A Brief Study on Design Synthesis

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ABSTRACT:

System engineering's crucial design synthesis process allows the development of complex systems by combining a variety of parts and subsystems to achieve desired performance and functionality. To provide the best possible realisation of system requirements, it entails the methodical investigation, assessment, and integration of design alternatives. The main ideas, approaches, and important factors of design synthesis in system engineering are highlighted in this abstract. The goal is to succinctly explain the relevance and function of design synthesis in the creation of reliable and effective systems. The necessity of design synthesis as a link between system requirements and their physical implementation is emphasised in the abstract's first paragraph. It examines the iterative nature of the process, which involves a number of design iterations before settling on the best answer. The abstract goes on to discuss the necessity for a multidisciplinary strategy that involves specialists from different fields to guarantee thorough system integration. The abstract also discusses the use of cutting-edge ideas and upcoming technology in design synthesis. It examines the difficulties of integrating cutting-edge technology while preserving system coherence and dependability, such as artificial intelligence, the Internet of Things, and sophisticated materials.

KEYWORDS:

Design Synthesis, Design Development, Interface Integration, System Decomposition.

I. INTRODUCTION

Engineering design synthesis is a critical stage when the conceptual design of a system or product is translated into a comprehensive and workable solution. To build a thorough and effective design that satisfies the required criteria and objectives, it entails integrating a variety of design elements, components, and subsystems [1], [2]. Engineers synthesise the results of earlier design stages, such as requirements analysis, functional analysis, and conceptual design, throughout the design synthesis process to provide a cogent and optimised design solution. Transforming high-level thoughts and ideas into concrete, workable designs that may be further developed and realised is the aim.

The following essential stages are often included in the design synthesis process:

System Decomposition: Taking into account the functional requirements, system architecture, and performance goals, the total system is divided into smaller subsystems or components. This breakdown facilitates the design's organisation into manageable components and offers a clear knowledge of the system's hierarchy and organisational structure [3], [4].

Component Design: Each subsystem or component is carefully planned, taking into account variables like material choice, geometry, measurements, and manufacturing procedures. Engineering analysis, simulations, and prototypes are used in this stage to fine-tune the design and make sure it satisfies performance, safety, and other pertinent requirements.

Interface Integration: Interfaces between various subsystems or components are developed and integrated throughout the design synthesis process. A flawless integration and functioning of the whole system need the establishment of communication protocols, mechanical interfaces, electrical connections, and any other interfaces [5], [6].

Trade-Off Analysis: When there are competing needs or design options, design synthesis often uses trade-off analysis to help make judgements. To choose the best design solution, engineers examine several design possibilities while taking into account elements like cost, performance, reliability, manufacturability, and environmental effect.

Design Synthesis: The design synthesis phase also focuses on the design's performance, cost, and efficiency optimisation. To enhance the functioning of the design, reduce risks, and accomplish the intended results, engineers may use simulations, optimisation methods, and iterative refinement procedures [7], [8].

Communication and Documentation: During the design synthesis process, documentation is essential for preserving design choices, requirements, and justifications. good documentation allows for future reference and adjustments as well as good communication between stakeholders.

Engineers may close the gap between conceptual ideas and actual execution by engaging in design synthesis. Through this process, abstract ideas are converted into specific design solutions that may then be created, produced, and incorporated into the finished product or system. Engineers can overcome technological obstacles, improve functionality, guarantee compatibility, and provide a design that meets the needs and expectations of the stakeholders thanks to design synthesis. In the end, design synthesis is a critical stage in the engineering process when high-level ideas are converted into specific and useful designs. It entails breaking down the system into its component parts, designing each one separately, integrating interfaces, doing trade-off analyses, optimising the design, and recording the design choices. Engineers may provide a thorough and optimised design solution via the design synthesis process, laying the groundwork for the phases of implementation, production, and realisation that follow [8], [9].

II. DISCUSSION

Design Development

The process of developing ideas or designs based on the functional descriptions that come from functional analysis and allocation is known as design synthesis. Design synthesis is a creative process that creates a physical architecture (a collection of hardware, software, and/or system components) capable of carrying out the necessary tasks within the parameters of the specified performance levels. Synthesis prepares trade studies to choose the best candidate architecture from a pool of hardware and/or software architectures that have been designed to meet a particular set of functional and performance criteria.

Design synthesis aims to integrate and reorganise software and hardware components in order to provide a design solution that can meet the given objectives. Synthesis creates system ideas and builds the fundamental connections between the subsystems throughout concept creation. Subsystem and component descriptions are expanded throughout preliminary and thorough design, and precise interfaces between every system component are specified. Specifications, baselines, and work breakdown structures (WBS) are all examples of design definition paperwork that are based on the physical architecture. The fundamental aspects of the synthesis process are shown in Figure 1.

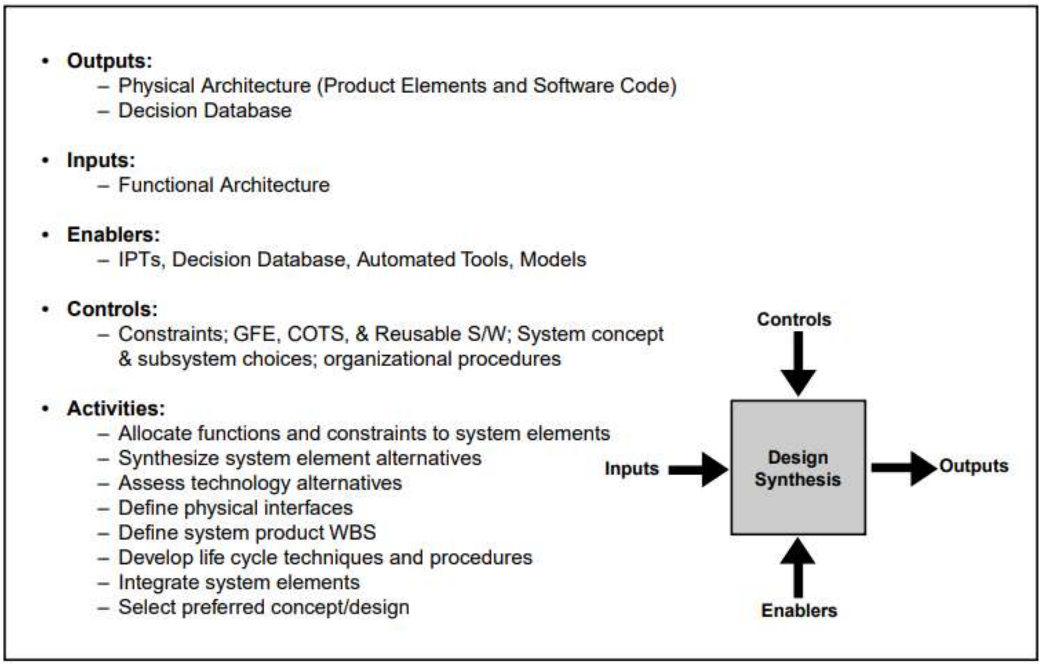

Figure 1: Illustrate the Design Synthesis.

Characteristics

The phrase "physical architecture" is dated. Contrary to its name, it consists of both software and hardware components. The following are some of the characteristics of the physical architecture (the main result of Design Synthesis):

1. Each physical or software component must satisfy at least one (or a portion of one) functional requirement to be correlated using functional analysis, albeit a component may satisfy more than one criterion.
2. Trade studies and effectiveness analysis support the architecture.
3. The physical architecture serves as the basis for a product WBS.
4. Metrics are created to monitor KPP progress, and
5. A database contains documentation for all supporting data.

Modular Designs

Components that execute a single independent function or a single logical purpose, have a single entrance and exit point, and are independently tested are grouped to create modular designs. Grouping similar functions makes it easier to find modular design solutions and also raises the likelihood that the product architecture will be able to adopt open-systems methods.

The modular components should have low coupling, good cohesion, and minimal connection. The degree of coupling between modules, or the quantity of information transferred between two modules, is a measure of their dependency. Module decoupling reduces development risks and makes it simpler to implement changes in the future. The similarity of activities carried out inside the module is referred to as cohesion (sometimes termed binding). High cohesiveness is preferable because it enables the employment of same or similar (family or series) components or the multifunctional usage of a single component. Connectivity describes the connection between internal components in one module and internal components in another module. High connection is bad since it results in complicated interfaces that might make testing, development, and design more difficult.

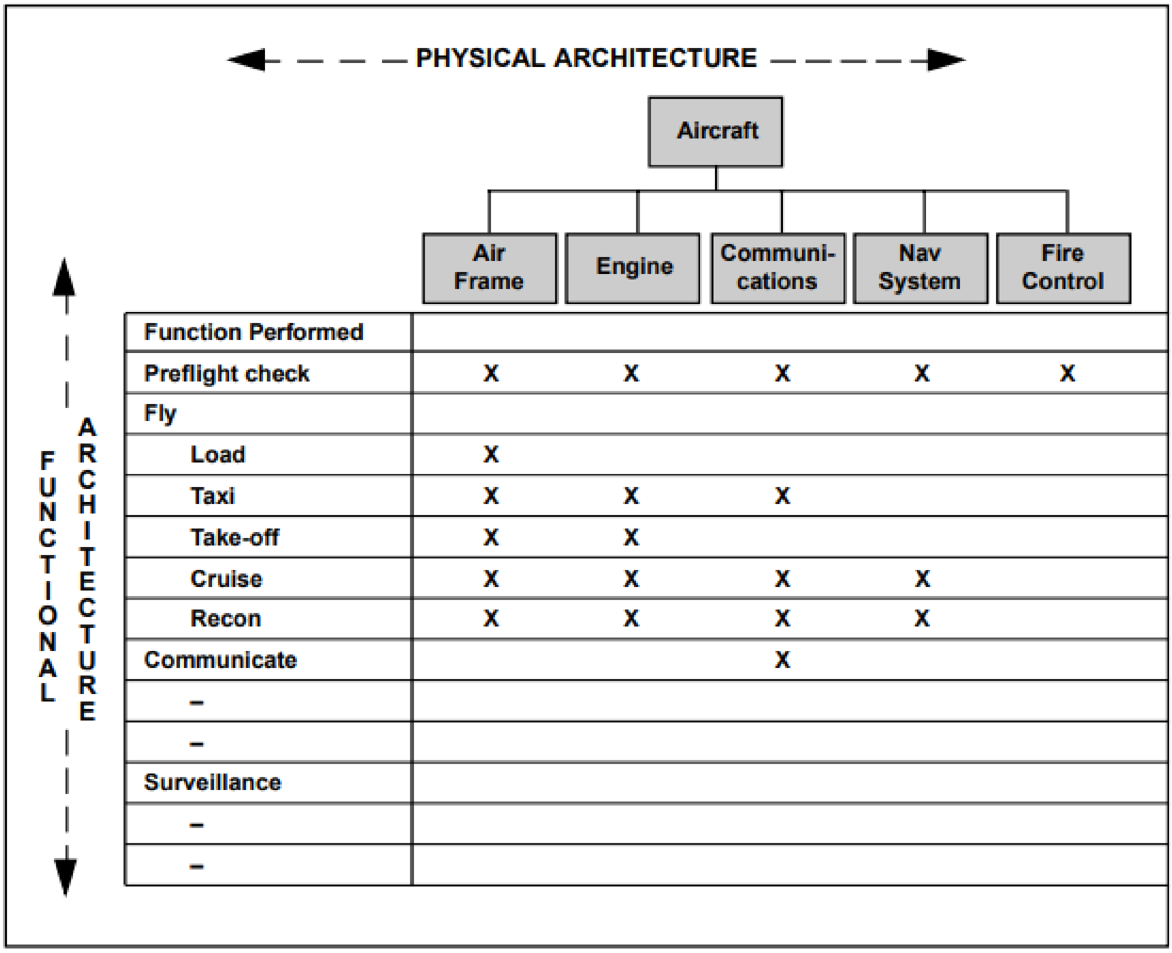

Figure 2: Functional/Physical Matrix.

Design Loop

In order to ensure that the physical architecture generated complies with the functional and performance requirements, the functional architecture must be reviewed throughout the design cycle. Between the functional and physical architectures, there is a mapping. An example of a simple physical architecture and its relationship to the functional architecture is shown in Figure 2. Re-evaluating the functional analysis during design synthesis may be necessary due to design flaws that call for a review of the original decomposition, performance allocation, or even higher-level needs. These problems might include the discovery of a viable physical solution or open-system prospects with functional properties different from those anticipated by the original functional architectural criteria.

Synthesis Tools

Many analytical, engineering, and modelling tools are utilised during synthesis to help and record the design work. Trade studies and other analytical tools help decision-makers optimise physical solutions. Requirements Traceability to the functional and performance requirements is provided by Allocation Sheets (RAS). The idea Decription Sheet (CDS), a straightforward explanation, aids in visualising and communicating the system idea. Logic models define the design and the interactions inside the system, such as the Schematic Block Diagram (SBD).

The design effort may be organised, coordinated, and documented with the use of automated engineering management systems like Computer-Aided Design (CAD), Computer-Aided-Systems Engineering (CASE), and Computer-Aided-Engineering (CAE). In addition to producing SBDs, detailed drawings, three-dimensional and solid drawings, and tracking various technical performance metrics, CAD also provides thorough documentation outlining the product design. CAD may contribute significantly to simulations and virtual modelling. Additionally, it gives integrated design innovations access to a shared design database. Computer-Aided Engineering may provide cost assessments, analyses pertaining to the eight major functions, and evaluations of system needs and performance in support of trade studies. Engineering with computer assistance may automate technical management assessments and documentation [10].

Modeling

Prior to making design choices, modelling approaches enable the visualisation and assessment of the physical result. Models provide for the ideal distribution of functional and performance needs among the system's components, the optimisation of hardware and software parameters, performance forecasting, the development of operational sequences, and more. The Schematic Block Diagram serves as the standard form of logical prototyping in Design Synthesis.

III. CONCLUSION

Engineers divide the entire system into smaller subsystems or components and carefully design each of them as part of the design synthesis process. This entails taking into account variables like material choice, geometry, measurements, and production methods to make sure the design is feasible and useful. Integration of interfaces across many subsystems or components is another aspect of design synthesis that enables efficient coordination and communication. When competing design options or needs exist, trade-off analysis is used to provide an optimum design solution that balances numerous criteria including cost, performance, reliability, and manufacturability.

The design optimisation phase, when engineers hone the design to improve efficiency, performance, and cost-effectiveness, is also stressed throughout the design synthesis phase. Engineers work to increase functionality and reduce design risks using simulations and optimisation approaches. By preserving design choices, requirements, and justification, documentation is essential to the design synthesis process. This documentation aids in efficient stakeholder communication and acts as a guide for upcoming adjustments and upgrades. Engineers close the gap between conceptual ideas and actual execution via the process of design synthesis. It guarantees that the design is complete, cohesive, and in line with the demands and expectations of the stakeholders. Design synthesis lays the foundation for the future phases of implementation, production, and realisation, which together enable the system or product to be successfully developed and deployed.

In conclusion, the design synthesis step is crucial because it unifies different design components, integrates interfaces, does trade-off analysis, optimises the design, and makes sure that the documentation is accurate. It converts vague ideas into concrete designs that can be implemented, laying the groundwork for the next engineering steps. Engineers develop intricate and workable solutions via design synthesis that satisfy the system's or product's operational, performance, and functional requirements.

REFERENCES

[1] S. Yuan et al., “Stable Metal–Organic Frameworks: Design, Synthesis, and Applications,” Advanced Materials. 2018. doi: 10.1002/adma.201704303.

[2] B. Chen, “Conceptual design synthesis based on series-parallel functional unit structure,” J. Eng. Des., 2018, doi: 10.1080/09544828.2018.1448057.

[3] A. G. Baldwin et al., “Design, Synthesis and Evaluation of Oxazaborine Inhibitors of the NLRP3 Inflammasome,” ChemMedChem, 2018, doi: 10.1002/cmdc.201700731.

[4] S. Han et al., “Design Synthesis of ITE Zeolite Using Nickel-Amine Complex as an Efficient Structure-Directing Agent,” ACS Appl. Mater. Interfaces, 2018, doi: 10.1021/acsami.8b10620.

[5] B. Chen and Y. B. Xie, “A function unit integrating approach for the conceptual design synthesis in the distributed resource environment,” Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci., 2018, doi: 10.1177/0954406217692008.

[6] B. R. Kim et al., “Design, synthesis, and evaluation of curcumin analogues as potential inhibitors of bacterial sialidase,” J. Enzyme Inhib. Med. Chem., 2018, doi: 10.1080/14756366.2018.1488695.

[7] K. H. Hyun and J. H. Lee, “Balancing homogeneity and heterogeneity in design exploration by synthesizing novel design alternatives based on genetic algorithm and strategic styling decision,” Adv. Eng. Informatics, 2018, doi: 10.1016/j.aei.2018.06.005.

[8] K. C. Nicolaou et al., “Streamlined Total Synthesis of Shishijimicin A and Its Application to the Design, Synthesis, and Biological Evaluation of Analogues thereof and Practical Syntheses of PhthNSSMe and Related Sulfenylating Reagents,” J. Am. Chem. Soc., 2018, doi: 10.1021/jacs.8b06955.

[9] W. D. Seider, J. D. Seader, and D. R. Lewin, “Product and Process Design Principles: Synthesis, Analysis and Design,” Product and Process Design Principles: Synthesis, Analysis and Design. 2018.

[10] K. Zhu, Y. Ju, J. Xu, Z. Yang, S. Gao, and Y. Hou, “Magnetic Nanomaterials: Chemical Design, Synthesis, and Potential Applications,” Acc. Chem. Res., 2018, doi: 10.1021/acs.accounts.7b00407.