PROCEEDINGS OF
THE 2013 INTERNATIONAL CONFERENCE ON
DATA MINING

DMIN 2013

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WORLDCOMP'13
July 22-25, 2013
Las Vegas Nevada, USA
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Foreword

We are pleased to present this collection of papers submitted to the 9th International Conference on Data Mining 2013, DMIN'13 (www.dmin-2013.com), July 22-25, 2013, The New Tropicana Hotel, Las Vegas, Nevada, USA.

Data mining is a relatively young discipline that is critically important if we want to effectively learn from the tremendous amounts of data that are routinely being generated in science, engineering, medicine, business, and other areas. Data mining attracts innovative and influential contributions to both research and practice, across a wide range of academic disciplines and application domains. DMIN conferences seek to acknowledge and facilitate excellence in research and applications in the area of data mining. DMIN conferences are held annually within WORLDCOMP, the largest annual gathering of researchers in computer science, computer engineering and applied computing. WORLDCOMP'13 assembles a spectrum of 22 affiliated research conferences, workshops, and symposiums into a coordinated research meeting. Each conference has its own program committee as well as referees and own indexed proceedings. Attendees have full access to all 22 conferences' sessions, tracks, and tutorials. DMIN seeks to reflect the multi- and interdisciplinary nature of data mining and to facilitate the exchange and development of novel ideas, open communication and networking amongst researchers and practitioners in different research domains. As in 2012 and the years before, we hope that the 2013 International Conference on Data Mining will provide a forum for you to present your research in a professional environment, exchange ideas, and network and interact across research areas. DMIN actively supports students and beginning researchers from lesser developed countries by funding registration and accommodation, in order to allow for a truly international networking and understanding. The 2013 conference has provided an international and multicultural experience with contributions from 26 different countries. We consider the resulting diversity in attendees and the mixture of established and starting researchers as a particular advantage of an engaging conference format.

DMIN'13 attracted a large number of submissions of theoretical research papers as well as industrial reports and case studies on applications. The program committee would like to thank all those who submitted papers for review. We strived to establish a review process of high quality. To ensure a fair, objective and transparent review process all review criteria were published on the website. Papers were evaluated regarding their relevance to DMIN, originality, significance, information content, clarity, and soundness on an international level. Each aspect was objectively evaluated, with alternative aspects finding consideration for application papers. Each paper was refereed by at least two researchers in the topical area, taken the reviewers' expertise and confidence into consideration, with most of the papers receiving three reviews. The review process was competitive. The overall paper acceptance rate for papers was 45%.

We are very grateful to the many colleagues who helped in organizing the conference. In particular, we would like to thank the members of the DMIN'13 program committee. Their continuing support has been essential to further improve the quality of accepted submissions and the resulting success of the conference. The DMIN'13 program committee members are (in alphabetical order):

Mahmoud Abou-Nasr, Lamine M. Aouad, Jérôme Azé, Souhaib Ben Taieb, Daniel Berrar, James Buckley, Alina Campan, Peng Chen, Paulo Cortez, Christian Dawson, Qin Ding, António Dourado, Mengling Feng, Philippe Fournier-Viger, Shunkai Fu, Peter Géczy (JP), Corani Giorgio, Zahid Halim, Tzung-Pei Hong, Yo-Ping Huang, Ulf Johansson, Rikard König, Madjid Khalilian, Sebastian Klenk, Terje Kristensen, Philippe Lenca, Chuan Li, Wen-Yang Lin, José M. Merigo Lindahl, Tanja Magoc, Jun Meng, Sergey Morozov, Hossein Peyvandi, Torsten Reiners, Lotfi Ben Romdhane, Gerald Schaefer, Sabrina Senatore, Xuequn Shang, Victor Sheng, Yong Shi, Vijendra Singh, Robert Stahlbock, Shun-Hung Tsai, Nicole Vincent, Baoying Wang, Chamont Wang, Fan Wang, Simon Wang, Xuewei Wang, Gary M. Weiss, Zijiang Yang, Yun Zhai, Defu Zhang, and Shang-Ming Zhou.

We would also like to thank our publicity co-chairs Ashu M. G. Solo (Fellow of British Computer Society, Principal/R&D Engineer, Maverick Technologies America Inc., Intelligent Systems Instructor, Trailblazer Intelligent Systems, Inc.), and Sven F. Crone (Lancaster University, UK) for circulating information on the conference..

Considering the increasing efforts of all towards the quality of the review process, the conference sessions and the social program of DMIN'13 we are confident that you can look forward to participating and attending a leading and reputable international conference. It is a particular pleasure to provide data mining oriented invited talks and tutorials presented by the following esteemed members of the data mining community: Vladimir Cherkassky (University of Minnesota, USA), Peter Geczy (AIST, Japan), and Alfred Inselberg (Tel Aviv University, Israel).

The DMIN'13 conference organizers are also thankful to a number of co-sponsors, without whom the conference would not have been possible. The conference was sponsored and or supported by the US Chapter of World Academy of Science (http://www.world-academy-of-science.org/); Computer Science Research, Education, and Applications Press (CSREA); Aldebaran Robotics Inc., USA; Taylor & Francis, United Kingdom. In addition, a number of university faculty members and their staff (names appear above and also on the cover of the proceedings), several publishers of computer science and computer engineering books and journals, chapters and/or task forces of computer science associations/organizations from 5 countries, and developers of high-performance machines and systems provided significant help in organizing the conference as well as providing some resources.

We are also grateful for support by the Institute of Information Systems at Hamburg University, Germany (www.uni-hamburg.de/IWI) and the Business Intelligence Laboratory, B I^{3}S lab, Hamburg, Germany (www.bis-lab.com). Furthermore, we would like to thank all members of the steering committee of the 2013 congress: Dr. Selim Aissi, (formerly: Chief Strategist - Security, Intel Corporation, USA), Senior Business Leader & Head of Global Enterprise Security Architecture, Visa Corporation, USA; Prof. Nizar Al-Holou, Professor and Chair, Electrical and Computer Engineering Department, Vice Chair, IEEE/SEM-Computer Chapter, University of Detroit Mercy, Detroit, Michigan, USA; Prof. Hamid R. Arabnia, Professor of Computer Science, Editor-in-Chief of The Journal of Supercomputing (Springer), Elected Fellow of Int'l Society of Intelligent Biological Medicine (ISIBM), The University of Georgia, Georgia, USA; Prof. Babak Akhgar, Fellow of the British Computer Society, CITP, Professor of Informatics, Co-Director of CENTRIC (Centre of Excellence in Terrorism, Resilience, Intelligence & organised Crime research), Sheffield Hallam University, Sheffield, UK; Prof. Kevin Daimi, Director, Computer Science and Software Engineering Programs, Department of Mathematics, Computer Science and Software Engineering, University of Detroit Mercy, Detroit, Michigan, USA; Prof. George Jandieri, Chief Scientist, The Institute of Cybernetics, Georgian Academy of Science, Georgia, Editorial Board Member of International Journal of Microwaves and Optical Technology, The Open Atmospheric Science Journal, American Journal of Remote Sensing, Georgian Technical University, Tbilisi, Georgia; Prof. Dattatraya V. Kodavade, Head of Computer Science and Engineering, D.K.T.E Society's Textile & Engineering Institute, Ichalkaranji, Maharashtra State, India; Prof. George Markowsky, Professor and Associate Director, School of Computing and Information Science, Chair of International Advisory Board of IEEE IDAACS, Director 2013 Northeast Collegiate Cyber Defense Competition, Chair Bangor Foreign Policy Forum, President Phi Beta Kappa Delta Chapter of Maine, Cooperating Professor Mathematics and Statistics Department UMaine, Cooperating Professor School of Policy & International Affairs UMaine, University of Maine, Orono, Maine, USA; Prof. G. N. Pandey, Vice-Chancellor, Arunachal University of Studies, Arunachal Pradesh, India and Adjunct Professor, Indian Institute of Information Technology, Allahabad, India; Prof. Fernando G. Tinetti, Co-editor of Journal of Computer Science and

Technology (JCS&T), Professor, School of Computer Science, Universidad Nacional de La Plata, La Plata, Argentina; Dr. Predrag Tosic, Microsoft, Washington, USA; Prof. Vladimir Volkov, The Bonch-Bruevich State University of Telecommunications, Saint-Petersburg, Russia.

Most importantly, we wish to express again our sincere gratitude and respect towards Professor Hamid R. Arabnia (Univ. of Georgia, USA; Elected Fellow, ISIBM; Editor-in-Chief, The Journal of Supercomputing (Springer); Member), General Chair and Coordinator of the federated congress, for his excellent and tireless support, organization and coordination of all affiliated events. His exemplary and professional effort in 2013 and all the years before in the WORLDCOMP steering committee makes these events possible!

Thank you all for your contribution to DMIN'13! We hope that you will experience a stimulating conference with many opportunities for future contacts, research and applications.

Robert Stahlbock
DMIN'13 General Conference Chair

Gary M. Weiss

Steering Committee DMIN'13
www.dmin-2013.com

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REAL-WORLD DATA MINING APPLICATIONS, CHALLENGES, AND PERSPECTIVES

Chair(s)

Drs. Mahmoud Abou-Nasr
Robert Stahlbock
Gary M. Weiss

Maintenance Knowledge Management with Fusion of CMMS and CM

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***Abstract-* Maintenance can be considered as an information, knowledge processing and management system. The management of knowledge resources in maintenance is a relatively new issue compared to Computerized Maintenance Management Systems (CMMS) and Condition Monitoring (CM) approaches and systems. Information Communication technologies (ICT) systems including CMMS, CM and enterprise administrative systems amongst others are effective in supplying data and in some cases information. In order to be effective the availability of high-quality knowledge, skills and expertise are needed for effective analysis and decision-making based on the supplied information and data. Information and data are not by themselves enough, knowledge, experience and skills are the key factors when maximizing the usability of the collected data and information. Thus, effective knowledge management (KM) is growing in importance, especially in advanced processes and management of advanced and expensive assets. Therefore efforts to successfully integrate maintenance knowledge management processes with accurate information from CMMSs and CM systems will be vital due to the increasing complexities of the overall systems.**

Low maintenance effectiveness costs money and resources since normal and stable production cannot be upheld and maintained over time, lowered maintenance effectiveness can have a substantial impact on the organizations ability to obtain stable flows of income and control costs in the overall process. Ineffective maintenance is often dependent on faulty decisions, mistakes due to lack of experience and lack of functional systems for effective information exchange [10]. Thus, access to knowledge, experience and skills resources in combination with functional collaboration structures can be regarded as vital components for a high maintenance effectiveness solution.

Maintenance effectiveness depends in part on the quality, timeliness, accuracy and completeness of information related to machine degradation state, based on which decisions are made. Maintenance effectiveness, to a large extent, also depends on the quality of the knowledge of the managers and maintenance operators and the effectiveness of the internal & external collaborative environments. With emergence of intelligent sensors to measure and monitor the health state of the component and gradual implementation of ICT) in organizations, the conceptualization and implementation of E-Maintenance is turning into a reality. Unfortunately, even though knowledge management aspects are important in maintenance, the integration of KM aspects has still to find its place in E-Maintenance and in the overall information flows of larger-scale maintenance solutions. Nowadays, two main systems are implemented in most maintenance departments: Firstly, Computer Maintenance Management Systems (CMMS), the core of traditional maintenance record-keeping practices that often facilitate the usage of textual descriptions of faults and actions performed on an asset. Secondly, condition monitoring systems (CMS). Recently developed (CMS) are capable of directly monitoring asset components parameters; however, attempts to link observed CMMS events to CM sensor measurements have been limited in their approach and scalability. In this article we present one approach for addressing this challenge. We argue that understanding the requirements and constraints in conjunction - from maintenance, knowledge management and ICT perspectives - is necessary. We identify the issues that need be addressed for achieving successful integration of such disparate data types and processes (also integrating knowledge management into the "data types" and processes).

Keywords: CMMS, CM, Maintenance Knowledge Management, Experience Management, I-Maintenance

I. INTRODUCTION

The production and process industry are passing through a continuous transformation and improvement for last couple of decades, due to the global competition coupled· with advancement of information and communication technology (ICT). The business scenario is focusing more on e-business intelligence to perform transactions with a focus on customers' needs for enhanced value and improvement in asset management. Such prognostic business requirement compels the organizations to minimize the production and service downtime by reducing the machine performance degradation. The above organizational requirements necessitate developing proactive maintenance strategies to provide optimized and continuous process performance with minimized system breakdowns and maintenance. Implementing solutions from the business world concepts such as e-intelligence, e-factory, e-automation, E-Maintenance, e-marketing and e-service have emerged.

E-Maintenance provides the organization with intelligent tools to monitor and manage assets (machines, plants, products, etc.) proactively through ICT, focusing on health degradation monitoring and prognostics, instead of fault detection and diagnostics. Maintenance effectiveness depends on the quality, timeliness, accuracy and completeness of information, knowledge and earlier experiences related to machine degradation state and support processes, based on which decisions are made. This translates into a number of key requirements: preventing data and information overload, ability to differentiate and prioritize data and actions (during collection as well as reporting), to prevent, as far as possible, the occurrence of information islands and to effectively communicate status and vital information to relevant actors. Integration and inclusion of maintenance knowledge management (MKM) into the processes and infrastructures of E-Maintenance creates the foundation for a more comprehensive approach to ICT-based maintenance solutions which one can call I-Maintenance ("Intelligence-based Maintenance"). The I-Maintenance approach not only aim at integrating maintenance knowledge management into the solutions but also offer integration of collaborative environments, remote computational services, ontology's for effective tagging of resources, solutions etc. all designed to be effectively used across different levels of the organization and between organizations.

CMMS and CM are the most popular repositories of information in maintenance, where most of deployed technology is installed and unfortunately isolated information islands are usually created. While using CMMS and CM technology as isolated systems can bring the achievement of maintenance goals, combining the two into one seamless system can have exponentially more positive effects on maintenance group's performance than either system alone might achieve. The combination of the strengths of an effective top-notch CMMS (preventive maintenance (PM) scheduling, automatic work order generation, maintenance inventory control, and data integrity) with the wizardry of a leading edge CM system (multiple-method condition monitoring, trend tracking, and expert system diagnoses) allows work orders to be generated automatically based on information provided by CM diagnostic and prognostic capabilities. Over the last 15 years, linking CMMS and CM technology was mostly a vision easily dismissed as infeasible or at best too expensive and difficult to warrant much investigation. Now, the available technology in CMMS and CM solutions has made it possible to achieve such a link relatively easily and inexpensively. Integration of a MKM component with the CMMS and CM environments introduces risks of creating additional information islands and complexities if not properly designed, developed and implemented. One promising approach for integrating MKM into overall solutions that also integrates CMMS and CM data is utilization of SOA (Service Oriented Architectures) in combination with implementation of software agents. The danger of trying to intimately integrate MKM, collaborative structures, CMMS and CM into one unified solution is that the overall solution with a high probability will be sub-optimized if not planned and implemented properly. This is especially dangerous when implementing solutions with a high rate of change in structure and processes – MKM is one of these types of solutions. Currently the most viable route for integrating CMMS, CM and I-Maintenance modules and solutions is to integrate at the end-user level, utilizing a combination of application servers with end-user environments that allows for modular integration of different information sources, services and functions.

A high specification CMMS can perform a wide variety of functions to improve maintenance performance. It is the central organizational tool for World-Class Maintenance WCM, primarily designed to facilitate a shift in emphasis from reactive to preventive maintenance. It achieves this shift by allowing maintenance professionals to set up automatic PM work order generation. A CMMS can also provide historical information that is then used to adjust a PM system to minimize repairs that are unnecessary, while still avoiding run-to-failure repairs. PMs for a given piece of equipment can be set up on a calendar schedule or a usage schedule based on measurements and readings. A fully featured CMMS also includes inventory tracking, workforce management, purchasing, in a package that stresses database integrity to safeguard vital information. The final result can be optimized equipment up-time, lower maintenance costs, and better overall plant efficiency dependent on the ability of the maintenance staff to use the systems and processes, factors highly dependent on the knowledge level and experience of the maintenance staff. On the other hand, CM system should accurately monitor real-time equipment performance, and alert the maintenance professional to any changes in performance trends. There are a variety of measurements that a CM package might be able to track including vibration, oil condition, temperature, operating and static motor characteristics, pump flow, and pressure output. These measurements are squeezed out of equipment by monitoring tools including ferrographic wear particle analysis, proximity probes, triaxial vibration sensors, accelerometers, lasers, and multichannel spectrum analyzers. The preferred CM systems are expert systems that can analyze measurements such as vibration and diagnose machine faults. Expert system analysis can place maintenance procedures on hold until absolutely necessary, thus extracting maximum equipment up time. In addition, expert systems should offer diagnostic fault trending where individual machine fault severity can be observed over time.

MKM allows for effective dissemination of experiences, manuals, collaborative structures for access of internal and external specialists and knowledge resources. In the context of support for the CMMS the MKM can integrate management of documentations, instructions, access to remote servicing, decision support and experience capture and management. In the context of support for CM the MKM can support the analysis processes of CM data by access of collaborative structures for internal and external specialists, in addition provide access to external CM analysis tools / computational engines and interaction with external vendors specialized support structures. The MKM component can be instrumental in the ability of the maintenance staff to properly interpret the results from the measurements and computations.Both CMMS and CM systems have strong suits that make them indispensable to maintenance operation improvements. CMMS is a great organizational tool, but cannot directly monitor equipment conditions. A CM system excels at monitoring those equipment conditions, but is not suited to organizing your overall maintenance operation. The logical conclusion, then, is to combine CMMS and CM technologies into a seamless system that avoids catastrophic breakdowns, but eliminates needless repairs to equipment that is running satisfactorily. The MKM environment can have a strong role in improving the accuracy and quality of the analysis and the resulting decisions. MKM also has an important role in minimizing the risk for mistakes and human error in the implementation of the decisions and the quality of the maintenance work performed on the work floor or in the field. It also allows for improved quality of the decisions made over time due to more accurate feedback of experiences and observations by the maintenance operators.

Technology providers are trying to develop advanced tools while the maintenance departments often struggle with daily problems of implementing, integrating and operating such systems. MKM systems can have a vital role in speeding up effective implementation of these more advanced ICT centric solutions by integrating competence resource structures into the solutions, allowing the end-users of different types to get support and instructions optimized for their own work roles and work contexts. MKM systems can supply infrastructures for experience capture and management supporting the maintenance departments to manage ever-increasing complexities in assets and process flows. The CMMS and CM technology providers or the users do generally not know the feasibility of applying CMMS or CM technologies, but apparently they seem to improve the efficiency of the maintenance activities. The users combine their experience and heuristics in defining maintenance policies and in usage of condition monitoring systems – an approach that can be effectively supported by a well functioning MKM implementation. The existing maintenance systems seem to be a heterogeneous combination of methods and systems in which the integrating factor of the information and business processes is the maintenance personnel, personnel that often cannot utilize the full functionality of the underlying systems. The information in the maintenance systems goes through these human minds forming an organizational information system and creating a high reliance on the expertise of the maintenance staff. Thus, increasing the support for the human component in the overall system to perform their work more accurately, securely and more effective improves the overall maintenance processes and the effectiveness of the overall operations. In this context MKM has an important role to fill at the same time as the vulnerability for the organization due to loss of vital staff can decrease [9].

With emergence of intelligent sensors to measure and monitor the health state of the component and gradual implementation of information and communication technologies (ICT) in organizations, conceptualization and implementation of E-Maintenance is turning into a reality [1]. While E-Maintenance techniques can provide benefits to an organization, seamless integration of information and communication technologies (ICT) into the industrial environment still remains a challenge. It is necessary to understand and address the requirements and constraints from the maintenance as well as the ICT standpoints in parallel. Thus, increasing the support for the human component in the overall system to perform their work more accurately, securely and more effective improves the overall maintenance processes and the effectiveness of the overall operations. In this context MKM has an important role to fill.

II. AN INTEGRATED APPROACH TO ASSET MANAGEMENT

Two main maintenance information sources found in the industries to be merged: Computer Maintenance Management systems (CMMS) and Condition Monitoring (CM). CMMS uses context-specific textual data to record information such as asset load and usage, component failures, servicing or repairs, and inventory control. Although for a given platform, there may exist several different implementations, the underlying structure is typically heavily regulated, allowing for a large base of consistently structured data. These systems are the core of traditional scheduled maintenance practices and rely on bulk observations from historical data to make modifications to regulated maintenance actions. CM systems collect component-specific quantitative data to assist maintenance crews in the identification of failures that are imminent or have already occurred. Typically there exists no standardization in the way data is collected across platforms or vendors, primarily because the technology is still in its infancy. There is still a need to investigate and debate on the type of information required for asset health diagnostics and information used to meet CBM objectives. CMMS environments do not today effectively support client platforms. More advanced resources such as multimedia and integrated collaborative environments, are useful for effective remote support and interaction with internal and external specialists. Core functionalities for effective experience capture are not present in current CMMS environments - the main challenge is the lack of effective meta-data management. CMMS, CM and MKM have to be linked. The measurements and analysis implementations supported by MKM and made by a CM package must be available to maintenance planners who work with a CMMS for the purpose of scheduling predictive and other types of work orders, these maintenance planners are also supported by MKM. In the past, maintenance organizations that used both CMMS and CM technologies linked the two systems by inputting CM data manually into the CMMS. While this is an acceptable way to transfer data for the purpose of scheduling predictive maintenance work orders, it is also time-consuming. Another CM data transfer method that has been used recently is a passive data exchange, which involves writing pertinent CM data to a specified local or network directory. Relevant data to be exchanged includes equipment identification, date and time stamps, repair priority, repair recommendations, and observations.

The CMMS program would routinely check this directory, and if a transfer file is found, the CMMS reads it and imports it into the CMMS database. Historically, this method of data transfer has been very specific to formal cooperation between various manufacturers of CM and CMMS software. The passive data transfer method is better than manual data entry, but still falls well short of the total automation and instant access to information that is possible when the CMMS and CM program are totally integrated. Integration of MKM solutions can support effective training and learning of the staff responsible for the data capture (increasing the quality), the staff responsible for the analysis and the information / experience exchange between internal and external specialists when developing the CM processes and results implementation. In future scenarios the CM analysis can be performed remotely, eventually by different companies with different specializations. A MKM environment can aid the internal analysis staff in selecting the correct CM analysis & modeling vendor / analysis approaches and handle the eventual initial training efforts needed for the services and analysis efforts. Integration has been addressed this far largely from the view point of representing the collected information to the end-user (operator or manager) in an effective manner, i.e., bridging the gap between information collected from plants and equipment and the enterprise resource planning (ERP) platforms. A major initiative has been the development of information integration specifications to enable open, industry-driven, integrated solutions for asset management. However, some of the efforts to standardize the E-Maintenance platforms currently underway are: Machinery Information Management Open Systems Alliance (MIMOSA) [2], GEM@WORK [3], CASIP [4] and PROTEUS [5].

Such platforms provide an information schema at the application-level and an application programming interface (API) to communicate with the underlying protocol stack. To our knowledge, existing communication technologies are not well-suited for reliable and timely delivery of appropriate data between distributed end-systems in industrial environments; this, in our opinion, remains a critical missing link in the seamless integration vision. Added to this is the current lack of effective integration of knowledge management structures into the overall maintenance environments. Effective integration of MKM solutions will become vital over time due to the increasing complexity of processes and products in combination with increased competition for knowledgeable staff and specialists.The main challenge for future maintenance systems is to effectively support the end-users of different types in their efforts to manage a complex work environment, complex and advanced assets and processes and management of their overall work situation to decrease stress and risks.

A. Integration of data sources

The first step of integrating a CMMS, CM and MKM packages into an automatic system is setting up a way for the systems to communicate. In the case of CMMS and CM technologies the first step can be to set up consistent data in each system that will allow them to communicate using a common base of information. Next, there must be a system of data cross-references between the sensors, meter tags, or other measurement tools in a CM system and the appropriate module in the CMMS that associates readings in one system with readings in the other. Meter readings or alarm triggers that are out of the acceptable range set up in the CMMS should trigger a pre-defined work order. Any discrepancy in this cross-reference for a piece of equipment will nullify the link for that piece of equipment, making the ability to predict problems problematic. This makes the initial planning of data entry rules and database setup a critical part of the pre-integration process. The third step is to provide a direct link between the systems' data tables. This is referred to as an "active exchange" of data. In today's environment, CMMS databases feature open architecture such SQL, Oracle and others. The most obvious obstacle in the integration of CMMS, CM and MKM data and information is the disparate nature of the data types involved, and attempts to remedy this problem have been met with inconsistent implementation and limited scalability. The first such technique is to assign the qualitative CMMS data with quantitative indexing, allowing for CM data to be separated into discreet maintenance states. Integration of MKM systems and environments has not been a factor at all in these earlier implementations due to the specialization of the vendors of the CMMS and CM system vendors – Knowledge Management has been seen as a separate area with its own markets and usage contexts and not viable to integrate in an efficient manner into CMMS and CM environments. It is the responsibility of the maintainer to correctly insert the appropriate fault or work code into the maintenance logs, which to date has not been done with sufficient accuracy or consistency to be deemed reliable. The example presented in figure 1, is a demonstrator of an integrated end-user environment supporting modular and work context-centric approach to information management for multiple organizational layers in an I-Maintenance structure. This demonstrator presents the ability to support end-user adaptation of the overall work environment depending on work roles, deployment environment and user access control structures. It also presents a concept for end-user controlled mash-up (systems able to present and manage information from many disparate information sources and services – all presented in one unified end-user environment). This demonstrator is based on research covering end-user environments for qualified maintenance of advanced technical systems (military fighters) allowing integration of knowledge / practices / experiences / standards management into a unified and integrated environment [8].

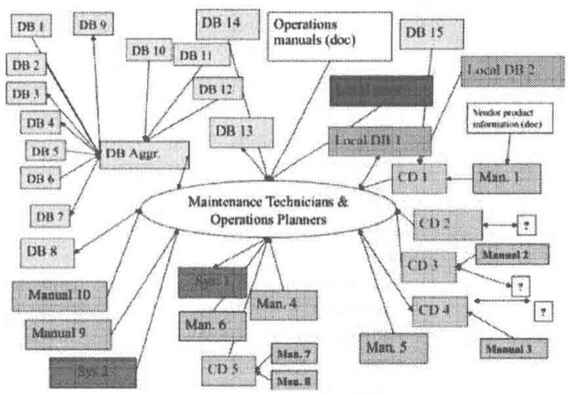

Figure 1: Integration of CM/CMMS/MKM and support for multiple work contexts. Courtesy of Enviro Data, Sweden