The Development of a Grid-based Engineering Design Problem Solving Environment

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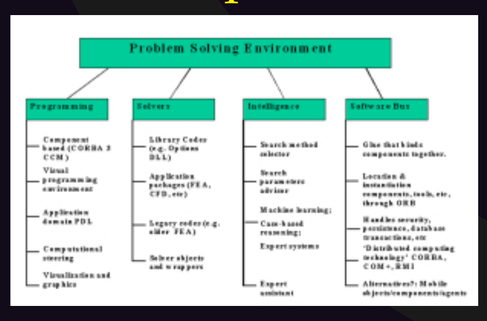
Why Problem Solving Environments (PSEs)

To enhance engineering insight, reduce development costs and improve product quality, design studies are increasingly using sophisticated analysis packages together with optimisation tools. This combined approach requires a high level of systems integration and the ability to exploit clusters of networked workstations to achieve efficient and re-usable design systems.

What is a PSE

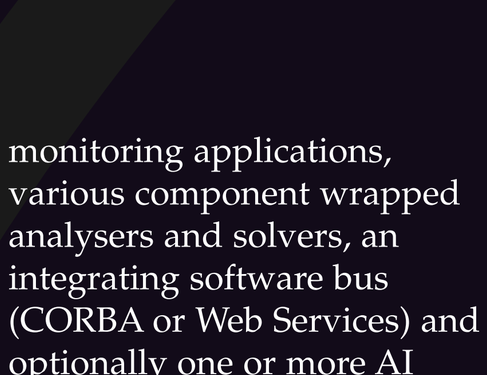
"A PSE is a computer system that provides all the computational facilities needed to solve a target class of problems." (J. Rice - Purdue University)

PSE Components



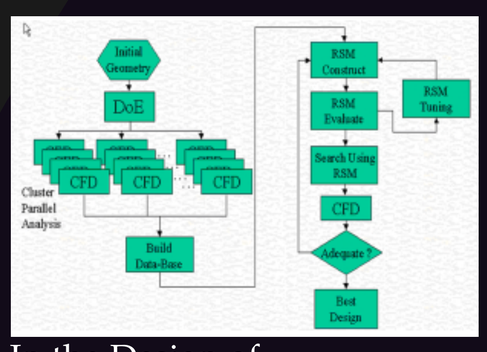
The main PSE sub-systems include visual-programming environments for graphically composing, steering and monitoring applications, various component wrapped analysers and solvers, an integrating software bus (CORBA or Web Services) and optionally one or more AI systems to assist the user formulate a computational strategy.

Prototype Engineering Design PSE:



We have developed a prototype PSE built around our Options suite of search/optimisation programs and various CFD codes. Our current Engineering Design PSE incorporates the Cardiff University Visual Component Composition Environment (VCCE) as its front-end and uses CORBA 2.3 as its distributed object middleware (software bus above). Components are dragged from the Component Repository on the left column of a sketchpad display and dropped onto the canvas of the Component Composition Tool on the right of the display. Components can then be joined together if their interfaces are compatible to form a task graph. This defines the execution order and dependencies between the various components making up a job. For a component to be available for use in VCCE, an XML definition of the component must be available in the Component repository. The component's XML definition is based on the Component Model defined in VCCE.

Design Studies Process:



In the Design of Experiments(DoE)/Response Surface Modelling(RSM) process (left part of diagram above) some technique (e.g., Latin hypercubes) is used to select a set of initial design points (typically say 100 points) that will span the design space. The analysis codes are then run for each design point, ideally in parallel on some large compute cluster, as the design point evaluations are independent of each other. From the resulting database, a response surface is built using the chosen approximation method (e.g., kriging). If satisfactory, the surface is searched for an optimal design point (right part of diagram) and if found, full analysis codes are run at that point. If the analysis is satisfactory and all design constraints are met, the process terminates; otherwise the new design point is added to the design set, the surface regenerated and the optimisation repeated.

Engineering Design Grid Portal/PSE Architecture:

From a user perspective, the RSM process suggests a data-centric approach to the computational workflow, where the user is primarily looking at problem design point and results data to-date (and possibly other test data such as flight trial or wind tunnel results in aerospace design problems) in order to decide where new problem analyses need to be run. From a computational perspective, the aim is to achieve the maximum amount of parallelism in the analysis computations by exploiting the various cluster resources available. This can be accomplished by de-coupling the search engine computation from the analysis computations and using some form of task farming to schedule parallel running of analysis tasks over the available resources.

The Globus Grid Resource Allocation Management (GRAM) protocol and client API:

Rapid advances in commodity computing and the emerging nation-wide computational grid are significantly influencing the development of the next generation of PSE's. The term 'commodity computing' encompasses the development of distributed computing technologies (Web services, Java, JINI, CORBA, DCOM, etc.), plus the use of standard PC hardware in networked clusters. 'Grid computing' refers to the high-performance computing community's creation of Grids; advanced infrastructures designed to enable the co-ordinated use of distributed high performance