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**Session 7 - New Methods and Technologies for Medicine and
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Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.

I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff
Rector, TU Ilmenau



Professor Christoph Ament
Head of Organisation

Table of Contents

CONTENTS

	Page
6 Environmental Systems: Management and Optimisation	
T. Bernard, H. Linke, O. Krol A Concept for the long term Optimization of regional Water Supply Systems as a Module of a Decision Support System	3
S. Röhl, S. Hopfgarten, P. Li A groundwater model for the area Darkhan in Kharaa river Th. Bernard, H. Linke, O. Krol basin	11
A. Khatanbaatar Altantuul The need designing integrated urban water management in cities of Mongolia	17
T. Rauschenbach, T. Pfützenreuter, Z. Tong Model based water allocation decision support system for Beijing	23
T. Pfützenreuter, T. Rauschenbach Surface Water Modelling with the Simulation Library ILM-River	29
D. Karimanzira, M. Jacobi Modelling yearly residential water demand using neural networks	35
Th. Westerhoff, B. Scharaw Model based management of the drinking water supply system of city Darkhan in Mongolia	41
N. Buyankhishig, N. Batsukh Pumping well optimi ation in the Shivee-Ovoo coal mine Mongolia	47
S. Holzmüller-Laue, B. Göde, K. Rimane, N. Stoll Data Management for Automated Life Science Applications	51
N. B. Chang, A. Gonzalez A Decision Support System for Sensor Deployment in Water Distribution Systems for Improving the Infrastructure Safety	57
P. Hamolka, I. Vrublevsky, V. Parkoun, V. Sokol New Film Temperature And Moisture Microsensors for Environmental Control Systems	63
N. Buyankhishig, M. Masumoto, M. Aley Parameter estimation of an unconfined aquifer of the Tuul River basin Mongolia	67

M. Jacobi, D. Karimanzira 73
Demand Forecasting of Water Usage based on Kalman Filtering

7 New Methods and Technologies for Medicine and Biology

J. Meier, R. Bock, L. G. Nyúl, G. Michelson 81
Eye Fundus Image Processing System for Automated Glaucoma Classification

L. Hellrung, M. Trost 85
Automatic focus depending on an image processing algorithm for a non mydriatic fundus camera

M. Hamsch, C. H. Igney, M. Vauhkonen 91
A Magnetic Induction Tomography System for Stroke Classification and Diagnosis

T. Neumuth, A. Pretschner, O. Burgert 97
Surgical Workflow Monitoring with Generic Data Interfaces

M. Pfaff, D. Woetzel, D. Driesch, S. Toepfer, R. Huber, D. Pohlers, 103
D. Koczan, H.-J. Thiesen, R. Guthke, R. W. Kinne
Gene Expression Based Classification of Rheumatoid Arthritis and Osteoarthritis Patients using Fuzzy Cluster and Rule Based Method

S. Toepfer, S. Zellmer, D. Driesch, D. Woetzel, R. Guthke, R. Gebhardt, M. Pfaff 107
A 2-Compartment Model of Glutamine and Ammonia Metabolism in Liver Tissue

J. C. Ferreira, A. A. Fernandes, A. D. Santos 113
Modelling and Rapid Prototyping an Innovative Ankle-Foot Orthosis to Correct Children Gait Pathology

H. T. Shandiz, E. Zahedi 119
Noninvasive Method in Diabetic Detection by Analyzing PPG Signals

S. V. Drobot, I. S. Asayenok, E. N. Zacepin, T. F. Sergiyenko, A. I. Svirnovskiy 123
Effects of Mm-Wave Electromagnetic Radiation on Sensitivity of Human Lymphocytes to Ionizing Radiation and Chemical Agents in Vitro

8 Embedded System Design and Application

B. Däne 131
Modeling and Realization of DMA Based Serial Communication for a Multi Processor System

M. Müller, A. Pacholik, W. Fengler Tool Support for Formal System Verification	137
A. Pretschner, J. Alder, Ch. Meissner A Contribution to the Design of Embedded Control Systems	143
R. Ubar, G. Jervan, J. Raik, M. Jenihhin, P. Ellervee Dependability Evaluation in Fault Tolerant Systems with High-Level Decision Diagrams	147
A. Jutmann On LFSR Polynomial Calculation for Test Time Reduction	153
M. Rosenberger, M. J. Schaub, S. C. N. Töpfer, G. Linß Investigation of Efficient Strain Measurement at Smallest Areas Applying the Time to Digital (TDC) Principle	159
9 Image Processing, Image Analysis and Computer Vision	
J. Meyer, R. Espiritu, J. Earthman Virtual Bone Density Measurement for Dental Implants	167
F. Erfurth, W.-D. Schmidt, B. Nyuyki, A. Scheibe, P. Saluz, D. Faßler Spectral Imaging Technology for Microarray Scanners	173
T. Langner, D. Kollhoff Farbbasierte Druckbildinspektion an Rundkörpern	179
C. Lucht, F. Gaßmann, R. Jahn Inline-Fehlerdetektion auf freigeformten, texturierten Oberflächen im Produktionsprozess	185
H.-W. Lahmann, M. Stöckmann Optical Inspection of Cutting Tools by means of 2D- and 3D-Imaging Processing	191
A. Melitzki, G. Stanke, F. Weckend Bestimmung von Raumpositionen durch Kombination von 2D-Bildverarbeitung und Mehrfachlinienlasertriangulation - am Beispiel von PKW-Stabilisatoren	197
F. Boochs, Ch. Raab, R. Schütze, J. Traiser, H. Wirth 3D contour detection by means of a multi camera system	203

M. Brandner Vision-Based Surface Inspection of Aeronautic Parts using Active Stereo	209
H. Lettenbauer, D. Weiss X-ray image acquisition, processing and evaluation for CT-based dimensional metrology	215
K. Sickel, V. Daum, J. Hornegger Shortest Path Search with Constraints on Surface Models of In-the-ear Hearing Aids	221
S. Husung, G. Höhne, C. Weber Efficient Use of Stereoscopic Projection for the Interactive Visualisation of Technical Products and Processes	227
N. Schuster Measurement with subpixel-accuracy: Requirements and reality	233
P. Brückner, S. C. N. Töpfer, M. Correns, J. Schnee Position- and colour-accurate probing of edges in colour images with subpixel resolution	239
E. Sparrer, T. Machleidt, R. Nestler, K.-H. Franke, M. Niebelschütz Deconvolution of atomic force microscopy data in a special measurement mode – methods and practice	245
T. Machleidt, D. Kapusi, T. Langner, K.-H. Franke Application of nonlinear equalization for characterizing AFM tip shape	251
D. Kapusi, T. Machleidt, R. Jahn, K.-H. Franke Measuring large areas by white light interferometry at the nanopositioning and nanomeasuring machine (NPMM)	257
R. Burdick, T. Lorenz, K. Bobey Characteristics of High Power LEDs and one example application in with-light-interferometry	263
T. Koch, K.-H. Franke Aspekte der strukturbasierten Fusion multimodaler Satellitendaten und der Segmentierung fusionierter Bilder	269
T. Riedel, C. Thiel, C. Schmallius A reliable and transferable classification approach towards operational land cover mapping combining optical and SAR data	275
B. Waske, V. Heinzl, M. Braun, G. Menz Classification of SAR and Multispectral Imagery using Support Vector Machines	281

V. Heinzl, J. Franke, G. Menz Assessment of differences in multisensoral remote sensing imageries caused by discrepancies in the relative spectral response functions	287
I. Aksit, K. Bünger, A. Fassbender, D. Frekers, Chr. Götze, J. Kemenas An ultra-fast on-line microscopic optical quality assurance concept for small structures in an environment of man production	293
D. Hofmann, G. Linss Application of Innovative Image Sensors for Quality Control	297
A. Jablonski, K. Kohrt, M. Böhm Automatic quality grading of raw leather hides	303
M. Rosenberger, M. Schellhorn, P. Brückner, G. Linß Uncompressed digital image data transfer for measurement techniques using a two wire signal line	309
R. Blaschek, B. Meffert Feature point matching for stereo image processing using nonlinear filters	315
A. Mitsiukhin, V. Pachynin, E. Petrovskaya Hartley Discrete Transform Image Coding	321
S. Hellbach, B. Lau, J. P. Eggert, E. Körner, H.-M. Groß Multi-Cue Motion Segmentation	327
R. R. Alavi, K. Brieß Image Processing Algorithms for Using a Moon Camera as Secondary Sensor for a Satellite Attitude Control System	333
S. Bauer, T. Döring, F. Meysel, R. Reulke Traffic Surveillance using Video Image Detection Systems	341
M. A-Megeed Salem, B. Meffert Wavelet-based Image Segmentation for Traffic Monitoring Systems	347
E. Einhorn, C. Schröter, H.-J. Böhme, H.-M. Groß A Hybrid Kalman Filter Based Algorithm for Real-time Visual Obstacle Detection	353
U. Knauer, R. Stein, B. Meffert Detection of opened honeybee brood cells at an early stage	359

10 Mobile Communications

K. Ghanem, N. Zamin-Khan, M. A. A. Kalil, A. Mitschele-Thiel Dynamic Reconfiguration for Distributing the Traffic Load in the Mobile Networks	367
N. Z.-Khan, M. A. A. Kalil, K. Ghanem, A. Mitschele-Thiel Generic Autonomic Architecture for Self-Management in Future Heterogeneous Networks	373
N. Z.-Khan, K. Ghanem, St. Leistritz, F. Liers, M. A. A. Kalil, H. Kärst, R. Böringer Network Management of Future Access Networks	379
St. Schmidt, H. Kärst, A. Mitschele-Thiel Towards cost-effective Area-wide Wi-Fi Provisioning	385
A. Yousef, M. A. A. Kalil A New Algorithm for an Efficient Stateful Address Autoconfiguration Protocol in Ad hoc Networks	391
M. A. A. Kalil, N. Zamin-Khan, H. Al-Mahdi, A. Mitschele-Thiel Evaluation and Improvement of Queueing Management Schemes in Multihop Ad hoc Networks	397
M. Ritzmann Scientific visualisation on mobile devices with limited resources	403
R. Brecht, A. Kraus, H. Krömker Entwicklung von Produktionsrichtlinien von Sport-Live-Berichterstattung für Mobile TV Übertragungen	409
N. A. Tam RCS-M: A Rate Control Scheme to Transport Multimedia Traffic over Satellite Links	421
Ch. Kellner, A. Mitschele-Thiel, A. Diab Performance Evaluation of MIFA, HMIP and HAWAII	427
A. Diab, A. Mitschele-Thiel MIFAv6: A Fast and Smooth Mobility Protocol for IPv6	433
A. Diab, A. Mitschele-Thiel CAMP: A New Tool to Analyse Mobility Management Protocols	439

11 Education in Computer Science and Automation

S. Bräunig, H.-U. Seidel Learning Signal and Pattern Recognition with Virtual Instruments	447
St. Lambeck Use of Rapid-Control-Prototyping Methods for the control of a nonlinear MIMO-System	453
R. Pittschellis Automatisierungstechnische Ausbildung an Gymnasien	459
A. Diab, H.-D. Wuttke, K. Henke, A. Mitschele-Thiel, M. Ruhwedel MAeLE: A Metadata-Driven Adaptive e-Learning Environment	465
V. Zöppig, O. Radler, M. Beier, T. Ströhla Modular smart systems for motion control teaching	471
N. Pranke, K. Froitzheim The Media Internet Streaming Toolbox	477
A. Fleischer, R. Andreev, Y. Pavlov, V. Terzieva An Approach to Personalized Learning: A Technique of Estimation of Learners Preferences	485
N. Tsyrelchuk, E. Ruchaevskaia Innovational pedagogical technologies and the Information educational medium in the training of the specialists	491
Ch. Noack, S. Schwintek, Ch. Ament Design of a modular mechanical demonstration system for control engineering lectures	497

T. Neumuth / A. Pretschner / O. Burgert

Surgical Workflow Monitoring with Generic Data Interfaces

Introduction

During the next years the digital operating room (DOR) and its future requirements will emerge and influences the technical development in the medical engineering field [1]. Workflow management systems (WfMS) supporting the data flow between surgical assist systems (SAS) during the surgical treatment of the patient are strongly involved in the future scenarios. WfMS can contribute to intraoperative interventions by synchronizing the surgical treatment of the patient with surgical process models (SPM) [2, 3] and by providing the relevant parts of patient models. The SPM represent knowledge of the general treatment support and the support of patient specific surgical decisions.

Due to the multiplicity of operating room equipment, and thus multiple heterogeneous data sources, no unique methodology for the acquisition, storage and analysis of data in operating rooms was established in practice. The already available data structures and communication protocols originate from the field of Picture Archiving and Communication Systems (PACS) related to radiology, and are standardized in DICOM [4], an ISO-standard for the description and exchange of images that aims at the interoperability of vendor-specific PACS systems. The DICOM-standard is currently extended for the use in surgical scenarios, currently ongoing as *Surgical-DICOM*-developments [1, 5].

One emerging issue related to WfMS is the situational awareness in the OR [1]: The WfMS has to recognise which part of the surgical procedure is being performed at the moment, and which parts have already been performed.

The definition of generic interfaces to the surgical workflow monitoring system and the connection to the peripheral systems are essential. Both of them are caused by the integration efforts for the infrastructure in the operating room and the need for workflow monitoring on a higher abstraction level during surgical interventions.

The objective of this publication is the proposal of a subpart for the infrastructure for the integration of device-specific metadata and higher-level sensor data into the Surgical

Workflow monitoring system offering a generic interface to the process.

Infrastructural Scenarios and Use Case

Currently, the interoperability between SAS in operating rooms is very limited. Existing network capabilities are restricted either to data transfer capabilities such as DICOM, or to vendor specific conformance initiatives for interfaces between a few number of devices such as tracking and navigation devices. The existing infrastructure cannot be used for surgical workflow monitoring because of missing interfaces and networking capabilities of the systems.

Lemke and Vannier [1] proposed a Therapy Imaging and Model Management System (TIMMS, cf. Fig. 1) for the digital operating room (DOR). The functional support of model guided therapy and the added user value originating from advanced networking capabilities are essential to this infrastructure.

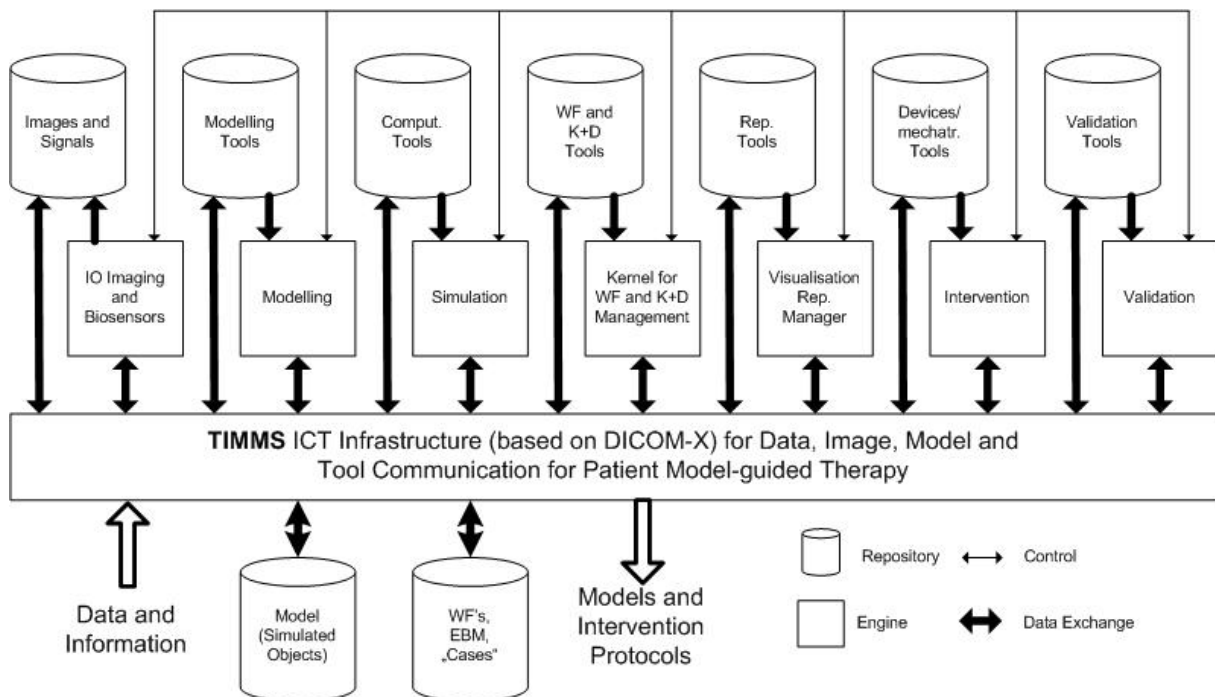


Figure 1: Therapy Imaging and Model Management System (TIMMS) [4]

One functional unit of the TIMMS infrastructure should be a module providing situational awareness [1]. For an intraoperative treatment this can be realized by a surgical workflow monitoring system.

The surgical workflow monitoring system receives messages from peripherally distributed sensor systems and relates them to one another to form a higher description

context of the surgical treatment. The methodology is based on a structured transfer of metadata from stand-alone devices into the Surgical Workflow Monitoring system. Metadata designates the capabilities and interfaces of devices as well as (higher level) parameters and data types.

A simplified cut-out from the TIMMS infrastructure is shown in Fig. 2. To illustrate the cooperation of a surgical workflow monitoring system with the peripheral equipment in the OR, we present our approach with a use case of platform-variant tracking devices. The use case example adds distribution capabilities to situation recognition approaches such as proposed in [6, 7]. In the surgical workflow both approaches aim at the detection of phases based on machinery sensory data. The low level tracking data are obtained by sensor systems and need to be interpreted in a higher context. The decision which data have to be transferred over the network relies on the design of the overall system.

For the example set-up shown in Fig. 2 the following communication scenarios are possible:

1. Non-interpreted low-level sensory data are transmitted from the tracking device to the surgical workflow monitoring system and they are integrated into the actual surgical process model.
2. Non-interpreted low-level sensory data are transmitted from the tracking device to the reasoner and interpreted by the reasoner.
3. Interpreted higher level data are transmitted from the reasoner to the surgical workflow monitoring system and are integrated into the surgical process model.

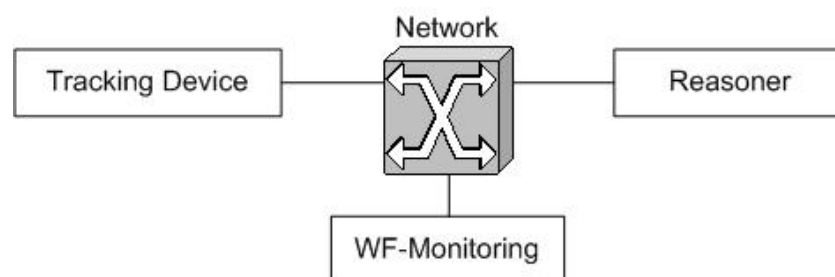


Figure 2: Infrastructural Scenario for Surgical Workflow Monitoring

Although it is possible to transmit non-interpreted low-level sensory data to the monitoring system, it is not useful in every case. A motion tracking system monitoring the movement of an instrument in the surgeons main working hand might either transmit detailed data of the x-/y-/z-trajectories over time or just the context “cutting from ... to ...” that was interpreted by the reasoner. To transmit abstracted data such as the context

would require reasoning capabilities of the tracking system. If no reasoning capabilities are available, the low level sensor data might be transmitted to a reasoning module in the same or different network, interpreted, and then transferred into the monitoring system. In the latter case, one more component participates in the “process chain”.

Technical Approach to Solution

The proposed use case demands a high flexibility originating from the multiple roles every participating system can play. Units need to behave as clients or servers, for some scenarios as both. The high complexity requires the use of established technologies. A technical approach designed for this challenge is OPC Unified Architecture [8]. OPC stands for *Object Linking and Embedding for Process Control* and was formerly based on the Microsoft component model (COM/DCOM). OPC Unified Architecture (OPC UA) is a platform independent standard for the communication of a multitude of systems and applications. Servers and clients are able to communicate beyond network environments. OPC UA defines service groups that are placed at disposal by a server which can furthermore be supported by clients. The specification of OPC UA especially emphasizes the independence of platforms and operating systems. A special communication interface enables server/client communication as well as a communication amongst various servers. The OPC UA server application programming interface (API) and the OPC client API divide the client and the server application on the one hand, and the communication stack on the other. Thereby, a high level of modularity is made available to the user. OPC - UA allows for the choice of the protocol: if both devices support OPC, than the binary protocol might be chosen; if that is not the case, one can fall back on Simple Object Access Protocol (SOAP). The interface lies underneath the user program and it is implemented via software. Due to this fact, it does not compete with field bus systems such as PROFIBUS or CAN, but combines application programs and sub-assembly drivers. The fact that the protocol between clients and servers can be chosen as binary protocol or web-service provides the system engineer with advanced design opportunities. Thus, the decision of using only pure middleware approaches such as Remote Procedure Calls (RPC), Common Object Request Broker Architecture (CORBA), Component Object Model (COM/DCOM), or Java Remote Method Invocation (Java RMI) or a pure web-services solution such as Simple Object Access Protocol (SOAP) turns into a choice for combining the advantages

of both worlds. The design choice relies especially on the required flexibility, advanced networking for passing firewalls, and the time-criticalness of transmission.

Conclusions

The operating room of the future has a need for enhanced inter-device communication. Surgical Workflow Monitoring systems for high-level monitoring and data collection will become an important future part of the OR. These systems need to deal with a variety of devices, messages, and processes.

We propose the use of OPC UA as Service Oriented Architecture for Surgical Workflow Monitoring systems. The use of OPC UA enables the implementation of a standardized software interface for data exchange between applications of different vendors. OPC services can be extended to any platforms with XML and HTTP support as web service. Complementary to OPC UA several technologies necessary for networked ORs can be applied from already existing device description languages such as Field Device Tool (FDT) or Electronic Device Description Language (EDDL) [9]. That would also contribute to an integration of devices. Furthermore, a uniform interface for data acquisition and data analysis is available to the Surgical Workflow Monitoring system via OPC UA.

The approach highlights the abstraction of the device- and vendor-specific operating systems. That has several consequences, such as the unification of the heterogeneity of the used computer platforms; the concealment of the distribution of applications due to local transparency and uniform namespaces; and basic mechanisms for distribution, such as directory service, tracing service, and interface adoption.

The application is only achievable by agreement of different manufacturers. The design of the boundary conditions should reach two aims: on the one hand it should ensure the specific internal know-how of the manufacturers and on the other hand the surplus value of this new interface should lead to increased user value or saving of expenses.

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