4D integrated technologies and process simul project management meth

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Abstract for a limited budget and Public Works during the successful completion of the project, accura scale projects, especially for. Tsinghua University and the Hong Kong Polytechnic University at 4D-CAD construction process simulation conducted fruitful areas of research, introduced separately for the proj collaborative research, this article will be a combination of both research results, a new construction pr software systems. The method is based on the adoption of integrated CPM (Critical Path Method) of 4D overcome the shortcomings of both, exert their expertise, based on the implementation of the 4D proje system at Deep Bay in Hong Kong the practical application of the viaduct project, verify its feasibility.

Key construction projects, the progress of management, process simulation, visualization, 4D-CAD

Construction Planning Methodology Integrat Operations Simulation

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Abstract Effective and detailed planning of large-scale, complex construction projects is of great impor Tsinghua University of China and The Hong Kong Polytechnic University, the four dimensional-compute construction operations simulation methodology have been researched for years respectively, resulting construction planning. By crossing upon the two areas, we propose a construction planning methodolo 4D-CAD with operations simulation in order to provide a more useful tool that overcomes the shortcom methodology on a precast viaduct construction project in Hong Kong is presented.

Key words Construction engineering, Construction planning, Operations simulation, Visualization, 4D-

1 outlines

In recent years, the project has a complex structure of the tense period, the venue is crow implementation schedule for the projects development and communicate becomes more and construction process design, site layout and resource allocation of the necessary constructior the use of information technology to provide decision support. Information technology in the Construction) applications have been for many years, with time compared to hand-made ove productivity. For the construction progress of the project management, critical path method Project Planner (P3) has been very popular. Methods because of their very nature, difficult t questions: (1) dynamic resource with the construction of mobile and interactive process moc expression of the construction progress plan (rather than abstract Gantt Chart and Network critical path method based on the progress of program management deficiencies exist, 4D-C has become the subject of much research scholars, and formed a large number of software t management challenges.

Tsinghua University and the Hong Kong Polytechnic University at 4D-CAD (Four Dimensi process simulation conducted fruitful areas of research, launched separately 4D construction and simplification of discrete event simulation (SDESA), and applied to the Beijing Olympics engineering. Through collaborative research, this article will be a combination of both resear management methods and software systems. The method integrates the critical path metho simulation, to overcome the shortcomings of both, exert their expertise, based on the impler construction management. Software system at Deep Bay in Hong Kong the practical applicat

Process Simulation

Discrete event simulation approach has been at the field of construction has been widely modeling, deal with the allocation of resources and conflict detection [1]. Process simulation optimal layout configuration, set up by the construction process on a computer simulation m project cost and implementation period balance. Now have a number of ways for the constru the construction process from the initial CYCLONE [2], programmable STROBOSCOPE [3] to Si increase.

Simplified discrete event simulation (SDESA, Simplified Discrete-Event Simulation) develo the purpose of the project provide a direct simulation tools, description, evaluation and impr SDESA transport program to improve the application in the previous studies have elaborated construction plan of the transport and storage of component programs [6], (2) the optimal us ready-mixed concrete to different sites distributed problem [7]. Lu and Wong [8] compared th is mainly used in manufacturing). The study by PROMODEL platform SDESA and treatment c that during the construction SDESA modeling more flexible and direct. Ways SDESA purpose modeling as easy as the key line method [5]. SDESA will be extended in 3D Spaces on the de integrated with the construction site status [9].

2 based on the CPM of 4D construction management

In the current engineering practice, the design of the main results to two-dimensional de construction plans are based on the CPM describes the progress of plans. When the project p the venue combines detailed progress status information when necessary in the brain by the components, and then these building components and processes that corresponds to. Howev almost difficult to complete. 4D-CAD technology in the process can be visualized in the 3D e 4D-CAD theory from Stanford University, CIFE (Center for Integrated Facility Engineering) in in this regard. Adjei-Kumi [11] proposed PROVISYS model-oriented implementation of the vis about the construction management. Rad [12] proposed the maintenance of 4D model, focus color change calculations. Tanyer [13] based on the IFC (Industry Foundation Classes) and 4

Tsinghua University since 1991, beginning a 4D-CAD visualization in engineering and en 1995, developed a construction management system GCPSU (Graphics for Construction Plan based on 4D-CAD technology, virtual reality environment at the construction process simulat [16] system set up at 4DSMM + + model (4D Site Management Model + +) based on the const resource allocation optimization technology, implementation of the construction schedule, ma 4D dynamic layout management, and integrated throughout the construction process of the

3 advantages of system integration

SDESA and 4D-GCPSU are two advanced technologies used computer systems for the au issues of concern and methods are different. SDESA based on discrete event simulation met process resources of mobile and interactive questions. To realize precise simulation analysis, parameters, these parameters required modeling through data collection and collation be. D questions SDESA Do not need to use simulation, engineers can easily estimate the required space requirements. In addition, while a built-in icon SDESA express two-dimensional anima is still not intuitive, and the lack of real venue layout. In contrast, 4D-GCPSU can be shown Construction status of building components, facilities and construction resources that can be colors to express different processes, so that CPM schedule easier to understand and commu expression of resources and space constraints. Will SDESA with integrated 4D-GCPSU from t management of the actual demand, as well as SDESA and 4D-GCPSU up in the functional com make up for process simulation and the inadequacy of their respective CPM Ways to give full p integrated system, can achieve the following functions.

3.1 **functional complementarity**

The construction process because of the uncertainty and complexity of the construction p experience to complete the arduous task, involving manpower, materials, machinery, space, process can not be defined analytical expressions. Therefore, CPM method can play a very g construction should not clearly describe the problem, or for process simulation parameters te has just begun at the time, the construction operation in the test run period, the problem has required data in process simulation required at trial operation period can be achieved, (2) th can be performed by experienced engineers to easily control. For example, a typical process with the same task has been completed and received. However, for some other cases, engin assisted analysis, such as construction technology to consider, resources and market factors (including experts in the field of scarce, expensive construction equipment, transportation ar required to obtain through various means. In this case, the selection of construction process

In this study, a combination of these two kinds of progress of the project management n process simulation of the CPM and the construction of a new management model. Figure 1 d together SDESA interactive job. Engineer as usual in 4D-GCPSU at CPM schedule set up. Co mission 1 and mission 2 for the easy task, its duration and the use of resources can easily es resources and sites related to space constraint. In the integrated mission system can simula Through the construction process simulation can be a more accurate period 3 mission estima original plan CPM.

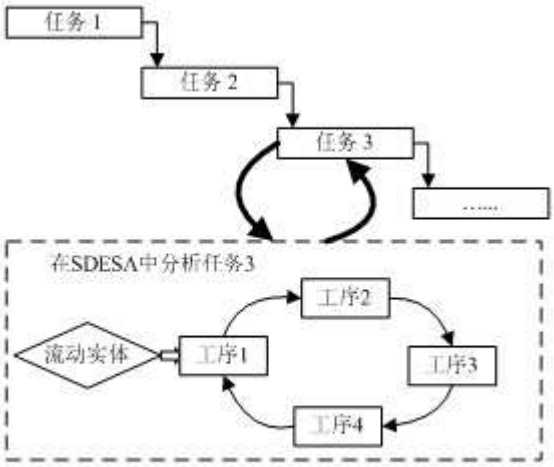


图 1 集成 4D-GCPSU 和 SDESA 的工作模式

3.2 **access to data from the 3D model**

Medium SDESA set up in the process of simulation models first need to input the initial in and other entities. This information can be passed to obtain 4D-GCPSU automatically withou temporary building sites, processing facilities, roads, cranes can be at 4D-GCPSU at the com up. 4D model space entities are part of, the construction site layout plan can be associated w date, venue entities synchronization status changes followed. SDESA can get the latest venu coordinates), as well as process simulation and related resources entities. In addition, 3D infor also be automatically extracted. Automatically generated a list of unit of work includes buildi information.

Adequate space and 3D information for the process of building components provides the of the venue provides a more realistic simulation environment, integrated system for more p

3.3 **vivid animation of the construction process simulation**

In the integrated system, 3D building components and associated CPM schedule. Theref visualization methods to view, different colors representing different construction processes, hidden. Can adjust different parameters to control 4D construction simulations, including (1) month), (3) data (simulated data or actual data plan), (4) speed (normal, fast and slow) and construction process simulations, the lower-left corner of the screen pie chart shows the pro

of the screen shows the list of processes ongoing process information, including the proc units and resources. Users can roaming 3D environment in order to observe the constructior

The above functionality is already in the implementation of 4D-GCPSU, the platform SDE platform for animation. Many fine Analog Engineer in terms of data difficult to understand, tl in tables, charts, animation manner described can effectively enhance the understanding of s 2D view of SDESA venue provides a user-friendly, easy-to-use environment, 2D animation o Venue to express the circle, to connect via a straight line to express both venues. Resources a different icon. Simulation, different icons in a straight line down to move between different improved for the 4D-GCSPU of 3D animation. In the 3D environment, you can (1) Analog See observation of building components, resource entities (such as vehicles, truss crane, crane) facilities, (3) different perspective SDESA model validation.

4 System implementation

SDESA and 4D-GCPSU 2005 are two independent systems. SDESA to C + + language de Library) technology integrates different modules. 4D-GCPSU user interface from Microsoft Vi and its graphics platform set up at OpenGL graphics library on the foundation. According to b up a shared data structure. Through the Application Programming Interface (API, Applicatior database systems implementation of data exchange, as shown in Figure 2.

图 2 SDESA 与 4D-GCPSU的数据共享

4.1 **Functional Analysis**

According to the model structure SDESA, entities can be divided into four categories, na place of work, resources and process entities entities. Entities in order to realize object-orier variables and member functions. 2D site view with contrast enhanced 3D view reflected in th

(1) the work unit entity

Entities that work unit to be constructed building components. At venues SDESA 2D viev mobile unit to another venue, the corresponding icon from one venue to another venue. Har work unit entity component does not have to be constructed of the actual property. In the 3 3D model of building their own 3D geometric description. Size, volume, surface area, coordi calling the function to obtain. To obtain the parameters SDESA simulation model can be use resource analysis and conflict analysis Spaces. 3D model of the work unit can be first in Aut to build, and then imported into 4D-GCSPU system.

(2) the key to job sites entity

Express the key entities in place of work processes in place to implement. Resources are of work at the key to move between the physical object. Occupied by mobile resources requi related to the location of the venue. However, because of the complexity of the problem, mc mobile consumption time, or recommend that users will deal with questions such as "process embedded subsystems mobile resources without the need to insert redundant processes. Fo taken into account the time-consuming to obtain a better simulation accuracy. At the venue *y, z)* of the circle, said pre-defined key to their place of work. In the 3D environment, differe different models that make it easier to identify. Entities can be the key place of work at a co set up, its property coordinates can be automatically extracted for the process simulation.

(3) resource entities

At SDESA resource entities can be divided into mobile resources, supplementary resourc bulldozers, mixer and other resources for mobile resources. 2D view at the venue, they are key job in different locations between the mobile. In the 3D environment, different types of be observed by mobile resources unit of work load and the ensuing exercise. Supporting res

language of the notes in different colors. Initial position of resources in accordance with set.

(4) process entities

SDESA process entity is divided into mobile processes and production processes. At the processes for connecting two key job sites have the color line. Line segments in different col processes. Multiple processes at the same time, it is difficult to distinguish which processes o mobile processes closer to reality. For example, a unit of work loaded with a trailer from a w at the venue, the production processes corresponding job in the same place of work, let the f abstract unit of work which is being difficult to distinguish between the treatment. In the 3D unit of work at job sites which are being dealt with. In addition, the upper left corner of the of each unit is in a job which processes the processed. 3D environment in a more vivid expr SDESA model.

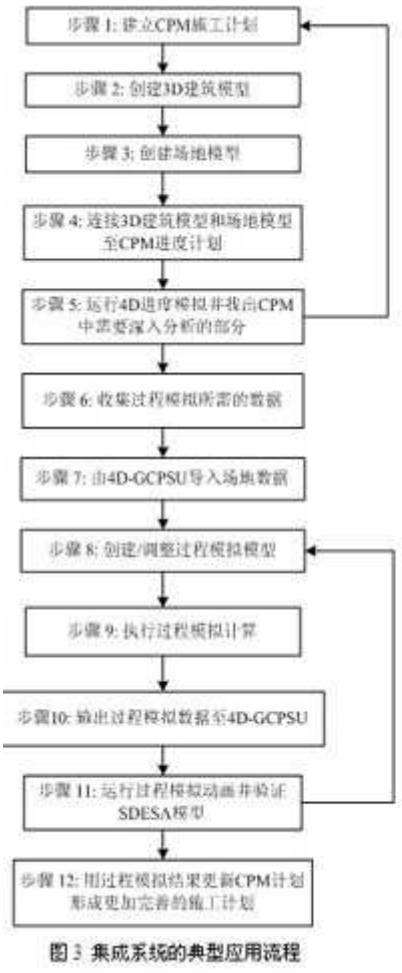


图 3 集成系统的典型应用流程


图 4 用于安装桥面的巨型


图 5 预制构件临时存储于工作场地

4.2 **Application flow**

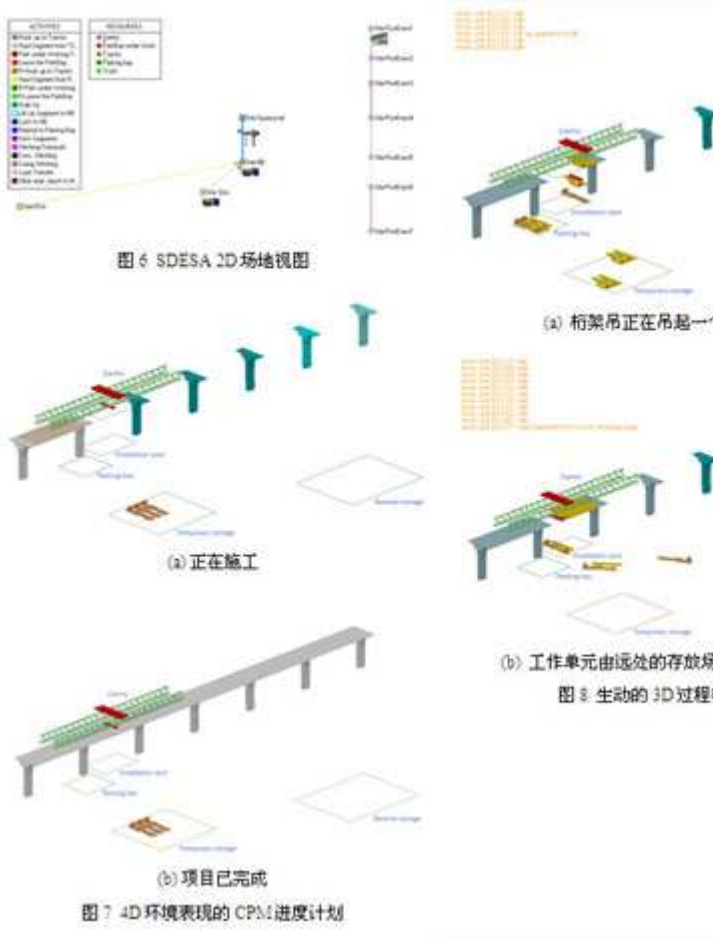
In the integrated system, in accordance with the project engineers can the complexity o and management of simulation projects. Figure 3 describes the typical application of integra progress of 4D model of the CPM plan visualization. Engineer can be observed connected to and site model, was found in which part of CPM plans to conduct in-depth analysis required. step through the steps 6 to 11 set up the process of simulation model. In the model to consi constraints. Data between the two systems can be at step 7 and step 10 to pass through the simulation animation, animation Engineer can be observed to verify the model and modifying model to best adjust status, you can use the results of CPM schedule update. Thus, access to

5 Case Studies

Deep Bay project is a precast concrete viaduct project, connecting Shenzhen and Hong K
Corridor. Contract calls for the establishment of a 4.2 km long concrete viaduct, the viaduct f
across the existing trunk roads and rail. Contract clients are the Department of the Hong Ko
contracts for HK $ 1716 million (US $ 220 million), engineering from October 2003 to Octobe
its has more than 70 subcontractors.

The project used prefabricated truss construction crane 227 Ways to install cross-bridge,
and rail traffic has been affected. A complete cross-bridge construction process consists of th
erection of piers at both will be suspended on the truss to the design of precast lifting positic
jack truss crane will move to the next inter-position. Figure 4 shows for the installation of pr
suspended through the location of the calibration, they start to install the precast. Trailer wil
the bridge span under the care of the work area. For cross-bridge near enough space, comp
bridge span to close the storage site construction, and sometimes cross the bridge near the
large-scale (12m x 2.5mx 2.8m ; Figure 5), components need to be stored in places away from
to the work area, the crane beam from the trailer up to the design of precast lifting position,
crane at the main beam. When all cross the bridge in place after hoisting precast, concrete p
truss bridge span suspended by the current move to the next bridge span.

In order to meet the construction requirements at the same time reduce the constructio
construction period, the project SDESA and the use of 4D-GCPSU to provide decision suppor
exchange of information between the Department. At the beginning of the project, set up th
construction process, including foundation engineering, bridge pier construction works as we
3D model of building models and venues. Engineer in 3D visualization environment throughc
environment adjust schedule. However, for the work space should not store more than enou
a reliable analysis. The delivery of prefabricated units, the use of resources, as well as cross
experience of engineers come up with a reasonable estimate. Therefore, SDESA used to sim
determine the problem: (1) distant storage points should be placed where can be protected
distance should be kept in storage the number of prefabricated can safeguard the efficient o
site information from the 4D-GCPSU into SDESA, simplifying the process of simulation model
output to 4D-GCPSU, at 4D-GCPSU view vivid animation process simulation. Figure 6 shows
Figure 7 shows the 4D environment building components and facilities. Figure 8 shows the 4
animation. Integration of both systems to enhance their own construction management at th



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References

[1] Pang, H.; C. Zhang; A. Hammad. 2006. "Sensitivity Analysis of Construction Simulation Us
of the 2006 Winter Simulation Conference. Monterey, California, 2021-2028.
[2] Halpin, DW, 1977, "CYCLONE - Method for Modeling Job Site Processes", Journal of the C
[3] Martinez, JC 1996. "STROBOSCOPE: State and Resource Based Simulation of Construction P
Michigan, Ann Arbor, Michigan.
[4] Hajjar, D., and SM AbouRizk. 1999. "Simphony: An Environment for Building Special Purpos
of the 1999 Winter Simulation Conference, 998-1006.
[5] Lu, M., "Simplified Discrete-Event Simulation Approach for Construction Simulation.", Jou
ASCE, 129, no.5, 537-546.
[6] Chan, WH, and M. Lu. 2005. "Logistics and Operations Simulation in Precast Viaduct Cons
2005 ASCE International Conference on Computing in Civil Engineering. Cancun, Mexico, Pap
[7] Lu, M., and HC Lam. 2005. "Optimized concrete delivery scheduling using combined simul
the 2005 Winter Simulation Conference. Orlando, Florida, 2572-2580. [8] Lu, M ., and LC Wong
Modeling Construction Operations." In Proceedings of 2005 Winter Simulation Conference. O
[9] Lu, M.; M. Cao; JP Zhang. 2003. "Synchronize Operations Planning and Site Layout Planni
Simulation Approach (SDESA)." In Proceedings of Second International Conference on Constru
Polytechnic Univ. and Florida International Univ., Hong Kong, 573-580.
[10] McKinney, K.; J. Kim; M. Fischer. 1996. "Interactive 4D-CAD.", Computing in Civil Engine
[11] Adjei-Kumi, T., and A. Retik. 1997. "Library-Based 4D Visualization of Construction Proces
Visualization Conference Proceedings of the International conference on Information Visualiz
[12] Rad, HN, and F. Khosrowshahi. 1997. "Visualization of Building Maintenance Through Tir
Visualization Conference Proceedings of the 1997 International Conference on Information vi

[13] Tanyer, AM, and G. Aouad. 2005. "Moving beyond the Fourth Dimension with an IFC-base
Construction, 14, no.1, (January) :15-32.
[14] Yabuki, N., and T. Shitani. 2005. "A management System for Cut and Fill Earthworks Based
2005 ASCE International Conference on Computing in Civil Engineering. Cancun, Mexico , 161
[15] Zhang, JP 1996. "A New Approach to Construction Planning and Site Space Utilization th
dissertation, the Hong Kong Polytechnic University.
[16] Zhang, Y.; JP Zhang; JL Li etc. 2006. "Research and Application of a 4D Construction Pla
1st International Construction Specialty Conference, Calgary, Alberta, Canada, May 23-26, 20

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