Chapter 14: Prototyping

Lecturer
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Teaching source book:
Chapter 14 of
Product Design and Development
Karl T. Ulrich & Steven D. Eppinger
Outline

- Irobot PackBot
- Understanding Prototypes
  - Definition
  - Types of prototypes
  - What are prototypes used for?
- Principles of Prototyping
- Prototyping Technologies
- Planning for prototypes
Irobot PackBot

- Today's example case
Understanding Prototypes

• Prototype is an approximation of the product along one or more dimensions of interest
## Physical vs. Analytical Prototype

<table>
<thead>
<tr>
<th>Physical</th>
<th>Analytical</th>
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<tbody>
<tr>
<td>• Tangible approximation of the product</td>
<td>• Nontangible, mathematical or visual model of the product</td>
</tr>
<tr>
<td>• Model that look and feel like the product</td>
<td>• Example: computer simulations, 3D cad, system of equation</td>
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<tr>
<td>• Proof-of concept prototypes</td>
<td>• Often allow more experimental freedom than physical models.</td>
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<tr>
<td>• Used to test idea quickly</td>
<td></td>
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<tr>
<td>• Validation of the functionality</td>
<td></td>
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<tr>
<td>• Best for communication</td>
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Focused vs. Comprehensive

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

**Comprehensive**
- Implement many or all attributes of the product.
- Full scale, fully operational version of the product.
- “Looks-like” or “works-like”
- Examples: foam models to explore the form of a product, hand built circuit boards to investigate electrical performance.
Analytical prototype

3D CAD for customer proposal

Finite-element analysis of wheel spoke geometry

Dynamic simulation model
From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)
What are prototype used for?

- **Learning**
  - Answering questions such as: “will it work?”, “how well does it meet the customer needs?”
  - Can be focused-physical or focused-analitical

- **Communication**
  - Usually physical prototypes
  - Communicate with customer, top management, vendors, among engineers etc.
What are prototype used for?

• Integration
  – Make sure that components and subsystems work together as expected
  – Integrate the perspectives of different functions on a development team (marketing, design, manufacturing)
  – Example:

  ![Prototype Example](image)

  This Alpha Model had Radio antennas on top center (exposed)
  This Beta Model had Radio antennas built into the body and improvements to the tracks
What are prototype used for?

- **Milestone**
  - Goals for the team, demonstrate progress, enforce the schedule.
  - Prototype made for passing “qualification test” before production
Principles of Prototyping

- Analytical prototypes are generally more flexible than physical prototypes
  - Example: changing a dimension in 3D cad modeling is really quick

- Physical prototypes are required to detect anticipated phenomena
  - Physical prototypes often exhibit unanticipated phenomena
  - Physical prototypes intended to investigate purely geometric issues will also have thermal and optical properties
A prototype may reduce the risk of Costly Iterations.

Compare between the conventional process vs process with prototyping.

Why the probability of success increases in process with prototyping?
A prototype may reduce the risk of costly iterations.

Products that are high in risk or uncertainty because of the high cost of failure, new tech will benefit from such prototypes.

Products that failure costs are low and the technology is well known do not gain as much benefit from prototyping.
• A Prototype may expedite other development stage

Example:
A CAD model can be used to make a prototype of the mold!

From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)
A prototype may restructure task dependencies.

With prototyping, a set of tasks can be completed in parallel way.
Prototyping Technologies

• 3D CAD Modeling and Analysis
  – Solidworks/Pro-e/NX/Inventor/sketch-up and many more
  – Finite Element Method
  – Computational Fluid Dynamics

• Free Form Modeling → rapid prototyping
  – Stereolithography
  – 3D printing → additive manufacturing technology

• Conventional manufacturing technology
  – CNC machining
  – Rubber molding, silicone molding,
  – Material: wood, plastic, foam
Prototyping Technologies

3D CAD Modelling enable many kinds of analysis:
- fitting & assembly
- manufacturability
- form and style
- kinematics
- finite element analysis, crash testing, CFD and many more

Example: Finite Element Method analysis
Planning for Prototypes

1) Define the purpose of the prototype
2) Establish the level of Approximation of the prototype
3) Outline an Experimental Plan
4) Create a Schedule for Procurement

Example

<table>
<thead>
<tr>
<th>Name of Prototype</th>
<th>PackBot Wheel Geometry/Impact Test</th>
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</thead>
<tbody>
<tr>
<td>Purpose(s)</td>
<td>• Select final wheel spoke geometry and materials based on strength and shock absorption characteristics.</td>
</tr>
<tr>
<td></td>
<td>• Confirm that wheels absorb shock to withstand impact and protect the PackBot and its payload.</td>
</tr>
<tr>
<td></td>
<td>• Correct wheel spoke geometry, materials, and platform load.</td>
</tr>
<tr>
<td>Level of Approximation</td>
<td>• Build 12 test wheels using six different materials, each with two spoke shapes.</td>
</tr>
<tr>
<td>Experimental Plan</td>
<td>• Mount the wheels to the test fixture.</td>
</tr>
<tr>
<td></td>
<td>• Conduct impact tests at a range of drop heights.</td>
</tr>
<tr>
<td>Schedule</td>
<td>1 August select wheel designs and materials complete design of test fixture</td>
</tr>
<tr>
<td></td>
<td>7 August wheels and test fixture constructed</td>
</tr>
<tr>
<td></td>
<td>14 August assembly completed</td>
</tr>
<tr>
<td></td>
<td>15 August testing completed</td>
</tr>
<tr>
<td></td>
<td>23 August analysis of test results completed</td>
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<tr>
<td></td>
<td>25 August</td>
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Courtesy of iRobot Corp.