

An Algebraic Model for Run-Time Reconfiguration of High-Performance Computing Systems

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Complex Problems in 21 Century

- Complex Problems: Definition
 - Change in the requirements of scientific computation
 - Need computer solvers for problems with unknown behaviors (*more complex problems*)
 - Problem complexity due to ever increasing dynamic interactions with external systems (environment); unpredictable by problem experts
 - Complexity $\propto$ Time
- 
- Behavior patterns only recognizable at runtime
 - Complex nature of problems: *dynamicity* and *interactivity*

HPC Challenge in Approach of Problem

- Customized HPC widely used successfully in satisfying the HPC needs of many scientists. According to TOP500.
- Tailored HPC has attracted a large share of HPC industry.
- Tailored HPC is essential for solving scientific problems.
- The main problem:

How Tailored HPC can Solve New Complex Problems?



The Truth

Fact 1: requirements of problem changes at runtime unpredictably

Fact 2: changes in requirements require system configuration change (*Reconfiguration*)

Fact 3: tailored HPC is used to once-for-ever customized configuration



Complexity and Dynamism of Problems Contradicts Once-for-Ever Customized Configuration of HPC Systems.

Complexity and Systematic View

- HPC and Complexity
- Complex problem and system
- Need to present a solution to handle complexity based on *Systems Theory* (Chechman system approach)

Tailored HPC and Systematic View

- Tailored HPC Solution → Customized Configuration
- Customized Configuration Model (Systematic view)
 - Phase 1: problem experts and HPCS experts cooperate.
 - Phase 2: problem experts build a set named problem technical accounting (PTA) based on problem features.
 - Phase 3: HPCS experts develop a management system using the PTA set and information about the set of available compute resources in the system.
 - Phase 4: since it is a static problem its processes are static, as well. The management system must manage the process.
 - Phase 5: HPCS experts leave the system and the system enters execution phase.

Tailored HPC v Dynamic Problems

- Supporting dynamic problems by Tailored HPC
 - System Expert is an external entity
- To reconfigure the system at runtime
 - What element can take the responsibility of system reconfiguration at runtime based on newly created needs?
 - Reconfigure the system based on what model?
 - How the element can realize some process is showing a behavior with dynamic nature (what criterion)?
 - Which states trigger dynamicity?

Configuration in Systematic View

- What is the goal of configuration in Tailored HPC in view of HPC Experts?



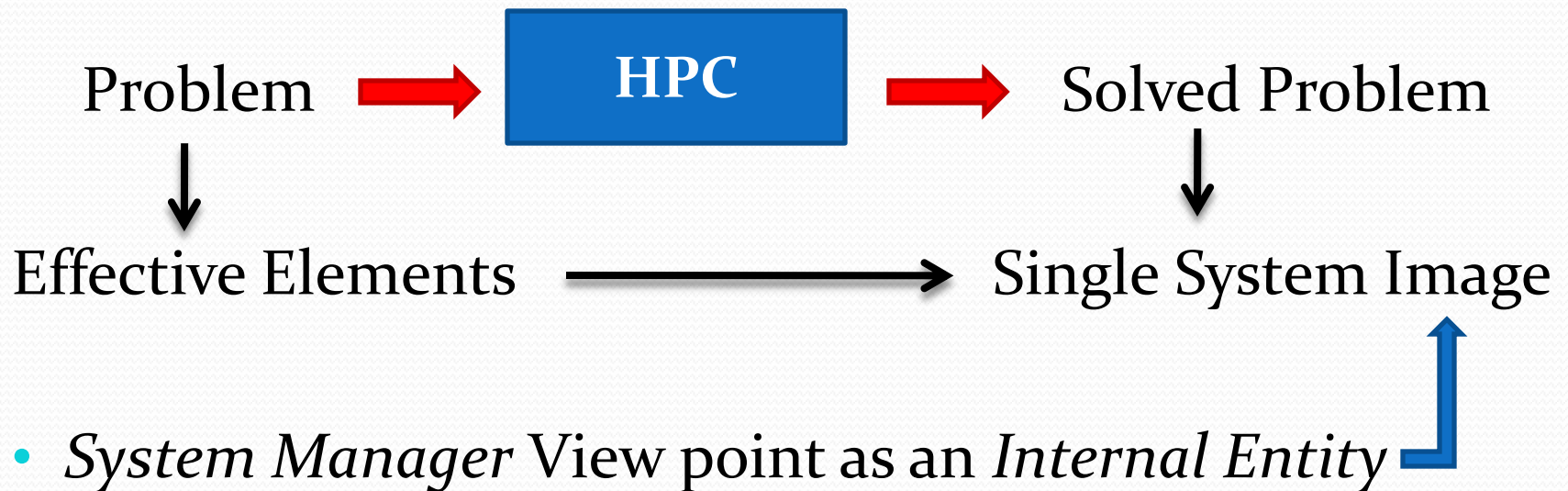
- Is this not the definition of management?

Manager in a Systematic View

- The first point in this view is:
 - Which **elements** based on which model of management exist in the system.
- We categorize the effective elements in solving problem to: *Hardware, System Software, Application Software* and *Functionality*, based on heterogeneity concept.

Model of Reconfiguration

- Based on configuration model in system expert 's view
- *System Expert View* regarded as an *External Entity*



Model of Reconfiguration

Effective Elements
of Reconfiguration

Hardware (Ron Sass, Aju M. Jacob)
System Software (Peter Sloot, Marta Beltran)
Application Software
Functionality

Resource Category

I/O Elements
Memory Elements
Processing Elements
Storage Elements

Model of Reconfiguration

Configuration in view of manager is the HPC Mission:

Mission of *HPCS* Manager: $(H, SS, AS, F)^n \rightarrow (SSI_{I/O}, SSI_{Memory}, SSI_{File}, SSI_{Process})$

What is the generator space of this function???

<Set of Resources, SSI>



Model of Reconfiguration

- Based on which model reconfigure the system?
 - Based on vector algebra.

Process Structure {

.....

.....

Filled with Vector requirements;

}

Vector Operations are very primitive and fast to execute

The Criteria?

- How the element can realize some process is showing a behavior with dynamic nature (what criterion)?
- Problem Technical accounting → General Status Vector
- Per activity of Process, a value is added to the subspace that changes the direction of the vector
- Compare the direction of the vector with basic direction

Vector and Process

$$\begin{aligned}
 Problem_v = & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{H_{IO}} \cup \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{H_p} \cup \bigcup_{i=1}^{n(Effective - Elements)} Problem_{H_M} \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{H_F} \cup \bigcup_{i=1}^{n(Effective - Elements)} Problem_{A_F} \\
 & \bigcup_{i=1}^{n(Cluster - Provide)} Problem_{A_{IO}} \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{A_M} \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{A_P} \cup \bigcup_{i=1}^{n(Effective - Elements)} Problem_{S_F} \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{S_{IO}} \\
 & \bigcup_{i=1}^{n(Effective - Elements)} Problem_{S_M} \cup \bigcup_{i=1}^{n(Effective - Elements)} Problem_{S_P}
 \end{aligned}$$

Criteria in Technical View

- There are 4 types of heterogeneity → 4 types of effective elements in solving the problem
- Heterogeneous HPC is a collection of different machines each of which may have some advantage over others.
- Activity of each process that causes the vector of each subspace to deviate from the direction of general status vector should be improved by transferring the process to a better place and vice versa.

Systematic Solution to Reconfiguration for Dynamic Problems

- In economy, there are some classic problems that have been successfully solved.
- When a new problem is raised, its deviation with a classic problem (Coefficient of Variation) is determined.
- Solution to the classic problem is applied to the new problem to lower the Coefficient of Variation of the new problem.
- We utilize this same solution for reconfiguration.

Which States Cause Dynamic Nature to be Formed?

- Complexity of problems in 21 century is due to increasing interactions of their processes with system and environment that it is unpredictable by problem experts
 - Interactions of Processes with Resources (Implicit / Explicit requests)
 - Interactions of Processes with Processes
- Two operators are defined based on *Vector Algebra*
 - Two elements of vector space (SSI) can interact with each other
 - $\forall i, j \in SSI\ Set : v = i \# j : v \in SSI\ Set$ and v presents cooperation between i, j
 - One vector can interact with a scalar (i.e. a set of resources)

$$\forall i \in Set\ of\ Resources\ and\ j \in SSI\ Set : v = i \Delta j$$

Remarks

- It is possible to map re-configurability requirement of new scientific applications to a vector space.
- Vector space operations and structures can be added to system software with considerably low overhead: *primitiveness*.
- The vector space can guide how to reconfigure the HPC
- Dynamicity is fairly modeled and handled by vector algebra



Thank You

Related Work

- Approaches proposed for solving this problem can be categorized into 2 groups.
- The first group include researches on solving dynamism of problems by manufacturing reconfigurable hardware. These researches aim to bring the same degree of flexibility represented in software into hardware. Many of these researches make use of FPGA [10, 11]. By the introduction of dynamic problems, efforts on adding runtime capabilities to these systems have been carried out. ~~programs at runtime~~??????????.

Related Work

- Hassan va hossein ??? [12] have introduced a Partial Run-Time Reconfiguration for ~~computing systems~~ hardware with reconfiguration ability.
- Only partially satisfy increasing requests of problems at runtime due to limited resources; requests for resources NOT available or at disposal.
 - Need a solution that the underlying platform formed by reconfigurable hardware elements fully satisfy requests.

Related Work

- The second group includes researches that try to provide dynamism in computing platforms through dynamic management systems (software) [[hassano hossein 13, 14](#)].
- Dr. Sloot and his colleagues work to run problems based on homogenous HPC systems on heterogeneous and dynamic Grid platforms through an *adaptive load balancing mechanism*.

Related Work

- Dr. Marta Beltran and her colleagues works on considering a dynamic cluster with dynamic state as the underlying platform wherein changes caused by sudden and asynchronous behaviors of communication, scheduling mechanisms, heterogeneity of processes, and workload, and the effects of workload changes on performance of load balancing are investigated.