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APPLICATION OF DESIGN PATTERNS AND SPACE CONCEPTS IN THE DEVELOPMENT OF HEAT PIPES

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ABSTRACT

The phenomenon of condensation of vapors on a vertical fin is theoretically solved by coupling the thermal conduction in the fin to the constitutive equations of motion and energy of the condensate layer in an appropriate manner with relevant boundary conditions. The analysis accounts for the sub cooling effects of the condensate on the condensation heat transfer coefficient. A design equation that can be employed in the design of the condenser section of a flat plate heat pipe has been suggested in an earlier paper presented at the sixth international heat pipe conference held at Grenoble France.
In an technical note published in the international journal of heat and mass transfer, the process of condensation on a vertical plate fin of variable thickness is analyzed to establish the effect of fin geometry on the condensation heat transfer coefficient. The results presented are of significance in the optimization of fin geometry while developing the flat plate heat pipes.In yet another paper published in the Canadian journal of chemical engineering explicit solutions are obtained for the problems of condensation of vapors on the lateral surface of a long vertical plate fin of variable cross section. The formulation yields solutions to the limiting cases so that the results can be employed in the design of the condenser section of a flat plate heat pipe in which the fin is considered to be an essential element for augmenting the condensation heat transfer.Design can be considered as an integral part along with the process know how and knowledge of fabrication/assembly of the ultimate product such as the radiation shield with embedded heat pipes as in the case of the present study within the frame workof agile manufacturing.

Keywords: Design Patterns, Design Space, Heat Pipes Condenser, Evaporator.

INTRODUCTION

Design Space identifies the key functional and structural dimensions and used to create a system design in specific application domain. The design space is multi dimensional and each dimension describes a variation in one system characteristic or requirement. Values along a dimension correspond to different design alternatives rules are used to encapsulate design knowledge in the form of relationships between alternatives of different dimensions of the design space. The Quantified DesignSpace (QDS) is a structured encapsulation of design knowledge implemented in spreadsheet for a use by system and software designers. QDS is mechanism for translating system requirements into functional and structural design alternatives and for analyzing these alternatives in quantitative manner. The QDS can also be used to produce a model design for a desired system, analyze and compare existing designs or suggest improvements for an existing product. The QDS is based on two fundamental concepts the Design Space and Quality Functional Deployment (QFD). QFD is a quality assurance technique that helps translate customer needs into technical requirements needed at each stage of product development – from requirement analysis through design, implementation and manufacturing.

DESIGN PATTERNS IN HEAT PIPES

Design Patterns have been classified into Creational Patterns, Structural Patterns and Behavioral Patterns and the relationship is shown as figure 1. All the creational Patterns are applicable in the design and development of Heat Pipes and Thermo-siphon.To design and develop the heat pipe application there are two abstract things to be specified for a heat pipe:

- Working fluid and
- Amount of heat it has to handle.

CREATIONAL PATTERNS

Leaving the working fluid unspecified, leads to the Design Pattern of an Abstract factory and not deciding the amount of heat to be handled by a heat pipe leads to the Design Pattern of Factory Method which permits the instantiation of the concrete classes to sub classes of Evaporator and Condenser sections.

Abstract Factory

Provide an interface for creating families of related or dependent objects without specifying their concrete classes. A heat pipe without specifying a particular working fluid is a typical example for the abstract Factory. Since the working fluid is not specific, its associated phase change temperature and the operating temperatures of thee evaporator and condenser sections of the heat pipe are also generalized and hence appropriate for the Design and development of heat pipe applications.

Factory Method

Define an interface for creating an object, but let subclasses decide which class to instantiate. Factory Method lets a class differ instantiation to sub-classes. The heat pipe is classifiedbased on the amount of heat it has to handle and differs with the design of condenser and evaporator sections.

Builder

Separate the construction of a complex object from its representation so that the same construction process can create different representations. Filling noncondensable gas in a heat pipe along with the working fluid is a typical example for the builder Pattern where the same construction process is resulting in heat pipes with different representations gas filled or plain.

Prototype

Specify the kinds of objects to create using a prototypical instance and create new objects by copying this prototype. Specifying the source of heat for the evaporator section of nuclear power plant or type of cooling medium for the condenser section in a particular application needs building a prototype for demonstration purpose such as nuclear fuel source for the evaporator section or medium of sea water for a nuclear submarine condenser.

Singleton

Ensure a class only has one instance and provide a global point of access to it. Using solar power for all the transponders on a satellite which is cooled by the internal heat pipes to dissipate the heat from the single source to outer space can be looked upon as a Singleton Pattern.

STRUCTURAL PATTERNS

The utility of Structural Patterns in the design and development of heat pipes and their applications in various situations is dealt with in the following discussion.

Adapter

Convert the interface of one class into another interface clients expect. Adapter class lets classes work together that would not otherwise because of incomplete interfaces. A paper drying drum is an adapted version of the condenser section of the heat pipe into the form of a rotating paper drying drum.

Bridge

Decouple an abstraction from its implementation so that the two can vary independently. Establishing the abstraction of a condenser section or the evaporator performance improvement can be delinked from the actual implementation since the overall performance is dependent both on quality and quantitatively as well.

Composite

Represents the physical structure of the object. Compose objects into true structures to represent part whole hierarchies. Composite lets clients treat individual objects and the compositions of objects uniformly. Heat pipe can as such be treated as the composite of the condenser and evaporator objects in addition to the adiabatic section.

Decorator

Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to sun classing for extending functionality this can be used for embellishing the user interface. A radiation shield with built in heat pipe has the additional responsibility of acting also as a radiation shield in addition to its function as a heat pipe.

Façade

Provide a unified interface to asset of interfaces in a sub system. Façade defines a higher level of interface that makes the sub system easier to use. A pressure cooker provides a unified interface to its contents to be cooked in a solar cooker.

Flyweight

Use sharing to support large number of fine grained objects efficiently the nuclear fuel rod is an example of the flyweight pattern as it serves to provide place for a large number of nuclear fuel pellets inside it.

Proxy

Provide a surrogate or place holder for another object to control access to it. A nuclear reactor is the surrogate or place holder for the evaporator section of a nuclear power plant.

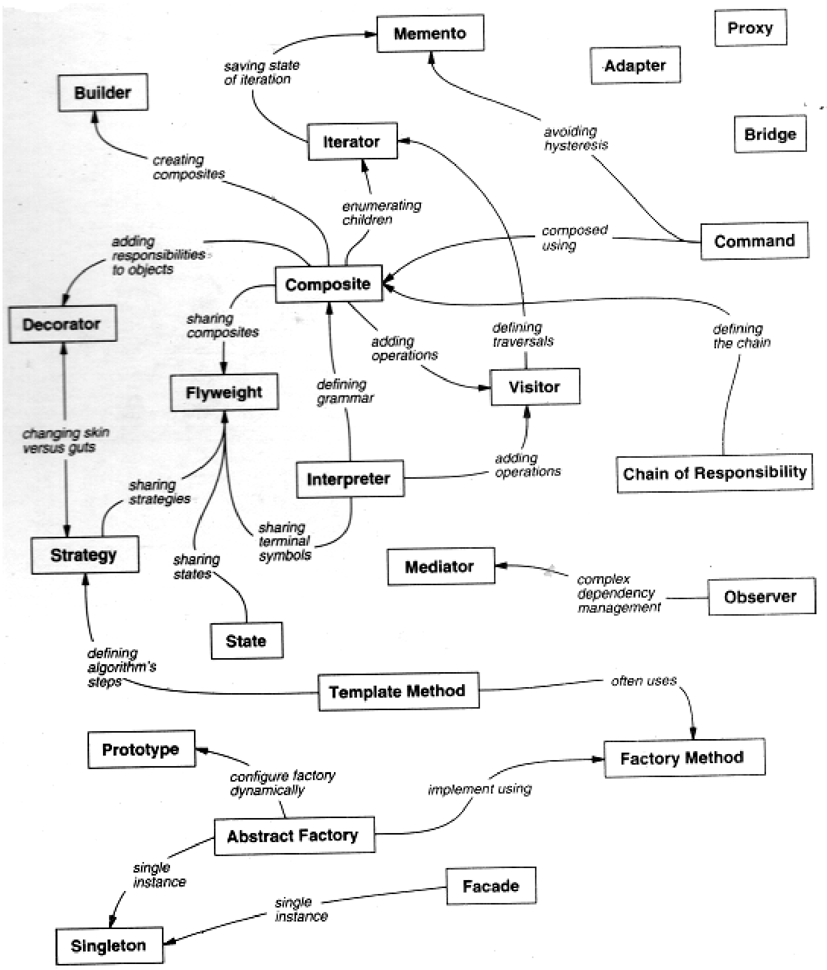

Figure 1 Design Pattern Relationships

BEHAVIORAL PATTERNS

In the following discussion heat pipe application situations have been dealt with the help of various BehaviouralPatterns.

Chain of Responsibility

Avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request. Chain the receiving objects and pass the request along the chain until an object handles it. Including the environment in which the condenser and evaporator section of the heat pipe will enhance the scope of the chain of responsibility of handling the heat between the source and the sink of the heat in particular application.

Command

Encapsulate a request asan object, thereby letting you parameterize clients with different requests, queue or log requests, and support undoable operations. Specifying the quantity of heat that can be handled within the operational limits commands the main parameters determination of the heat pipe components of the

Iterator

Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.The heat pipe is providing a way to the working fluid to access its basic elements of condenser and evaporator sections sequentially without any considerations to their underlying representation and configuration details.

Mediator

It is the interaction of objectsin an encapsulation. Mediator promotes loose coupling by keeping objects from referring to each other explicitly, and lets you vary their interaction independently. The adiabatic section of the heat pipe acts as the mediator between the evaporator and condenser sections and facilitates the transfer of heat by the working fluid.

Observer

Define a one to much dependency between objects so that when one object changes its state, all its dependents are notified and updated automatically.

State

Allow an object to alter its behaviour when it’s internal state changes. The object will appear to change its class. The excess temperature of the evaporator section and the degree of sub cooling in the condenser section in comparison with the saturation temperature of the working fluid in the heat pipe often determine the state of heat pipe during its operation and depict the temperature potential available for the operation of the heat pipe.

Strategy

Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it. The strategy for the detail design of the condenser and evaporation sections would naturally depend upon the state of the heat pipe in the particular application and hence will depict the flexibility available within the Design Space of the heat pipe application.

Template Method

Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template method lets subclasses redefine certain steps of an algorithm without changing the algorithm's structure. Depending upon the state and strategy adopted one would naturally determine the detailed step by step procedure for the development of the heat pipe application there by leading to the development of suitable template for the Design Space of the heat pipe application under consideration.

CONCLUSION

The creational patterns abstract the instantiation process. A class creation pattern uses inheritance to vary the class that is instantiated where as the object creational pattern will delegate instantiation to another object. Creational patterns become important as systems evolve to depend more on object composition than class inheritance. Creational patterns give a lot of flexibility in what gets created, who creates it, how it gets created and when. The applicability of creational patterns in the design and development of heat pipes is found to be quite satisfactory. Structural Patterns are concerned with how classes and objects are composed to form larger structures. Structural class patterns use inheritance to compose interfaces or implementations. The applicability of structural patterns to heat pipe applications is found to be advantageous.

Behavioral Patterns are concerned with algorithms and assignment of responsibilities between objects. Behavioral Patterns describe not only the Patterns of objects or classes but also the patterns of communication between them. They shift the focus from the flow of control to let you concentrate just on the way objects are interconnected. Behavioral Object Patterns use object composition rather than inheritance, where as behavioral class patterns use inheritance to distribute inheritance between classes. Some of the Behavioral Patterns can be comfortably used in the design of Heat Pipe applications such as solar feed water heating systems, fire hazard mitigation and waste heat recovery systems.

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