Resource management framework for manufacturing grid

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Abstract: Based on open grid service architecture (OGSA) and Globus Toolkit 3.0 (GT3), a manufacturing grid (MG) is proposed to realize resource sharing and collaborative working among manufacturing enterprises. Nevertheless, resource management in MG is much more complicated than that in other grid applications due to the geographically distributed manufacturing resources, which range from CAD, CAPP and CAE to various kinds of machine tools. With the interaction of manufacturing grid information service (MGIS, developed by ourselves) and globus resource allocation manager (GRAM, provided by GT3), a resource management framework is presented to perform the functions of resource encapsulation, registry, discovery and monitoring. Furthermore, the application architecture and an example are depicted to illustrate the utilization of the resource management system.

Key words: open grid service architecture (OGSA); manufacturing grid (MG); resource management; information service; globus resource allocation manager (GRAM)

Manufacturing enterprises are now facing serious challenges and pressures from the tide of globalization involving market-place, economy, trade, investment, finance, technology, and service, which are sweeping across the world. Collaborative working and resource sharing among enterprises distributed worldwide is growing rapidly. The global market is changing from a seller's market to a buyer's market by customers' demand. Moreover, competition for markets is more and more unrelenting for meeting customers' diverse demands for manufacturing products that must be supplied at lower prices, with shorter delivery dates, higher quality, better performances, and more satisfactory service. Therefore, for a single enterprise, it is increasingly difficult to occupy a powerful position in the competition for markets[1].

At the same time, with the development of open grid service architecture (OGSA), open grid service infrastructure (OGSI), and the implementation of Globus Toolkit 3.0 (GT3), grid computing platforms enable the sharing, selection, and aggregation of geographically distributed heterogeneous resources (such as supercomputers, storage systems, and specialized devices) for coordinated resource sharing and problems solving in science, engineering, and commerce[2,3].

In order to rapidly and cost-effectively satisfy various dynamic demands of the market and adapt to the unpredictable changing environment and increasing rates of new product introduction, the concept of a manufacturing grid (MG) is proposed in this paper. Nevertheless, manufacturing resources, ranging from software, such as CAD, CAPP, CAE and CAM, to various kinds of machine tools, such as CNC, FMS, rapid prototyping (RP), and rapid tooling (RT), are quite distinct from those computing resources or data resources. This particularity increases the complexity of resource management and scheduling in MG.

So, in this paper, a hierarchical resource management system is presented with the help of globus resource allocation manager (GRAM) and manufacturing grid information service (MGIS). The former, GRAM, provided by GT3, is designed to provide a single common protocol and API for requesting and using remote system resources. And the latter, MGIS, developed by us, provides fundamental mechanisms for remote resource encapsulation, registry, discovery and monitoring by integrating monitoring and discovery service (MDS) with various kinds of resource encapsulating templates. At the end of this paper, the application architecture is presented to illustrate the utilization of our resource management system.

1 Manufacturing Grid

In our research a manufacturing grid is defined as "standard and open protocol-based resource sharing and cooperative working in dynamic, distributed, decentralized control virtual manufacturing enterprises to deliver nontrivial qualities of service".

With OGSA as a system framework and GT3 as

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developing tools, MG is made up of a number of components[4] from enabling resources to end user applications. A layered MG system framework is shown in Fig.1.

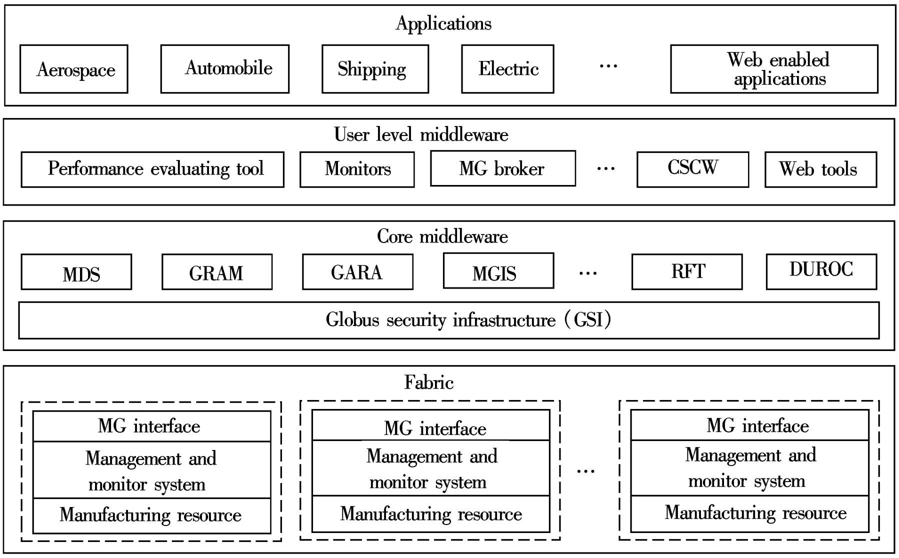

Fig.1 Manufacturing grid system framework

The key components of MG are as follows:

- MG fabric This consists of all the globally distributed manufacturing resources that are accessible from anywhere on the Internet. Various kinds of manufacturing resources, design software or machine tools, can be encapsulated into grid services if only they have their own management and monitor system.
- MG core middleware This offers core services provided by GT3, such as security, resource co-allocation, resource management, data management, resource reservation, and quality of service, as well as services developed by us, such as MGIS.
- MG user-level middleware This includes the services developed by ourselves, such as product manufacturing environments (computer supported cooperative work, CSCW), performance evaluating and monitoring tools, and necessary Web tools for application development in MG.
- MG applications MG applications are typically developed by using Java language. MG portals offer Web-enable application services, where customers can submit and collect results for their manufacturing products on remote resources through the Web.

2 Resource Management System

2.1 Manufacturing resource scope

Manufacturing is an integrated process including market prediction, product design, material choice, process planning, machining, quality control, sales, and after sales service, etc. And manufacturing resources are the facilities involved in this entire product life-cycle process. In our research, we classify manufacturing resources into the following four kinds of categories, as shown in Fig.2.

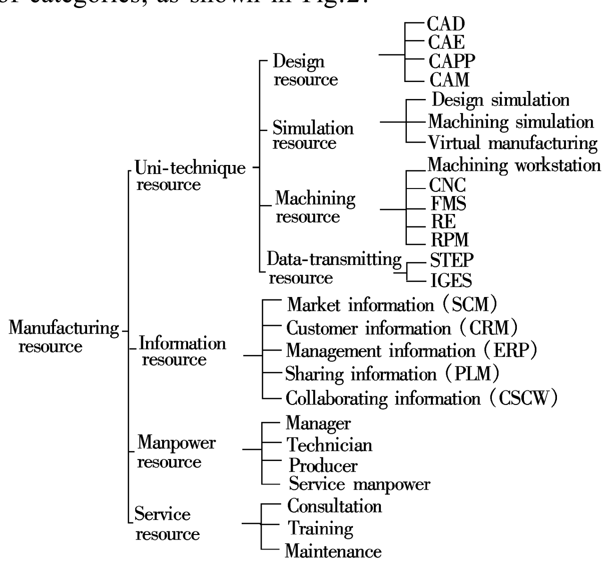

Fig.2 Manufacturing resource

- Uni-technique resource Including design resource, such as CAD/CAPP/CAE/CAM, simulation resource, such as virtual manufacturing (VM), machining resource, such as CNC/FMS/RE/RPM, data-transformation resource, such as STEP/IGES, etc;
- Information resource Including market information, got from the supply chain management (SCM) system, customer information, got from the customer relationship management (CRM) system, management information, got from the enterprise resource planning (ERP) system, sharing information, got from the product lifecycle management (PLM) system, collaborating information, got from the CSCW

environment, etc;

- Manpower resource Including manager, technician, producer, service manpower, etc;
- Service resource Including consultation, training, maintenance, etc.

Manufacturing resources distinguish from each other based on a set of attributes. And resource attributes have various degrees of dynamism, from mostly static attributes indicating their geometric and functional characteristics, like machining boundary, machining precision, and machining capability, to highly dynamic ones indicating their status and availability, like utilization rate, reliability, credit risk, and so on. The availability, usage and cost policies always vary with the particular user, time, priorities and goals. How to enable the sharing, selection, and aggregation of the various manufacturing resources, which are complicated, heterogeneous, geographically distributed and owned by different enterprises, is the primary problem which must be resolved in the MG system.

2.2 Resource management system in MG

In dealing with the complexities of resource management present in an MG system, traditional approaches are not suitable as they attempt to optimize system-wide measures of performance. Traditional approaches use centralized or decentralized policies that require complete state information and a common resource management policy. Due to the characteristics of manufacturing resources, it is difficult to construct such MG environments.

Hence, we investigate a hierarchical resource management architecture including GRAM and MGIS, as shown in Fig.3.

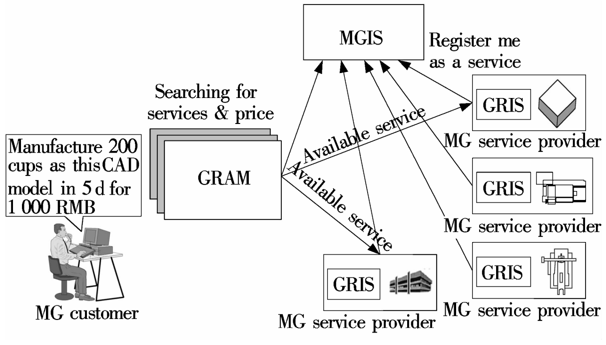

Fig.3 Resource management architecture

The former, GRAM, provided by GT3, is designed to provide a single common protocol and API for requesting and using remote system resources[5]. And the latter, MGIS, developed by us, provides fundamental mechanisms for remote resource encapsulation, registry, discovery and monitoring by integrating MDS with various kinds of resource encapsulating templates.

With this architecture, the MG system enables large-scale sharing of resources and collaborative working among formal or informal enterprises and/or institutions: what are called virtual organizations (VO) or virtual enterprise (VE). Resource management system administers resources and application execution depending on resource customers' and owners' requirements, and continuously adapts to changes in the availability of resources.

2.3 MG information service

In GT3, the MDS[6], which built on the top of the lightweight directory access protocol (LDAP), provides the following features: generating, publishing, storing, searching, querying, and displaying information. MDS includes a configurable information provider component called grid resource information service (GRIS) and a configurable aggregate directory component called grid index information service (GIIS). GRIS provides a uniform means of querying resources on a grid for their current configuration, capabilities, and status, and GIIS provides a means of combining arbitrary GRIS services to provide a coherent system image that can be explored or searched by grid applications.

With these characteristics and benefits provided by MDS, we construct the MGIS in MG system, as shown in Fig.4.

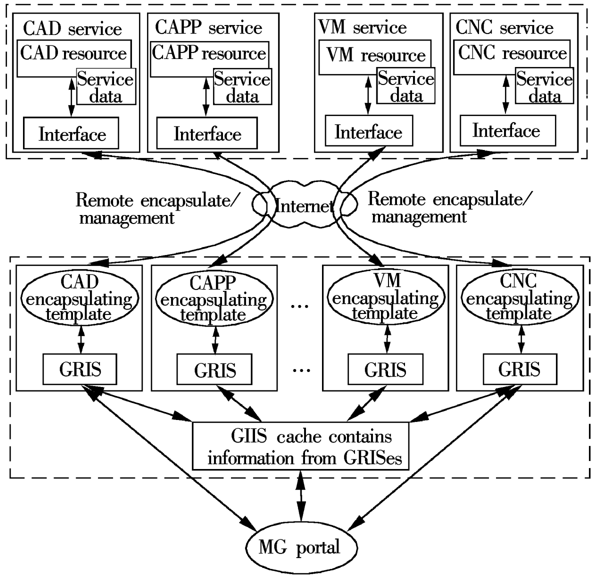

Fig.4 Framework of MGIS

MGIS adopts the method of integrating MDS with various resource templates to make the remote encapsulation and management of resource into reality. There are three important components in this system: resource templates, GRIS, and GIIS. Their functions are depicted as follows:

- Resource Templates In MG, resource differs greatly from each other in terms of its nature (physical characteristics, location, dynamicity, sensitivity, functionality), the demands placed on it (e.g., time, quality, cost, service), and the ways in which it is employed (e. g., discovery, brokering, monitoring, diagnosis, adaptation). Nevertheless, in each case we see a similar structure: the resources belonging to the same category are similar in characteristics and demands. So, we design many templates of inhomogeneous resources, which describe the attributes, demands and interfaces of these kinds of resources. And resource templates can increase with the expanding of MG system.
- GRIS Running on the local of the resource, GRIS can respond to queries from applications asking for information about local resource or other specific resource. GRIS authenticates and parses each incoming information request and then dispatches those requests to one or more "local" information providers, depending on the type of information named in the request. Results are then merged back to the client. And, GRISes are configured to register themselves with a GIIS so that resources can pass on information about the resource to others.
- GIIS Providing the collective-level indexing and searching functions, GIIS is used to obtain information from multiple GRIS resources, and acts as an organization-wide information server for a single site or for a multi-site collaboration.

3 Application Scenario

3.1 Application architecture

In order to explain the application of resource management system, we set up the application architecture to illustrate the interaction between GRAM, MGIS and the other services developed in MG, such as MG broker, local resource manager (CAD manager, data manager, etc.), as shown in Fig.5.

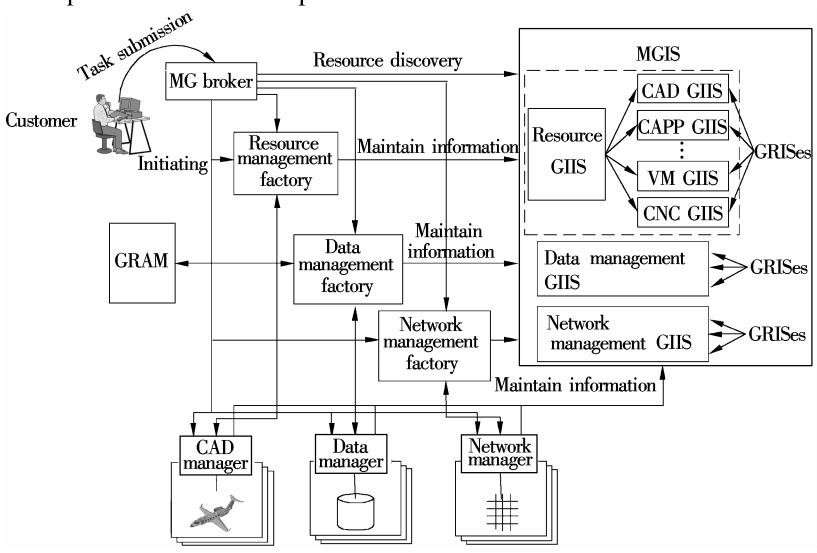

Fig.5 Application architecture

The following is the sequence of steps in using this proposed system:

① The end-user creates a job request for a new manufacturing application to the MG broker, specifying the resource requirements, such as type of service, job description, constraints, time to delivery, and cost. This request is submitted to the MG system.

② The MG broker sends "resource discovery" request to MGIS, and searches for resources in MGIS to satisfy the coarse requirements of the user. The resources may include manufacturing resources (CAD/CAPP/CAE/CAM), data management resources (databases), network management resources, and so on. The mapped resource lists are fed back to the MG broker.

③ Based on the discovered resource list, the MG broker selects the most suitable resources that can satisfy the requirements for the application to be launched. After that, the reservations are made on the selected resources by the MG broker.

④ At the requested time, the selected resource is allocated to the end-user, and the resource instance is created in the desired factory. The interactive session is then initiated between the allocated resource and the end-users.

⑤ The GRAM monitors the interactive session. The monitored data include resource status, resource utilization, percentage completion, remaining time, etc.

The MG broker uses the aggregated monitor data to predict the application behavior.

⑥ After the time specified in the reservation, the resource ends the current interactive session and then can perform other applications submitted by end-users.

3.2 Application instance

With the purpose of illustrating the usage of our developed resource management system, we integrate it into the manufacturing grid testing bed — rapid manufacturing grid (RMG), which takes rapid prototyping manufacturing (RPM) as the application fields and was developed by Shanghai University.

In this testing bed, RPM resources include: ① CAD software, such as UGII, Pro/E, CATIA, and AutoCAD; ② Reverse engineering (RE) machines, such as CMM, CT, and MRT; ③ CAE software, such as NASTRAN; ④ RP machines, such as LOM, SLA, SLS, and FDM; ⑤ RT machines, such as CJ150M3, HZK-I.

① At first, we encapsulate the resources into rapid manufacturing service nodes according to the OGSI specification, with the methods of Web services description language (WSDL) description, service mapping, service realization and service deployment. Ref. [7] gives more detailed descriptions about the encapsulating process;

② And then, we register the encapsulated resources into MGIS. Detailed description about resource registry is demonstrated in Ref. [8];

③ After that, a customer submits a task with the requirements as: "Manufacturing 200 pieces of cups in 5 d with 1 000 RMB, the cups are shown in this picture";

④ MG broker receives the task, and decomposes it into a series of sub-tasks, as shown in Fig.6;

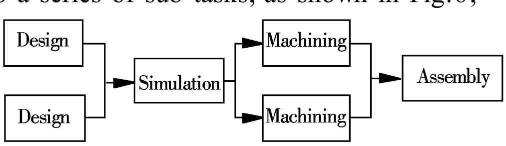

Fig.6 Sub-tasks

⑤ MG broker sends "resource discovery" to MGIS, searches for the available and useful resources, and selects the most suitable resource for each sub-task. For a detailed description of the discovery, evaluation, selection and scheduling of resources, readers can refer to Refs. [9, 10]. The result is shown in Fig.7.

⑥ During the running time, GRAM monitors the working process of each resource, updates the resource status in MGIS from time to time, and feeds back the result of this sub-task to the MG broker;

⑦ When the cups are manufactured, they will be sent to the customer.

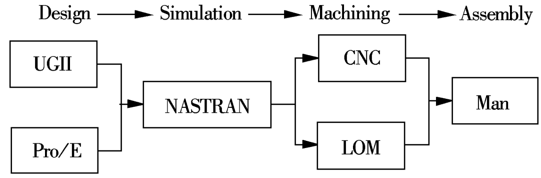

Fig.7 Resource selection result

4 Conclusion

The grid is becoming a mainstream technology for large-scale distributed resource sharing and system integration. Grids enable the sharing, selection, and aggregation of a wide variety of resources (including supercomputers, storage systems, data sources, and specialized devices that are geographically distributed and owned by different organizations) for solving problems in science, engineering, and commerce.

Based on grid computing characteristics, we develop manufacturing grid system with the aim of realizing resource-sharing and collaborative-working among manufacturing enterprises. However, manufacturing resources are much different from other resources, ranging from software, such as CAD, CAPP, CAE and CAM, to machine tools, such as CNC, FMS and RP/RT. This particularity increases the complexity of resource management in MG.

In order to handle dynamic changes in availability of manufacturing resources and user requirements, as well as to provide scalable, controllable, measurable, and easily enforceable policies, we develop a manufacturing grid information service to provide fundamental mechanisms for remote resource encapsulation, discovery and monitoring by integrating MDS with various kinds of manufacturing resource encapsulating templates. The application architecture and example are presented to illustrate the utilization of the resource management system.

In future, we plan to do more research on other problems, such as task scheduling, performance evaluating, which are also quite important in MG.

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制造网格中资源管理系统研究

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摘要: 为实现制造业的资源共享和协同工作, 以开放网格服务架构(OGSA)为系统框架, 以 GT3 (Globus Toolkit 3.0)为开发工具, 提出了制造网格的概念. 然而, 由于制造资源的复杂性、多样性、特殊性和分散性, 制造网格中的资源管理问题明显比其他网格应用项目困难得多. 因此, 开发了制造网格信息服务(MGIS), 该服务通过有效集成检测查询服务(MDS)和各种类型的资源封装模板, 实现了制造资源的远程封装、注册、发现和监控. 同时, MGIS 与 GRAM (globus resource allocation manager)共同构建了制造网格的资源管理系统, 解决了制约制造网格应用的瓶颈问题. 最后, 给出了该系统的应用框架, 并通过制造网格试验床中的一个具体应用实例说明了其实际应用过程.

关键词: 开放网格服务架构; 制造网格; 资源管理; 信息服务; GRAM

中图分类号: TH16; TP39