Complex Objects Measurement by Using an Optical 3D Measuring System

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Introduction

Due to the emergence of new production technologies, and an increase in product complexity, it is necessary to rely on new sophisticated measuring systems. Optical methods for measuring three-dimensional shapes have, in the last ten years, rapidly increased their market share. Optical 3D measuring systems have simple control procedure, high density of data and the possibility of integrated reverse engineering and inspection. With these systems it is possible to get a significant amount of information about the object – in a short time. The result of the optical 3D measurement system is a digitalised geometry which takes the form of a thick point cloud – or a polygon mesh which describes the surface geometry of the measured object. Using an optical 3D measurement system, it is possible to measure objects with complex geometry and to carry out a comparison of the geometry with the CAD model. The research that was carried out indicates that many influential variables exist in the measurement process which utilises the optical 3D system. Sources of uncertainty are divided into five groups: environment, measuring object, operator, scanning hardware, and scanning software. The aim of this research is to identify and determine the significance of each influential factor.

Methods

The Design of experiment (DOE) methods are being applied in the study of factors influencing the characteristics of processes and products. Seven influential factors (temperature, humidity, illumination, measurement object, coating, interpolation and polygonization) were included in the experimental design. All measurements were obtained using the ATOS Core 300 measurement system. In order to determine the significance of influencing parameters, the analysis of variance (ANOVA) was conducted.

Preliminary results

The analysis of variance points to 3 factors which have significant influence on measurement results. These factors are: measurement object, interpolation and polygonization. Furthermore, the results show that the measurement object has the largest influence on measurement results. The deviation from the model is not significant and there is no systematic error, so the results can be accepted.

Discussion

This research investigates influential factors. The next step in the research is to develop a mathematical model of the measurement process and a calculation of measurement uncertainty. Additionally, it is necessary to determine which of the measurement object characteristics has a significant level of influence on the measurement results.

Keywords

Optical 3D Measurement system, Influential factors, Measurement uncertainty

Cognitive Model of Closed Environment of Mobile Robot Based on Measurements

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Introduction

One of the main challenges in operation of today's mobile robots is their management inefficiency in an unstructured environment, within which they have to perform certain tasks. To perform a task, robot necessarily needs to map the environment, but to accomplish this it needs to move in a environment which is yet unknown. This is the main paradox of the so-called Simultaneous Localization And Mapping (SLAM) problem: how to simultaneously build a map and plan a motion in an unknown environment? Initial research on this topic was based on pure mathematical models (configuration environment, potential fields, equidistance path) and has resulted in exact models. However, due to the large limitations in the practical application of such methods, they have been abandoned and today the focus is on methods where the multi-system measurement fusion comes with probable character models.

Aims

The aim of the research is to build a cognitive model of the closed environment of mobile robot. The environment model would be built of robots position and orientation data, data about objects in environment, which are detected with camera mounted on robot, and data collected with distance sensors mounted on the robot. Fusion of this data would produce new data which is more than a simple sum of data parts before mentioned.

Methods

The research methodology will include the definition, analysis and placement of an appropriate interactive cognitive model of the closed environment of a mobile robot. Validation and verification of the model will be performed by a series of simulations of simpler problems. By shaping the work segments in whole, the entire model of interaction between the mobile robot and the environment will be gradually defined. The environment model will be built from position and robot orientation data, object data, which are detected with the robot camera, and data collected from the distance meters/sensors. The research segments will be implemented on a real system consisting of a mobile robot and a test polygon, equipped with sensors and vision systems. By interacting with the data collected, new data will be obtained that will help robot to know, after an acceptable time interval, that the environment is now known to it. Also data gives acknowledgement, with use of the basic cognitive elements, where robot is in environment and what it sees/detects.

Expected scientific contribution

1. Fusion of different types of data from different sources for the purpose of constructing more complex data suitable for the construction of the cognitive model of the closed environment in which mobile robot is positioned. 2. Data and methods selection for construction of closed environment model for execution in real-time. 3. Construction of the cognitive model of closed environment in which mobile robot is positioned. 4. Experimental test of given cognitive model of environment, with use of the mobile robot positioned in test polygon.

Keywords

mobile robots, cognitive model, closed environment, sensors

Application of Diamond-Like Carbon Coating in Orbital Hydraulic Motor

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Introduction

Tribology has been recognized as a very important discipline in different branches of industry within recent years as almost every mechanical system has some moving parts. Due to the relative motion between different mechanical parts, different contacts are formed. They are very often lubricated with oil. Presently, environmental protection and ecological awareness is becoming increasingly important, which in turn has resulted towards the direction of a low-carbon society, therefore, water has gained interest over the years. On the one hand, water is less environmentally damaging as a lubricant than oil, but on the other hand, water has very bad lubrication properties, as its viscosity is 100 times lower compared to the viscosity of oil. Limitations may be overcome with an appropriate surface engineering (i.e. Diamond-like carbon-DLC). Tribological tests were performed in oil and water for two different contacts. Steel/steel and steel/DLC were investigated. DLC was recognized as a very promising solution, which ensures low friction and low wear. DLC was deposited on real hydraulical part in orbital hydraulic motor and tested under real industrial conditions. The overall efficiency of hydraulic motor was measured.

Keywords

friction, wear, hydraulic motor, water, Diamond-like Carbon

Smart Sheet Metal Forming Tools Strip Layout Analysis Method

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Introduction

The differences in the design process of smart and conventional sheet metal forming tools are recognized in the practice and literature, so the goal of the research is to propose and evaluate a new applicable design process model. This paper present method for smart sheet metal forming tools strip layout analysis and presentation as an upgrade of conventional sheet metal forming tools strip layout analysis and presentation methods. Smart sheet metal forming tools are a specific segment of smart products. Controllable actuators in the direction different from the press opening direction and sensors that give information about workpieces, tools and processes regulate the production process parameters in real time. In comparison with conventional, smart tools enable production without bad products, without tool damage and without production breaks or with significantly less of them. They also allow the production of more complex products. In another hand, smart tools include more complex components in tools design, which conventional tools is not, or include them significantly less and more straightforward kind of them.

Methods

Smart sheet metal forming tools can have many kinds of actuators, sensors and another smart component. Conventional strip layout analysis and presentation methods with only work pieces shape and geometrical place of it in tool don't give enough information in this new situation. This paper present new method for analysis and presentation of smart sheet metal forming tool strip layout. Main characteristic of new method is that except shape of work pieces and geometrical place of a particular stage in progressive sheet metal forming tool include component of information infrastructure predicted in tool in different level of finishing from initial idea to final selection.

Preliminary results

Multidisciplinary information presented with this method increases quality of communication between members of multidisciplinary development team which kind is necessary for smart product development and enabled more effective organization of team work. Presented method by clear presented information in early phase of tool development that control and computer engineering specialists needed enable that they can be included in development team in such early phase of tool development. This method also communication with customer make easier.

Discussion

This paper present method for smart sheet metal forming tools strip layout analysis and presentation which have potential to be used in all smart product development process. In this purpose method should be completed with two more presentation. First one which describes function of each information infrastructure component with expectation of working range and setup parameters as well as selection of component and its control elements. Second one that present principle diagram of control software function including user interface. Completing of this method is current work in progress of this research and should be presented in future papers.

Acknowledgments

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Keywords

Smart product design, smart sheet metal tools, strip layout analysis

The Impact of Manufacturing Errors on Dispersion of Hits for Unguided Projectiles

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Introduction

For ammunition manufacturers of today, demands for ever higher manufacturing quality are being set. It is because of the need to avoid or at least to minimize collateral casualties that are common during urban conflicts. At the same time, there is a need to accept a certain level of manufacturing errors so to keep production costs acceptable.

Methods

Because of two aforementioned conflicting demands, i.e. one for precision and the other for lowering production costs, it became necessary to determine which requirements imposed on manufacturers are really justified and which only increase expenses, but do not contribute to a significant reduction of dispersion of hits. This paper shows how it is possible to combine a series of analytical methods to analyze the impact of particular manufacturing error, or more than one error at the same time, on projectile's flight. Methods include: 3D CAD model of rocket with geometrical and inertial characteristics adjusted to the real rocket; 6DOF model of flight showing the motion of rocket during the active and the passive phase; methods for statistical processing of results – Monte-Carlo simulation, regression analysis, worst-case scenario etc.

Preliminary results

Preliminary results show strong connection between changes of rocket's tensor of inertia and its trajectory. In case of dynamic unbalance, principal axes (depending of manufacturing errors, simulated in 3D CAD model) deviate from axes of geometrical symmetry, and center of mass is no longer positioned on longitudinal axis of symmetry. Since manufacturing errors are non-deterministic by nature, points of hit for a series of projectiles are being dispersed. Model shows that there is (among all factors influencing projectile's flight) an especially strong correlation between angle of deflection between principal axes and axes of geometrical symmetry, and an overall dispersion of hits.

Discussion

Using a set of methods and models, logically connected in such a way that each provides the input values for the next one, a comprehensive method is developed demonstrating how to set manufacturing tolerances for certain phase of production. Results show that it is really necessary to insist on extremely high precision for some parts of overall production, but also that less strict tolerance can be implemented for those manufacturing errors that have only limited impact on the projectile's flight or its dispersion of hits.

Keywords

unguided projectiles, manufacturing errors, 3D CAD model, 6DOF model of flight, Monte.Carlo simulation

Residual Stress Effect on Fatigue Crack Propagation

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Introduction

Forming induced residual stress (RS) plays a signifficant role in predicting fatigue life of a product. They are induced by inhomogeneous plastic flow which is exempt only in simply shaped geometry. In product service, RS takes a new equilibrium configuration which is based on deformation hardening that originates in cyclic loads especially in low cyclic fatigue where large plastic deformations are present. This new state of RS has a similar effect as mean stress on fatigue life. Classical fatigue calculation concerns in predicting the number of load cycles that nucleate the initial macro crack and stops here. Fracture mechanics is the current standard for crack propagation until complete fracture of product under study. This poses a severe obstacle in practical application of both methods, because each method requires different material properties which are gained after a series of time consuming and expensive laboratory work. We would like to push the boundary of classical fatigue calculations beyond the current scope of validity and develop a holistic approach for both, prediction of micro crack nucleation and its growth until fracture. Continuum damage mechanics (CDM) will govern our approach in describing the degrading material properties under cyclic loads. The scope of CDM is based on representative volume element (RVE) which describes the growth of intrinsically discontinuous micro cracks and voids as integral effects on nominal stress-strain response on RVE subjected to cyclic loads. Growth of discontinuities is postulated as damage and has a similar effect as a reduction of load bearing surfaces inside RVE.

Methods

A series of strain and stress fatigue testing will be conducted in order to build a reliable material damage model for low carbon structural steel. Inhomogeneous plastic flow will be introduced, via bending load, in a specimen to induce RS. Contour method for measuring RS will be applied after a series of increasing number of cyclic loads to gain insight into RS relaxation. As mentioned before, CDM postulates a RVE as its elementary object of study. RVE is by its principle similar to a volume element used in final element analysis (FEA) which will be used as central method for application of combined approach in fatigue. Node splitting between final elements will be used to simulate crack nucleation and growth in a specimen subjected to bending cyclic load, which is predominately uniaxial and proportional . Node splitting will be governed by the increasing damage of surrounding final elements and will occour when critical damage of fracture is reached. This is the basis of a united approach for modeling fatigue and fracture. Results obtained in this numerical fassion will be compared to experimentally driven fatigue and crack propagation.

Contribution

The before mentioned method will lend a hand in calculating or predicting complete fatigue life by using only one governing approach. A special insight will be given in crack growth under the influence of RS present deep below the surface of a product. This could reveal crack growth retardation in a field of compressive RS thus prolonging the product usability. Current focus is based on low carbon steel under proportional uniaxial loading.

Keywords

fatigue, residual stress, damage mechanics, fatigue crack propagation

Analysis of Thin-Film Lubrication Using Openfoam

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Introduction

In this work a thin film lubrication model implemented inside OpenFOAM framework is presented. Four lubrication regimes are considered: thick and thin film hydrodynamic regime, mixed regime and boundary regime. In hydrodynamic regime two surfaces in contact are completely separated by the lubricant. In thin film hydrodynamic regime surface roughness influences lubricant flow, while in thick film regime surface roughness can be neglected. In mixed regime contact pressure is shared between the lubricant and surface asperities. In boundary regime almost the whole contact pressure resides on asperities in contact, with the lubricant found in traces in asperities' valleys. The implemented model is able to calculate all three regimes continuously. As lubricant flows between two surfaces in relative motion heat is generated due to film shearing effects and due to traction between asperities in contact. Thermal effects are more evident in case of significant sliding between two surfaces in contact. Due to temperature changes lubricant transport properties can vary significantly. Also, in addition to temperature dependence, viscosity and density of the lubricant depend on pressure values. All these effects need to be accounted for when analyzing lubrication between two sliding engineering surfaces.

Methods

Lubricant flow is modelled using Reynolds equation, a partial differential equation governing pressure distribution in thin film flows. Reynolds equation is discretized using the Finite Area Method (FAM), a two-dimensional counterpart of the Finite Volume Method discretized over a curved surface. The film energy equation is also discretized using FAM assuming parabolic temperature profile across the lubricant film. Surface temperature increase is calculated using Carslaw and Jaeger model and FFT method. Surface deformation is modelled using elastic deflection principle where convolution integrals are calculated with FFT method, which significantly increases computational efficiency. Pressure and temperature dependent transport properties are implemented with respect to the type of lubricant oil.

Preliminary results

The model is validated using two test cases, where friction and film thickness values are compared to numerical results and experimental measurements from the literature. Case geometry considers ball-on-disc test rig where a rotating steel ball is in contact with a rotating glass or steel disc. Contact between the surfaces is lubricated. Two lubricants are considered: Turbo T9 and Turbo T68. Test case with T9 oil is calculated for hydrodynamic regime. Film thickness and friction coefficient results show very good agreement with the experimental measurements. Test case with T68 oil is calculated for the hydrodynamic and mixed regime. Friction coefficient results show good agreement with the experimental data considering that the transport properties of the lubricant are partially known.

Discussion

The developed model is able to calculate lubricated contact between two realistic rough surfaces giving very good results when complete information regarding lubricant properties is available. In case of mixed regime, surface roughness profile is also necessary in order to ensure good results.

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Keywords

OpenFOAM, lubrication, ball-on-disc, Reynolds equation, thin film thermal equation

Implementation of Fiber Dispersion in Finite Element Model of Abdominal Aortic Aneurysm

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Introduction

Abdominal aortic aneurysm (AAA) is a local and irreversible dilatation of the abdominal aorta caused by an imbalance in production and degradation of the extracellular matrix. It is an asymptomatic disease until complications occur, which can lead to rupture and death. Numerical growth and remodeling (G&R) models of AAA are developed for better understanding of the disease and to predict the likelihood of rupture. Aorta is considered as a multilayered fibrous composite with collagen fibers and smooth muscle cells embedded into a ground matrix. Experimental and imaging studies have shown that collagen fibers are dispersed within the aortic wall which has an effect on the mechanical response of the aortic tissue. Although G&R models take into account microstructure of the aortic wall, so far none of them has modeled collagen fiber dispersion. The aim of this work is to implement a fiber dispersion model into a current constrained mixture G&R model. Additionally, the influence of the fiber dispersion on the aneurysmal growth and the distribution of stresses inside the aortic wall will be analyzed.

Methods

G&R model of the aortic wall combined with the collagen fiber dispersion model was implemented into the finite element analysis program FEAP via subroutines for the user-defined material model. The G&R model is based on the constrained mixture theory and the theory of evolving configuration. The dispersion model is based on the generalized structure tensor approach and it can describe a non-symmetric fiber dispersion (i.e. different dispersions in the tangential plane and out-of-plane).

Preliminary results

After verification of fiber dispersion implementation, the influence of the collagen fiber dispersion on the evolution of an aneurysm was analyzed. For that purpose, an axisymmetric model of a fusiform aneurysm was used. The aortic wall was comprised of three layers and each layer had different mean fiber direction and fiber dispersion. The preliminary results show that an increased fiber dispersion (i.e. a higher degree of isotropy) in the intima and the media lead to a slower growth rate, while increased dispersion in the adventitia resulted in a faster growth rate. Moreover, an increase of fiber dispersion tends to level the circumferential and axial stresses throughout the wall thickness, while the more aligned fibers increase the axial stress in the adventitia and circumferential stress in the intima and the media.

Discussion

Verification has shown that the fiber dispersion model is correctly implemented. Furthermore, obtained results indicate that the fiber dispersion has a significant influence on the aneurysmal growth and on stress distribution in the aortic wall. Therefore, we suggest that the fiber dispersion should not be neglected in future G&R studies of AAA. Additionally, the inclusion of fiber dispersion is a valuable expansion of our current AAA model.

Acknowledgments

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Keywords

Abdominal aortic aneurysm, Finite element method, Fiber dispersion, Growth and remodeling

Modelling and Optimal Control of a Parallel Plug-In Hybrid Electric Vehicle

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Introduction

The thesis proposes an extension of a parallel Plug-In Hybrid Electric Vehicles (PHEV) powertrain backward model with a sub-model describing realistic transient effects while maintaining computationally efficient quasi-static structure. The extended backward model and a dynamic programming algorithm will be utilised to optimise PHEV powertrain control variables. The optimisation results will be used for synthesis and verification of a control strategy that considers powertrain transient effects. The control strategy can also extended by an algorithm that generates an optimal profile of battery state-of-charge (SoC) reference trajectory considering varying road grade and the presence of low emission zones.

Methods

Powertrain characteristics of a PHEV with parallel configuration can be described by the computationally efficient quasi-static (backward) vehicle model while the dynamical behaviour of PHEV powertrain can be described by more computationally demanding and more precise dynamical (forward) vehicle model. The effects of PHEV powertrain transients in terms of fuel and SoC consumption can be modelled with an appropriate static model based on the results of extensive forward model simulations. An expanded backward model is proposed which will include powertrain transient effects in dependence to a wide variety of transient scenarios with the aim to reduce computational load while maintaining precision of a forward model. Dynamical programming (DP) can be used for control variable optimisation of both backward and expanded backward models. The insights gained from optimal results analysis will be used for control strategy synthesis which will consider previously modelled transient effects with the aim of minimising energy consumption while maintaining acceptable levels of driving comfort and battery degradation. Optimal results gained by the DP can also be used for reference SoC trajectory synthesis for PHEV control strategy in the cases of blended operating regime and varying road grade and existence of low emission zones.

Preliminary results

The method for SoC reference synthesis in the case varying road grade and low emission zones for blended regime has been proposed and verified.

Discussion

The thesis is expected to result in: (i) computationally efficient backward PHEV model which includes effects of powertrain transients described by the static regression model, (ii) optimal energy management control strategy which will achieve additional fuel savings and driving comfort by taking powertrain transient effects into account and (iii) reference SoC trajectory synthesis in the case of varying road grade and low emission zones for the blended operating regime

Acknowledgments

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Keywords

Control, energy management, optimal battery state-of-charge, plug-in hybrid electric vehicle, expanded backward model

Multiagent System for Distributed Control of Cyber-Physical Systems

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Introduction

The number of sensing and actuating devices used for production control is growing rapidly. Advanced connectivity technologies and protocols enable integration of physical and computational devices into cyber-physical systems (CPS), focusing on integration of computation with physical processes. As CPS grow in size and complexity, traditional centralized control often fails to provide adequate response times and management of computational complexity. Researchers work on enhancing flexibility, robustness, adaptability, and reconfigurability of CPS by employing concepts of distributed and autonomous control in dynamic environments of cyber-physical production systems. A way to implement distributed control is by using autonomous computational entities called agents. Agents acquire information about their environment and take actions to influence the environment. In some applications, multiple software agents are used to collectively solve problems by interacting with each other and reaching mutual agreements through negotiations, bidding, and othercommunication mechanisms, enabling reconfigurability and scalability. Agents acting in parallel results in the system's global behaviour that may include emergent phenomena and is often difficult to predict in advance. Adaptiveness can be provided by intelligent capabilities of the agents.

Methods

In the first phase, the general model of the agent will be proposed. Experiments of the implementation of the agents in a CPS will be performed in software simulation. In the second phase, real demonstrators will be assembled using hardware with embedded computers to run the software agents and enable data connection and communication between agents. In the demonstrator, experiments on expansion/reduction of the system scale as well as experiments involving disturbances will be simulated. Through the measurement of selected key performance indicators during normal activity and in case of disturbances, scalability, robustness, and resilience of the system will be assessed.

Preliminary results

The model of the learning agent was implemented in a software simulation where a CPS with agents coupled with valves and switches was used for distributed control of industrial compressed air system. The agents use machine learning to learn the model of their environment and to adapt to disturbances. In the process of action selection, the agents communicate with other connected agents. The observations of the performance of the system in simulated experiments show that the system is scalable, and that the communication structure influences the robustness and the resilience of the system.

Discussion

The focus of the research work is to design the structure and the decision model of a learning autonomous agent for realization of distributed control of CPS by coupling agents with physical actuating devices. The model will be implemented and tested on demonstrators for two industrial use cases: an industrial compressed air system and an automated guided vehicles system. They will be used to show that a CPS with distributed control is more scalable, robust, and resilient than a centralized control system.

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Keywords

multiagent system, cyber-physical system, distributed control, production control

Information Support Framework for Processes in Manufacturing Systems Based on Big Data

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Introduction

Due to the intensive development of information and communication technologies, large amounts of data are being generated. Many new approaches, methods, techniques, and tools for advanced data analytics are being developed and, consequently, additional possibilities of using large amounts of complex data – also referred to as big data, are emerging. However, the application of advanced data analytics in the production domain lags behind in penetration and diversity in comparison to other domains, and the data available often remains unexploited. This study develops and demonstrates the use of a framework for information support for processes in manufacturing systems. The framework is a conceptual tool that facilitates the introduction of big data analytics into manufacturing systems. It provides a step-by-step procedure for introducing big data analytics into manufacturing systems and systematically shows what knowledge and skills, reference models, software and hardware tools, etc., are needed.

Methods

The framework is based on the development and research of several data-analytics solutions developed and implemented in the course of this study, as well as on other existing applications and conceptual solutions from literature and practice. The feasibility and wide applicability of the framework at all manufacturing-system levels are demonstrated and validated. For the development and validation of data analytics solutions, real industrial and internet data are used. Developed solutions for data analysis enable either new ways of using the data, a more effective reduction of the incompleteness of information, or more efficient discovery of new knowledge in comparison to conventional approaches in academia and industry.

Results

Results are the following: (1) a conceptual framework for the development and implementation of big data analytics solutions; (2) a method for identifying faulty operating conditions in cyclic manufacturing processes; (3) a data-driven approach to fault prognostics in cyclic manufacturing processes; (4) discovery of the possibility for data-driven prediction of unplanned machine stops in the plastic injection molding process; (5) a method for testing the possibility of data-sharing between similar machines for improving the data-driven fault-prediction model; (6) the identification of the possibility for improving the data-driven fault detection model through the sharing of data between injection molding machines; (7) an algorithm for data-driven prediction of the work-systems work overload and a visualization method of work-systems work overload in large-scale manufacturing systems; (8) the method for identifying the business and social networks in the domain of production by merging the data from heterogeneous Internet sources; (9) a data-driven method for predicting changes in the sequence of work order's operations based on MES data.

Acknowledgments

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Keywords

manufacturing systems, data analytics, big data, conceptual framework, data mining