

FROM NATURAL LANGUAGE TO EXECUTABLE OPTIMIZATION WORKFLOWS, A KNOWLEDGE GRAPH DRIVEN FRAMEWORK FOR MULTI DISCIPLINARY OPTIMIZATION

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Keywords: Natural language processing, knowledge graphs, multidisciplinary optimization, workflow automation, LLM grounded systems

Abstract

Multi disciplinary optimization MDO enables systematic exploration of trade offs across competing engineering metrics under feasibility constraints and is widely used to support early stage design decision making. By coupling analysis models with optimization algorithms MDO can accelerate design exploration compared with manual trial and error approaches. However deploying and operating MDO frameworks remains challenging in practice. A major barrier is the difficulty of translating high level design requirements into a structured and executable optimization formulation which often requires significant manual effort for workflow configuration tool integration and dependency management.

This paper presents a knowledge graph grounded framework that automatically translates free form natural language design requirements into a validated and executable multi disciplinary optimization workflow. The approach combines locally hosted large language models for intent extraction with a domain knowledge graph for variable grounding metadata retrieval and dependency based workflow planning. From a user request the system derives a structured specification consisting of objectives and constraints expressed as variable operator value tuples. The knowledge graph maps extracted terms to canonical variables retrieves relevant metadata such as bounds and default values and constructs a dependency consistent execution chain for the engineering models required to evaluate the requested metrics.

Candidate designs are evaluated through orchestrated Python based model execution with workbook reuse to reduce evaluation overhead and support coupled dependencies. A population based genetic optimization loop explores the bounded decision variable space while enforcing feasibility through constraint checking and penalty based ranking. The framework exposes parsed intents confidence scoring deterministic post validation and planned workflows to improve transparency. The approach is demonstrated through a vehicle concept optimization case study for early stage design exploration.