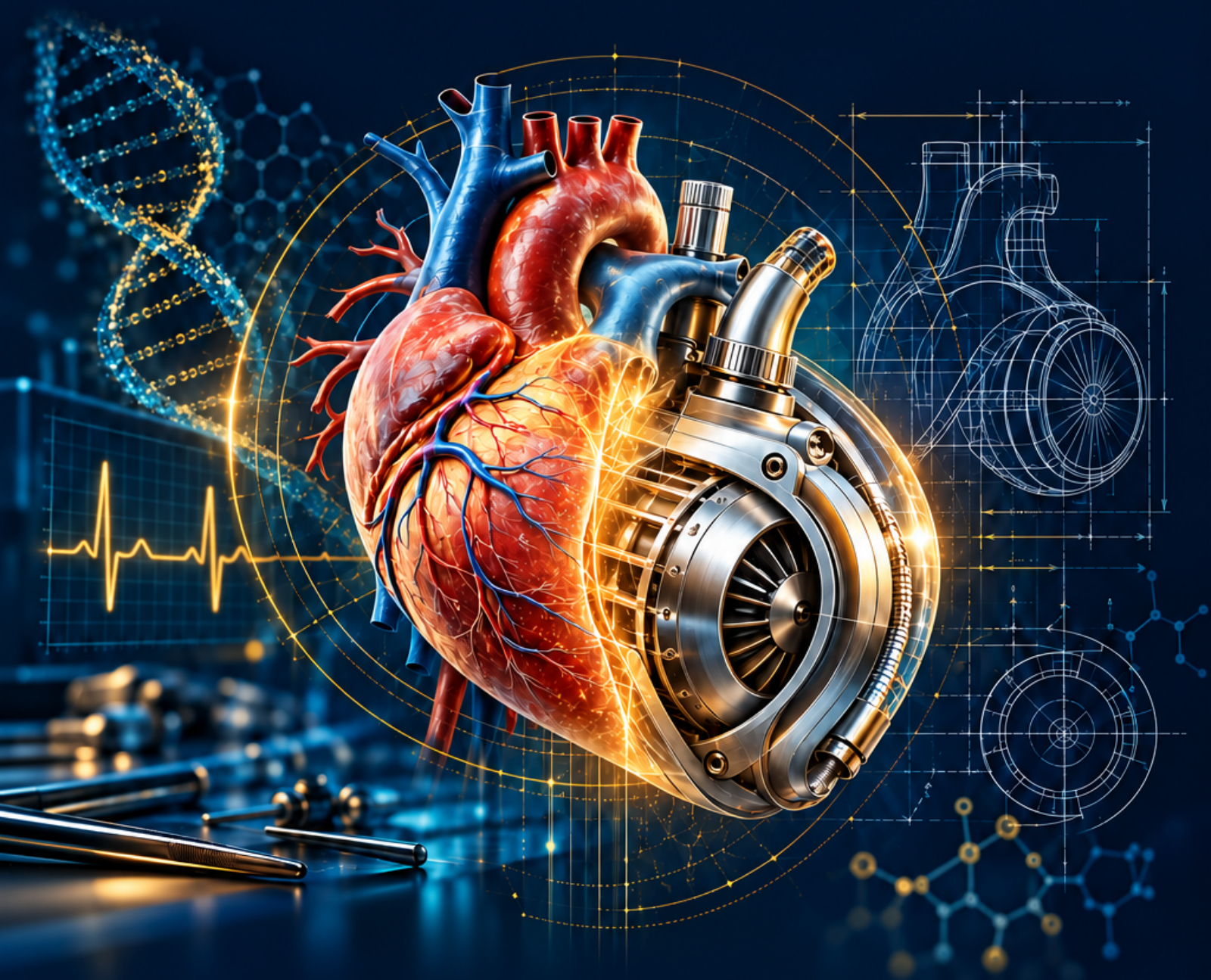


SYSTEMATIC INNOVATION IN MEDICAL ENGINEERING

TRIZ, Design Thinking and
Generative AI in Bioengineering



Sylvio Silveira Santos, Eng.

First Edition • 2026

Be transformed by renewing your mind (*)

Generative AI In Bioengineering and Instrument Analysis and Processes

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Dedication

To my beloved wife,

Maria de Lourdes Biagioni Santos, *In Memoriam*,
whose quiet presence, wisdom, and love continue to illuminate my path beyond
time.

To my dear sons,

Maria Silvia and **Celso Henrique**, whose lives, strength, and affection have
been a constant source of meaning and inspiration.

To **Simon Dewulf** and **Darrell Mann**, outstanding TRIZ specialists, for the use
of their methods in some parts of this book.

And with profound gratitude to **Professor Michael Orloff, Dr. Sc.**,
founder of the Modern TRIZ Academy, for his vision, encouragement, and
support which has inspired much of the intellectual spirit behind this work.

Sylvio Silveira Santos, Eng.

Enhanced Table of Contents (Commented)

Applications of TRIZ, Design Thinking and DIVA - PROFUN (PROPERTY-FUNCTION) in Medical Instrumentation

Chapter 1

Objectives and Scope of the Study

Comment:

This opening chapter explains the motivation for the work: the growing need for systematic innovation methods in modern medicine. It introduces the methodological framework used throughout the book, combining **TRIZ**, **Design Thinking**, and **Innovation Logic – DIVA® (ProFun®)** as complementary approaches to medical technological innovation.

The chapter also explains how the case studies were selected and what the reader can expect from the analytical structure used in the following chapters.

Chapter 2

Altshuller's Laws of Technological Evolution Applied to Diagnostic Medicine

Comment:

This chapter presents the **standard TRIZ Laws of Technological System Evolution**, originally formulated by **Genrich Altshuller**, and interprets them within the context of medical technologies.

Examples from diagnostic medicine illustrate how systems evolve toward:

- increased dynamization
- higher controllability
- miniaturization
- increased system intelligence

The chapter provides the **conceptual foundation** used in the subsequent case studies.

Chapter 3

Artificial Hearts: A TRIZ Perspective on the Evolution of Cardiac Substitution Systems

Comment:

Artificial heart technologies are analyzed as a case study of technological evolution. The chapter discusses:

- early mechanical cardiac pumps
- implantable ventricular assist devices
- total artificial hearts
- future autonomous bio-hybrid systems

Using TRIZ principles, the analysis reveals the **patterns guiding the evolution of cardiac replacement technologies**.

Chapter 4**Portable Ultrasound Devices: Miniaturization and Functional Integration****Comment:**

This chapter studies the rapid evolution of **portable ultrasound systems**, which moved from large hospital equipment to handheld diagnostic tools.

The analysis focuses on:

- miniaturization trends
- integration of digital signal processing
- AI-assisted diagnostics
- mobile medical imaging

TRIZ laws such as **increasing ideality** and **transition to micro-level technologies** are illustrated through this example.

Chapter 5**TRIZ and Design Thinking in the Analysis of a Robotized Hospital****Comment:**

This chapter examines the concept of a **robotized hospital**, where logistics, diagnostics, and surgical operations are increasingly automated.

The analysis combines:

- TRIZ (system evolution and contradictions)
- Design Thinking (user-centered innovation)

The discussion explores how hospitals may evolve toward **highly automated medical ecosystems** integrating robotics, AI, and telemedicine.

Chapter 6

Masks and Veins Under the Scrutiny of TRIZ and Design Thinking

Comment:

This chapter analyzes two apparently simple medical devices—**respiratory masks** and **vascular access systems**—to demonstrate how even simple technologies contain hidden innovation potential.

The chapter illustrates how TRIZ and Design Thinking can reveal:

- contradictions in comfort vs. efficiency
 - materials innovation
 - improvements in usability and safety
-

Chapter 7

Porous Materials with Active Elements in Innovation Logic – DIVA®

Comment:

This chapter introduces **Innovation Logic – DIVA® (ProFun ®)**, developed by **Simon Dewulf**, and applies it to the study of **porous biomaterials with active elements**.

The analysis explores how variation in parameters such as:

- structure
- density
- composition
- surface activity

can lead to new generations of **drug-delivery materials and therapeutic scaffolds**.

Chapter 8

Robotic Surgery

Comment:

This chapter analyzes the evolution of **robot-assisted surgery**, including the widely used **da Vinci Surgical System**.

Topics include:

- minimally invasive surgical robotics
- surgeon-robot interaction
- precision and motion scaling
- future developments in autonomous surgical systems

The chapter discusses how TRIZ principles help understand the **transition from manual surgery to intelligent surgical systems**.

Chapter 9

Glossary of Innovation and Medical Technology Terms

Comment:

This glossary provides definitions of the technical concepts used in the book, including terms from:

- TRIZ methodology
- Design Thinking
- biomedical engineering
- robotic surgery

It serves as a quick reference for readers from multidisciplinary backgrounds.

Appendix

The As-Matrix and the Af-Catalogs

Comment:

This appendix introduces the **As-Matrix and the associated Af-Catalogs**, which extend the classical TRIZ contradiction matrix.

The appendix explains how these catalogs organize innovation principles according to four main dimensions:

- | | |
|---------|--------------------------------|
| • Space | • Structure |
| • Time | • Material-Energy interactions |

PREAMBLE

Technological innovation has become one of the decisive forces shaping modern medicine. Over the past decades, advances in biomedical engineering, medical imaging, artificial organs, robotics, and materials science have profoundly transformed diagnostic and therapeutic practices. Hospitals that once relied almost entirely on manual procedures and analog instruments now operate within increasingly complex technological ecosystems that integrate computation, automation, and intelligent systems. In this rapidly evolving landscape, the ability to understand the underlying patterns of technological evolution has become essential for researchers, engineers, physicians, and healthcare innovators.

Despite the extraordinary pace of medical progress, the processes through which medical technologies evolve are often poorly understood. Many innovations appear to emerge through trial and error, incremental improvement, or isolated breakthroughs. However, research in the field of systematic innovation has demonstrated that technological development frequently follows identifiable patterns. Among the most influential frameworks for understanding these patterns is TRIZ (Theory of Inventive Problem Solving), developed by Genrich Altshuller and his colleagues some years ago, but has advanced today to a more efficient structured framework for applications in products, equipment and services. TRIZ proposes that technological systems evolve according to recognizable laws and trends, which can be studied, modeled, and applied to guide innovation.

In recent years, complementary approaches such as Design Thinking and Innovation Logic – DIVA® (Directed Variation), today called ProFun®, have expanded the methodological toolkit available to innovators. Design Thinking emphasizes a human-centered perspective, focusing on the needs, experiences, and constraints of users. ProFun®, developed by Simon Dewulf, provides a structured approach to exploring variation in system properties in order to generate new solution concepts. When used together, these methodologies form

a powerful framework capable of analyzing complex systems and revealing new opportunities for technological advancement.

This book explores the application of these systematic innovation approaches to a set of representative technologies in modern medicine. The objective is not merely to describe medical devices, but to analyze them as technological systems undergoing continuous evolution. Through this lens, diagnostic equipment, surgical robotics, biomaterials, and hospital infrastructures can be understood as systems that evolve toward higher levels of functionality, integration, intelligence, and efficiency.

The chapters that follow present a series of analytical studies addressing different areas of medical technology. Artificial hearts are examined as an example of how life-support technologies evolve through successive generations of mechanical and bio-engineered solutions. Portable ultrasound devices illustrate the trend toward miniaturization and functional integration in diagnostic equipment. The concept of the robotized hospital reveals how healthcare institutions themselves may be viewed as evolving technological systems, integrating robotics, artificial intelligence, and digital infrastructures. Other chapters explore porous biomaterials with active elements, surgical robotics, and seemingly simple medical devices such as masks and vascular access systems, demonstrating how even modest technologies can contain significant potential innovation when analyzed through systematic methodologies.

The purpose of this work is therefore twofold. First, it aims to demonstrate how the analytical frameworks of TRIZ, Design Thinking, and Innovation Logic – (DIVA® - Directed Variation) today named **ProFun**®, can be applied to the field of medical technology. Second, it seeks to contribute to a broader understanding of how healthcare technologies evolve and how future innovations might be anticipated and guided.

Medical innovation is increasingly interdisciplinary. Engineers, physicians, computer scientists, materials scientists, and designers must collaborate in order to create solutions that are technically feasible, clinically effective, and socially beneficial. By providing structured analytical tools capable of revealing patterns in

technological evolution, systematic innovation methodologies can play an important role in supporting this collaborative process.

The case studies presented in this book are intended to stimulate reflection and discussion among professionals working in biomedical engineering, healthcare innovation, and technology management. Rather than offering definitive answers, the analyses aim to open new perspectives on how systematic innovation methods can be used to understand, anticipate, and guide the evolution of medical technologies in the decades to come.

The author aspires for this work to resonate with scientists, researchers, bioengineering professionals, and all those interested in the synergistic application of TRIZ and DT. This convergence, framed within the context of Generative AI, is proposed as an emerging paradigm - referred to herein as Generative AI - Driven Bioengineering Analysis of Instruments and Processes.