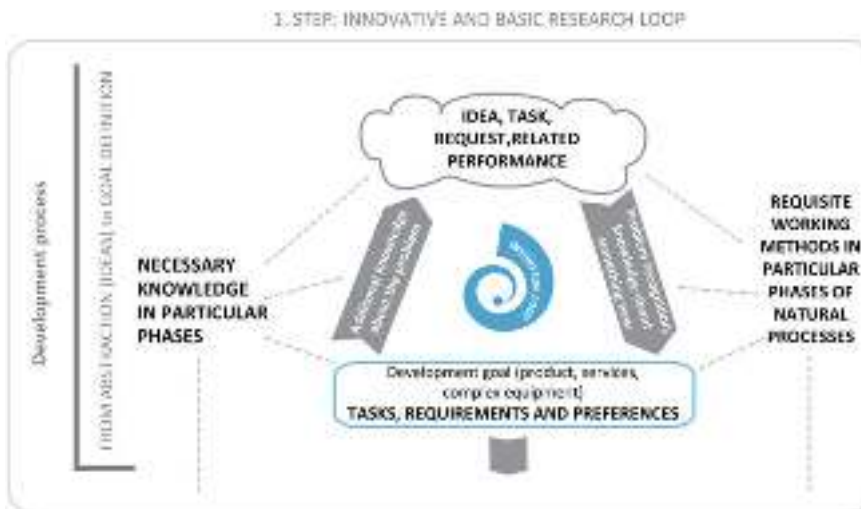


Fig. 1.7 Research and innovative loop and its detailed activities

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