CSR 平台驅動之工程系統全域最佳化
Global Optimization of Engineering Systems Powered by the CSR Platform

時　　間：2026/01/28（三）10:00~11:15 （09:50入場）
地　　點：國立陽明交通大學光復校區 工程四館 108階梯教室
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Dr. Chih-Ming Ho received his Ph.D. from Johns Hopkins University and his B.S. from National Taiwan University. He is the Ben Rich–Lockheed Martin Professor Emeritus at UCLA, where he also served as Associate Vice Chancellor for Research (2001–2005). Dr. Ho is a pioneer in personalized medicine, microfluidics, and turbulence control. In 1997, he was elected to the U.S. National Academy of Engineering, followed by his election to Academia Sinica. He has received a Doctor of Engineering Honoris Causa from the Hong Kong University of Science and Technology and holds eleven honorary professorships worldwide. Dr. Ho is a Fellow of AAAS, APS, AIMBE, AIAA, and the 3M-Nano Society. From 2001 to 2014, ISI ranked him among the world's top 250 most cited researchers across all engineering disciplines.

系統效率的最佳化是工程研究與發展的核心目標之一。系統效率同時取決於輸入參數P 的選擇及其對應水準 L 的配置，所形成的高維度設計空間 P^L，構成了系統最佳化的根本性障礙。以大數據為基礎的統計搜尋方法計算成本高昂，且易收斂於區域最佳解；傳統的試誤法則效率低落、耗時費力。

系統效率本質上屬於複雜系統的研究範疇。複雜系統為一跨領域研究方向，起源於 1970 年代物理學的新領域。在此類複雜系統中，交互作用的組成元件（例如合金元素）經由自組織過程（例如熔融與凝固），形成具非線性的動態系統。該動態系統進而呈現出新的系統性質 (例如降伏強度)。由於自組織過程高度複雜，組成元件與新系統性質之間的直接、定量關係長期難以建立，被視為複雜系統研究的「聖杯」。

透過一種不依賴機制的歸納式方法，我們發現系統輸入（交互作用的組成元件）可經由複雜系統反應（Complex Systems Response, CSR）函數，直接且確定地映射至系統輸出（新系統性質）。CSR函數為一二階非線性多項式，保證在整個設計空間內僅存在唯一的全域最佳解。

由於 CSR 不依賴任何機制，其有效性已在物理、化學及社會系統中獲得驗證，並於多工程應用中實現全域最佳化，例如：

- PECVD 薄膜沉積製程：沉積速率、介電常數與表面粗糙度分別提升 3.8 倍、1.02 倍與 1.51 倍；殘留應力最佳化至約 0 MPa（實驗驗證為 −1.7 MPa），相較於傳統製程之 40–300 MPa。
- 石墨烯奈米流體熱傳應用：用於 AI 晶片冷卻之熱傳效能提升達 10 倍。
- 線切割放電加工（Wire-EDM）：透過 CSR 為基礎之自適應熱平衡控制，尺寸誤差由 ±10 μm 降至低於 ±1 μm。

總結而言，CSR 平台是一項普遍適用於複雜系統的控制定律，使我們能夠在整個設計空間中識別全域最優解，從而重新定義製造流程、材料合成，以及廣泛類型的各種工程應用。

System efficiency optimization is a central objective of engineering research and development. Efficiency is jointly determined by the selection of input parameters, P, and their corresponding levels, L. The resulting large high-dimensional design space, P^L, presents a fundamental barrier to systematic optimization. Big-data–driven statistical search methods are computationally intensive and prone to convergence at local optima, while conventional trial-and-error approaches are inefficient and labor-intensive. System efficiency resides within the domain of complex systems, an interdisciplinary field that emerged from physics in the 1970s. Such systems feature interacting components (e.g., alloy constituents) that undergo self-organization processes (e.g., melting and solidification).

These processes give rise to nonlinear dynamical systems with emergent properties (e.g., yield strength). The direct, quantitative linkage between interacting components and emergent system-level properties is obscured by this intricate self-organization and has long been regarded as the "holy grail" of complex systems research.

Using a mechanism-free inductive approach, we discovered that system inputs (interacting components) can be directly mapped to outputs (emergent properties) through the Complex Systems Response (CSR) function. The CSR function is a second-order nonlinear polynomial that guarantees a unique global optimum over the entire design domain. Since CSR is mechanism-independent, its validity has been established across physical, chemical, and social systems. Global optimization has been experimentally demonstrated in multiple engineering applications, including:

- PECVD thin-film deposition: Deposition rate, dielectric constant, and surface roughness improved by 3.8×, 1.02×, and 1.51×, respectively; residual stress optimized to ~0 MPa (experimentally verified at −1.7 MPa), compared with conventional values of 40–300 MPa.
- Graphene nanofluid heat transfer: Heat-transfer performance for AI-chip cooling increased by 10×.
- Wire electrical discharge machining (Wire-EDM): Dimensional error reduced from ±10 μm to below ±1 μm via CSR-based adaptive thermal balancing.

In summary, the CSR platform constitutes a universal governing law for complex systems, enabling us to redefine the manufacturing, material synthesis and a broad class of engineering applications by identifying the global optima across the entire design space.

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