Queen Mary University of London

EBU5608 Product Development and Management

Topic 10 – Detail Design & Prototypes

©Paltalidis 2024

Queen Mary University of London

Agenda

- **Phase 3 - Detail Design**
  - Aim
  - Control Documentation
  - Departmental responsibilities
- **Prototype**
  - Definitions: Prototype, Prototyping
  - Phases of prototypes
  - Uses of prototypes
  - Types of prototypes

©N.Paltalidis 2024

Queen Mary University of London

Phase 3 – Detail Design

Queen Mary University of London

Phase 3 – Detail Design

- Phase 3 includes
  - the **complete specification** of the
    - geometry (i.e. physical dimensions)
    - materials, and
    - tolerances

    of **all** the unique **parts** in the product, and
  - the **identification** of all of the standard parts to be **purchased** from suppliers
- Two **critical issues** addressed in the detail design phase are
  - production cost and
  - robust design (or performance)

Today – Use of Prototype

See in Topic 11 and 12 for more details

©N.Paltalidis 2024

Queen Mary University of London

Control documentation

- The **output** of Phase 3 is the **control documentation** for the product
- The control documentation is:
  - The **drawings** or computer **files** describing the **geometry** of each part to be made and its production **tooling**
  - The process descriptions for the **fabrication** and **assembly** of the product
  - The specifications of the parts to be **purchased**

Queen Mary University of London

Departmental responsibilities

- Departmental responsibilities in this phase are
  - **Marketing**
    - Develop marketing plan
  - **Design**
    - Define part **geometry**
    - Choose **materials**
    - Assign **tolerances**
    - Complete industrial design **control documentation**

©N.Paltalidis 2024

Queen Mary University of London

Departmental responsibilities (cont.)

- **Manufacturing**
  - Define piece-part **production** processes
  - Design **tooling**
  - Define **quality assurance** processes



Queen Mary
University of London

Design for X Topics

- Design for Manufacturing
- Design for Production
- Design for Assembly
- Design for Recycling/Disposal
- Design for Life Cycle
- Design for Environment

©N.Paltalidis 2024

Queen Mary University of London

Product Development Process

- Prototyping is done throughout the development process
- It becomes most important at the Detail Design stage, and Testing stage

Queen Mary
University of London

Use of Prototypes in Phase 3 - Detail Design

©N.Paltalidis 2024

Queen Mary University of London

What is a prototype?

- In some industries, a prototype is a **small-scale model**:
  - a miniature car
  - a miniature building or town

Queen Mary University of London

What is a prototype / characteristics of a prototype?

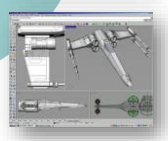
Or, it can be (among other things):

- a series of screen sketches
- a storyboard, i.e. a cartoon-like series of scenes
- a Powerpoint slide show
- a video simulating the use of a system
- a lump of wood (e.g. iphone)
- a cardboard mock-up
- **a piece of software with limited functionality written in the target language or in another language**

©N.Paltalidis 2024

Queen Mary University of London

What is a prototype?



- A prototype is
  - "an **approximation** of the product along one or more dimensions of interest"
  - i.e.
    - Industrial designers produce **prototypes** of their concepts, such as models
    - Engineers **prototype** a design
    - Software developers write **prototype** programs
- **Prototyping** is the **process** of developing such an approximation of the product

Queen Mary University of London

What is a prototyping?

Prototyping is the process of quickly putting together a **working model** (a prototype) in order to test various aspects of a design, illustrate ideas or features and gather early user feedback.- Wikipedia

IEEE defines **prototyping** as " A type of development in which emphasis is placed on developing prototypes early in the development process to permit early feedback and analysis in support of the development process."

©N.Paltalidis 2024

Queen Mary University of London

3 Phases of Prototyping

- There are **3 phases** of prototyping
- **Alpha** prototypes
  - Are typically used to assess whether the product works **as intended**
- **Beta** prototypes
  - Are typically used to assess **reliability** and to identify remaining **bugs** in the product
- **Pre-production** prototypes
  - Are the first products produced by the entire **production process**

Queen Mary University of London

Alpha Prototypes

- Early (alpha) prototypes are usually built with **production-intent** parts
  - These are parts with the same **geometry** and **material properties** as intended for the production version of the product
  - They will look similar to and perform the basic functions of the product
  - They are **not** necessarily **fabricated** with the actual processes to be used in production
- Alpha prototypes are tested to determine whether
  - the product will **work as designed**
  - the product satisfies the key **customer needs**

©N.Paltalidis 2024

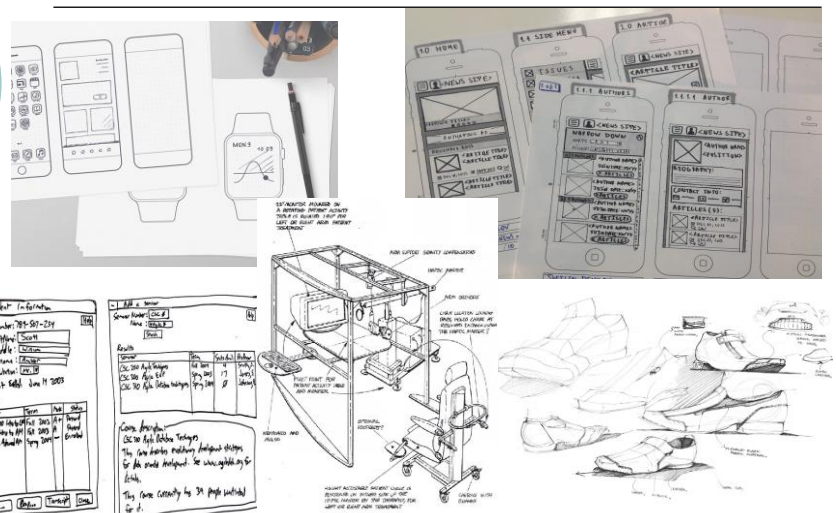
Queen Mary University of London

Beta Prototypes

- Later (beta) prototypes are usually built with parts supplied by the intended **production** processes
  - but may **not** be assembled using the intended final **assembly** process
- Beta prototypes are extensively evaluated **internally** and are also typically tested by **customers** in their own use environment
- The **goal** for the beta prototypes is usually to answer questions about **performance** and **reliability** in order to identify necessary engineering changes for the final product

Queen Mary University of London

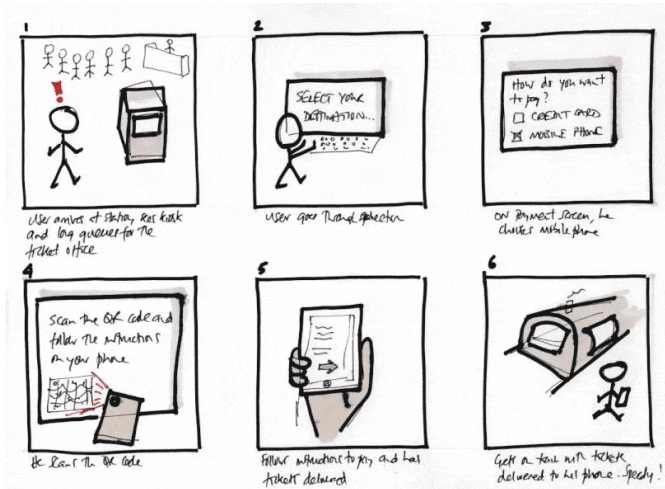
Prototyping example: Sketches



©N.Paltalidis 2024

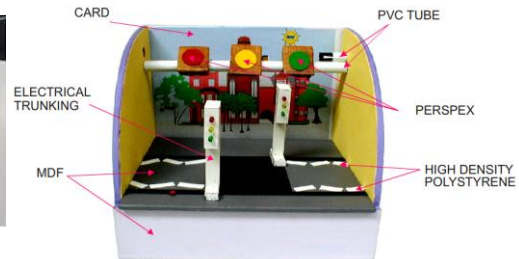
Queen Mary University of London

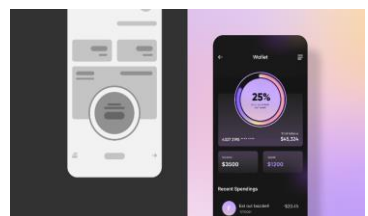
Prototyping example: Storyboard



Queen Mary University of London

Soft and Hard Models





©N.Paltalidis 2024

Queen Mary University of London

Uses of Prototypes

- There are four main uses of prototypes:
  1. **Learning**
     - Answering questions about performance or feasibility , such as
       - "Will it work?"
       - "How well does it meet the customer needs?"
     - For example, a proof-of-concept model

Queen Mary University of London

Uses of Prototypes (cont.)

2. **Communication**

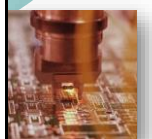
- Demonstration of a product to get **feedback** from all stakeholders
  - e.g. top management, vendors, partners, extended team members, customers and investors

- A **physical**, tactile, 3D representation of a product is much easier to understand than a verbal **description** or even a **sketch** of a product
  - e.g. 3D physical models of style or function

©N.Paltalidis 2024

Queen Mary University of London

Uses of Prototypes (cont.)

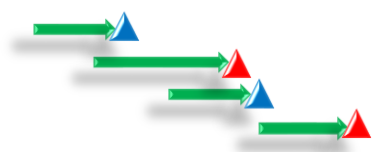


3. **Integration**
   - Prototypes are used to ensure that **components** and **subsystems** of the product **work** together as expected
   - **Comprehensive physical** prototypes are the most effective as **integration** tools in product development projects because they require the **assembly** and physical **interconnection** of all of the parts and subassemblies that make up a product
   - The integration of the prototype forces **coordination** between different **members** of the product development team
   - For example: alpha or beta test models

Queen Mary University of London

Uses of Prototypes (cont.)

4. **Milestones**
   - Provide goals for the development team's **schedule**
   - Milestone **prototypes** are defined in the product development project **plan**
     - 'Go/no go' decisions can be at these points



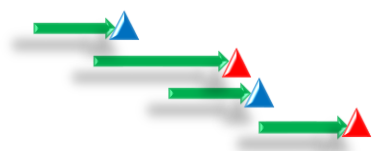
©N.Paltalidis 2024

Queen Mary University of London

Uses of Prototypes - milestones (cont.)

Mentimeter

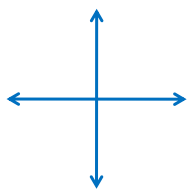
- The **number** of such prototypes and their **timing** is one of the key elements of the overall **development plan**
- As a **base case**, the development team should consider using alpha, beta and pre-production **prototypes** as milestones
  - e.g. first testable hardware



Queen Mary University of London

Types of Prototypes

- Prototypes can be classified along two dimensions
- **Physical** v **analytical**
  - Physical – e.g. a wooden model
  - Analytical – e.g. a computer model
- **Comprehensive** v **focussed**
  - Comprehensive - **most** of the **attributes** of the real product
  - Focussed – **one or a few attributes** of the real product



©N.Paltalidis 2024

Queen Mary University of London

Prototyping Example: iRobot PackBot Mobile Robot

Queen Mary University of London

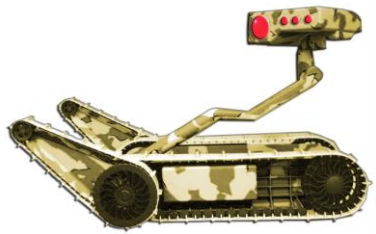
Physical prototype

- Physical prototypes are **tangible artefacts** created to approximate the product
- Aspects of the product of interest to the development team are actually **built** into an artefact for **testing** and **experimentation**
- **Examples** of physical prototypes include
  - **models** which look and feel like the product
  - **proof-of-concept** prototypes used to test an idea quickly
  - experimental **hardware** used to validate the functionality of a product

©N.Paltalidis 2024

Queen Mary University of London

Physical Prototypes



Looks-like model for customer communication and approval

Wheel prototype under load during creep testing

Sand test

Ulrich and Eppinger (4th ed., 2008) Exhibit 12-3

Queen Mary University of London

Analytical prototype

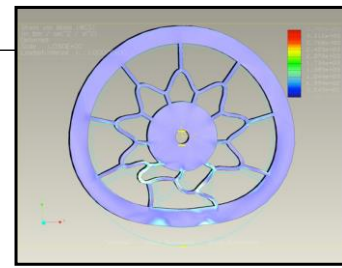
- Analytical prototypes represent the product in a non-tangible, usually **mathematical**, manner
- Interesting aspects of the product are **analysed**, rather than built
- Examples of analytical prototypes include
  - computer **simulations**
  - systems of **equations** encoded within a spreadsheet
  - computer models of three-dimensional **geometry**

©N.Paltalidis 2024

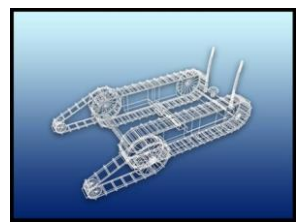
Queen Mary University of London

Analytical Prototypes

3D CAD rendering



Finite-element analysis



Dynamic simulation model

Ulrich and Eppinger (4th ed., 2008) Exhibit 12-4

Queen Mary University of London

Comprehensive prototype

- Comprehensive prototypes implement **most**, if not all, of the **attributes** of a product
- A comprehensive prototype corresponds closely to the **everyday use** of the work prototype – i.e. it is a **full-scale**, **fully operational** version of the product
- An example of a comprehensive prototype is one given to customers in order to identify any remaining design flaws before committing to production

©N.Paltalidis 2024

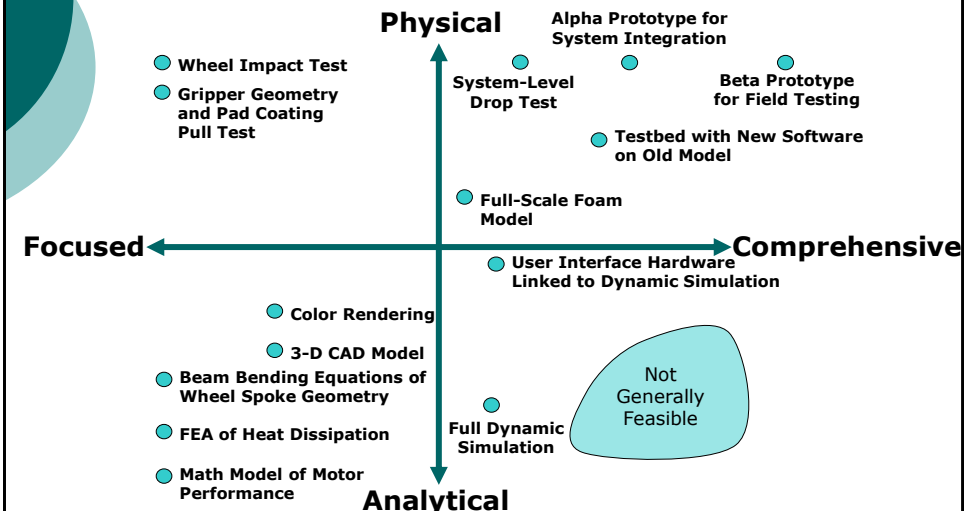
Queen Mary University of London

Focused prototype

- Focused prototypes implement **one**, or a **few**, of the attributes of a product
- Examples of focused prototypes include foam models to explore the **form** of a product and wire wrapped circuit boards to investigate the **electronic performance** of product design
- A common practice is to use **two or more** focused prototypes together to investigate the **overall** performance of a product
  - One of these prototypes is often a "looks-like" prototype, the other a "works-like" prototype
- By building two separate focused prototypes, the team may be able to answer its questions much earlier than if it had to create one comprehensive prototype

Queen Mary University of London

Types of Prototypes



Ulrich and Eppinger (4th ed., 2008) Exhibit 12-5

©N.Paltalidis 2024

Queen Mary University of London

Physical vs. Analytical prototypes

Physical prototypes

- **Tangible** approximation of the product
- May exhibit **unmodelled** behaviour
- Some behaviour may be a consequence of the **approximation**
- Often best for **communication**

Analytical prototypes

- **Mathematical** model of the product
- Can only exhibit behaviour arising from **explicitly modelled** phenomena (However, behaviour cannot always be predicted)
- Some behaviour may be a consequence of the **analytical method**
- Often allow more experimental **freedom** than physical models

Focused vs. Comprehensive prototypes

Focused prototypes

- Implement **one** or a **few** attributes of the product
- Answer **specific questions** about the product design
- Generally **several** are required

Comprehensive prototypes

- Implement **many** or **all** attributes of the product
- Offer opportunities for **rigorous testing**
- Often best for **milestones** and **integration**

©N.Paltalidis 2024

Queen Mary University of London

Prototyping technologies

- There are **many** technologies for prototyping including **high-speed machining, casting, moulding and extruding**

Some are very **old** – e.g. clay models

Two **newer** ones are

- **3D CAD modelling and analysis**
  - Allow easy, rapid changes
  - Can calculate dimensions accurately
  - Can feed into manufacturing tools

- **Free form fabrication**
  - also known a 3D printing
  - allows very rapid production of physical prototypes

Principles for choosing a Prototype type

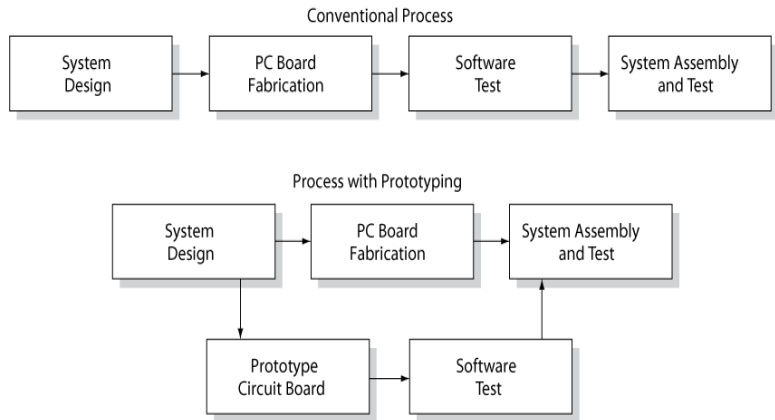
- Analytical prototypes are in general more flexible than physical prototypes
- Physical prototypes are required to detect unanticipated phenomena
- Prototypes may reduce the risk of costly iterations
- Prototypes may expedite other development steps
  - Example: add a prototyping step in the part design-mold design-molding process
- A prototype may restructure task dependencies

©N.Paltalidis 2024

Queen Mary University of London

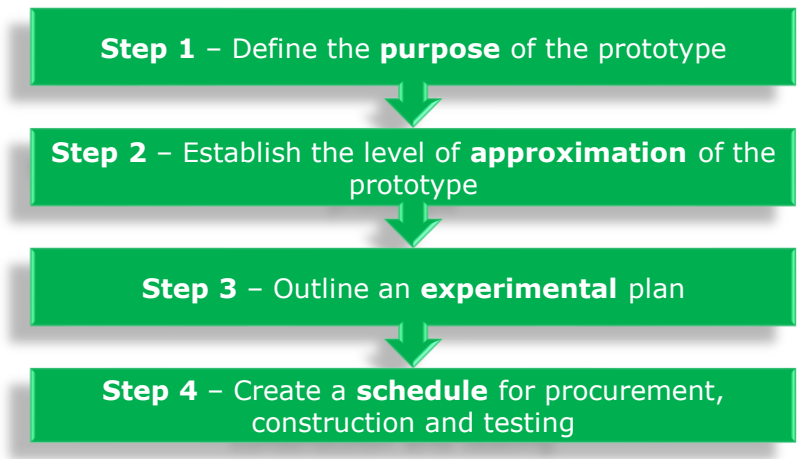
A prototype may restructure task dependencies

Mentimeter



From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

Planning a prototype
- the 4 steps (Ulrich and Eppinger)



©N.Paltalidis 2024

Queen Mary University of London

Planning a prototype - step 1

- Step 1 - define the **purpose** of the prototype
  - The team lists its specific **learning** and **communication** needs
  - Team members also
    - list any **integration** needs
    - decide whether or not the prototype is intended to be one of the **major milestones** of the overall product development project



Planning a prototype - step 2

- Step 2 – Establish the level of **approximation** of the prototype
  - The degree to which the **final** product will be **approximated** in the prototype must be defined
  - The team should consider whether a **physical** prototype is **necessary** or whether an **analytical** prototype would best meet its needs
  - In most cases the best prototype is the **simplest one** that will serve the purposes established in **Step 1**

©N.Paltalidis 2024

Queen Mary University of London

Planning a prototype - step 3

- Step 3 – Outline an **experimental** plan
  - The use of a prototype in product development can be thought of as an **experiment**
  - Good **experimental practice** helps to make sure that you get the maximum value from the prototyping activity
    - i.e. that you get useful test results

Planning a prototype - step 3 (cont'd)

- The experimental plan includes:
  - the identification of the **variables** of the experiment
  - the test **protocol**
  - an indication of what **measurements** will be performed
  - a plan for **analysing** the resulting data
- When **many variables** have to be explored, good experimental design makes this process much easier and more effective

©N.Paltalidis 2024

Queen Mary University of London

Example of a prototype planning template

- Consider a computer trackball

Queen Mary University of London

Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)

©N.Paltalidis 2024

Queen Mary University of London

Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
Level of Approximation	• Ball surface material as planned for production design • Support material as planned for production design • Support contact geometry as planned for production design

Queen Mary University of London

Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
Level of Approximation	• Ball surface material as planned for production design • Support material as planned for production design • Support contact geometry as planned for production design
Outline of Test Plan	• Build two sets of five different spacings for ball support • Test two balls with different inertias • Test spacings of 12.75, 13.00, 13.25, 13.50, 13.75 mm for each of the two ball inertias • Verify that all the spacings provide at least minimally acceptable performance • Have at least 20 users rank order the prototypes according to feel

©N.Paltalidis 2024

Queen Mary University of London

Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
Level of Approximation	• Ball surface material as planned for production design • Support material as planned for production design • Support contact geometry as planned for production design
Outline of Test Plan	• Build two sets of five different spacings for ball support • Test two balls with different inertias • Test spacings of 12.75, 13.00, 13.25, 13.50, 13.75 mm for each of the two ball inertias • Verify that all the spacings provide at least minimally acceptable performance • Have at least 20 users rank order the prototypes according to feel
Schedule	12 August Parts available 12 August Parts assembled 20 August Tests completed 22 August Analysis of results completed

Queen Mary University of London

Prototyping strategy

- Use prototypes to reduce **uncertainty**
- Make models with a **defined** purpose
- Consider **multiple forms** of prototypes
- Choose the **timing** of prototype cycles
  - Many **early models** are used to validate concepts
  - Relatively **few comprehensive** models are necessary to test integration
- Plan time to **learn** from prototype cycles
  - **Avoid** the "hardware swamp" - where you keep building different ways out of a problem without stopping to think

©N.Paltalidis 2024

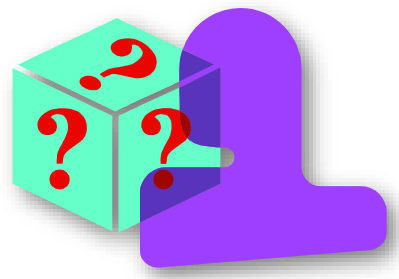
Queen Mary University of London

Summary

- Product development almost always requires the building and testing of prototypes.
- A prototype is an approximation of the product on one or more dimensions of interest.
- Prototypes are used for learning, communication, integration, and milestones.
- Prototypes can be usefully classified along two dimensions: (1) the degree to which they are physical as opposed to analytical and (2) the degree to which they are comprehensive as opposed to focused.
- Several principles are useful in guiding decisions about prototypes during product development.

Queen Mary University of London

Questions?



Go to www.menti.com to post your questions

Mentimeter

©N.Paltalidis 2024

Queen Mary University of London

Reading

- **Core Textbook** (Ulrich & Eppinger, 7th Edition)
  - Chapter 14. Prototyping
    pages 295 – 313

©N.Paltalidis 2024