Chapter 36
Prototyping Robotic Systems:
Methodology and Case Studies

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ABSTRACT

This chapter provides an experience-based framework of prototypes development and commissioning. It introduces elements learned directly from the practice that encompass aspects of project management, technology development process, and commercialization in the context of Small and Medium Enterprises (SMEs). The contents of this chapter are based mainly on the author's practical experience of leading an SME technology developer. The author is also a faculty member working as a researcher and teacher. Because of the interrelationship between research and technology development, his views and perception of the topic may be unique, and they are personal. The chapter presents a general framework for robotic systems prototyping. To back up the points made in the chapter, three case studies of robotic prototyping are included to help the reader perceive the outlined concepts.

INTRODUCTION

Robotics research is the framework for studying hypotheses and conjectures, synthesizing new ideas, and discovering phenomena in the context of robotic systems. The research usually leads to peer-reviewed publications, occasional patenting, and in some cases, construction of working prototypes that may or may not have commercial value or intent. Prototypes are normally used for proof-of-principle and functional demonstration. In many cases they are part of the product design and development process. In direct relationship to successful demonstrations of new technology using prototypes, and the existence or emergence of related markets, the prototypes could end up being used or redesigned for commercialization. The market may even accept, albeit rarely, a demonstration prototype as the first generation product. Yet, such prototypes normally would be re-designed at a later stage as commercial prototypes. The process of prototyping is complex, costly, and risky.

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A prototype is an early sample or model of a concept, idea, or process that would allow preliminary functional and performance evaluation to be conducted through experimentation. Prototypes serve as benchmarks against which the original idea is measured in terms of representation, functionality, and even manufacturability and servicing of the related product. The early evaluation helps alleviate the concerns and uncertainty as to whether or not the new product will actually perform what and how it is expected to, as new product designs, more often than not, raise unexpected problems.

A prototype is used as part of the product design process to allow exploring design alternatives, and confirm functionality and performance prior to proceeding to the design of the commercial prototype, and much earlier than introducing the new product to the market. Prototypes are used also to confirm and verify market interest and readiness to accepting a new product; other times, prototypes are used to verify the performance or suitability of a specific product or features for executing certain tasks.

In some product development organizations, prototyping specialists are employed - individuals with specialized skills and training in general prototype development and fabrication techniques. They can help bridge between theoretical ideas, designs, and the fabrication of commercial prototypes as a prelude to products.

This chapter addresses prototyping from the perspective of new robotic product development. It is a process similar to general prototyping, but it does not benefit from the anticipated experience with earlier products as reference. Prototyping in robotics is by-and-large opportunistic, and constrained only by the original idea and its functional purpose.

BACKGROUND

There is no general agreement on what constitutes a "prototype" and the word is often used interchangeably with the word "model," which may cause confusion. In general, "prototypes" can be of four basic types:

- **Proof-of-Principle Prototype**: In electromechanics it is sometimes called a breadboard. This type of prototype is used to test specific features of the intended design without attempting to emulate the visual appearance, required materials, or assembly process. Such prototypes are used to identify which design features may not work, and where further in-depth development and testing is necessary.
- **Functional Prototype**: This type of prototype allows designers to explore the basic size, look and functionality of a new product. It can help assess ergonomic factors, and provides insight into industrial design of the product. These prototypes capture the intended design aesthetic and emulate the appearance of the intended product. These prototypes are intended for marketing, and are generally durable enough to be shown and use by representative users and consumers. The prototypes are suitable for use in critical design reviews and photo shoots for sales literature.
- **Commercial Prototype:** This prototype provides the final design, aesthetics, materials and functionality of the intended product. The construction of this fully working full-scale prototype is the ultimate test of the original concept and the engineers' final check for design flaws to allow further improvements to be made before larger production runs begin.
- **Production Prototype:** The difference between the commercial and production prototypes is expressed by three elements:
  - **Material:** Production materials may require specific manufacturing processes involving higher capital costs than what was used for prototyping;