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CO-ORDINATED ENGINEERING: DESIGN INNOVATION THROUGH OPERATIONAL COLLABORATION

Tijana VULETIC, Alex DUFFY, Robert Ian WHITFIELD, Wenjuan WANG
University of Strathclyde, United Kingdom

ABSTRACT
Operational Collaboration Model (OCM) has been developed to provide net based, location and discipline independent solution for the exchange of design technology, service and information. Its development was preceded by the exploration of the state-of-the-art in the collaborative engineering design to provide the theoretical basis for the research, and the research of the current practices in European maritime sector. The OCM is facilitated through the Technology Collaboration Platform which provides the distributed integrated design capabilities and European Maritime Collaboration Platform which supports the collaborative capabilities for knowledge exchange. OCM allows for a variety of different modes of collaboration, provided by the integrated design framework. Six case studies are to be used for demonstration in engineering design environment and testing are currently in the initial stages of execution, and aim to demonstrate the capabilities of the model but also identify areas for improvement and potential issues in its implementation. Once thoroughly tested and validated in the maritime sector the OCM will be fit for wider implementation in engineering design community.

Keywords: collaborative design, computer aided design, knowledge management, engineering design, integrated product design

Contact:
Tijana Vuletic
University of Strathclyde
Design, Manufacture & Engineering Management
Glasgow
G4 0NG
United Kingdom
tijana.vuletic@strath.ac.uk

1 INTRODUCTION

The need for more extensive technology transfer and dissemination of innovative practices has been identified in the European maritime sector. The sector still largely operates without utilising all of the available technologies holding great potential to improve the networking, information, service and technology exchange, relying instead on old fashioned and location based services which severely limit each entities reach. The solution for this problem is explored in the EuroVIP project, an FP7 funded project the University of Strathclyde is coordinating,

Our solution for a net-based, location independent collaboration platform for the exchange of design based technology, services an information builds on the current modes of operation in the community and allows it to utilise state of the art collaborative practices in order to support the integration of new technology and innovative practices dissemination. It is conceptually based on an Operational Collaboration Model (referred to as the "Model" in this paper) which is implemented through the European Maritime Collaboration Portal (EMCP, referred to as the "Portal") to support operational collaboration as well as the Virtual Integration Platform (VIP, referred to as the "Platform") to support technology collaboration (Whitfield et al. 2012).

The model development and its application were informed by the collaboration requirements that SMEs in the Maritime sector have, collected using a survey to identify the current practices in the sector and the existing modes of collaboration and further supported by additional requirements collection from the EuroVIP project partners. Literature covering state-of-the-art developments in collaborative efforts in the CAD/CAE, PLM, exploring different modes of collaboration and models supporting them was reviewed. The collaboration solution will be tested in six case studies which are to be performed during 2013, and the case studies description is included later on in this paper. Currently this solution is focused on the maritime sector, but it is generic in nature and applicable to any domain.

2 LITERATURE REVIEW AND THE CONTEXT OF THE RESEARCH

2.1 Collaboration models and their requirements and issues

Strategic collaboration comes in three fundamental forms (Peterson, 1991): cooperation, coordination, and collaboration. Koney et al. (2000) add the coadunation to this list - relinquishment of autonomy of at least one partnering entity in an effort to attain the goal of the work performed. Collaboration often develops or is implemented in stages (Gajda, 2004). Partners collaborating in a virtual enterprise may work together to attain the same goal, sharing the risks, resources and rewards; but they may at the same time be competitors and work independently to improve their own performance and market attractiveness (Larsson et al., 2010; Thomson and Perry, 2006). Based on who/what makes decisions, initiates actions and performs matching for the collaborations four different realms of collaboration are identified: human-human; human-system; system-human and system-system (Horvath, 2012; Thimm and Rasmussen, 2009). Balanced provision of all design management competencies and co-ordination of roles (Katzy and Dissel, 2001) is a multi-criteria decision-making problem. State- of-the-art in design collaboration are network based models (Germani et al., 2012), ideally platform independent (Tay and Roy, 2003) and built on a modular structure (Tounsi, et al., 2011). Most collaboration models are supported by knowledge organised in the form of databases. Contextually categorising the structured, unstructured, explicit or implicit knowledge using a shared terminology enables its usage in a structured way (Meyer and Thieme, 2010; Zimmerman, et al., 2005; Wulan et al., 2010). Experiential knowledge and "knowing who knows" can be valuable, particularly in engineering design related disciplines, however it is hard to capture and becomes obsolete easily (Larsson et al., 2010). Our Model touches on all of these premises. It is modular in nature, human-system collaboration accounting for competencies and role-coordination decision making. It is platform independent and supported by structured knowledge collected and linked to the implementation facilities (the Portal and the Platform). The Model we are proposing would allow its users to start collaborating with previously unfamiliar partners with a high level of certainty that the collaboration outcome will be beneficial for both entities. Choice of collaboration partners can be influenced by the prior experiences for familiar partners (Thimm, et al., 2009). For previously unknown entities, the trust and identification with the community (Garisson, 2009) reduce risk and uncertainty and support the belief that the partner will not act opportunistically (Jeoungkun, et al., 2011). Trust is fleeting, hard to establish and perhaps even

harder to maintain (Gambetta, 2000) and to relieve the effect of the lack of trust each partner should know what they both bring to and take from the partnership (Larsson et al., 2010). In a virtual community post collaboration evaluation is often used to rate the trustworthiness of the potential collaboration partners (Xiong, et al., 2002; Lander, et al., 2004; Thomson, et al., 2006; Swoboda, et al., 2011).
Collaboration patterns can be identified manually from best practice data, by detecting prominent usage patterns trough recording and scanning communication channels for instance or by observing how community members either modify existing patterns or generate new ones (Tay and Roy, 2003) (Larsson et al., 2010; Popplewell, et al., 2008). As new collaboration patterns emerge our Model will be updated to include or address them. Finally the legal precursors to the collaboration need to be taken into account, as it might take a variety of forms, ranging from networking to a joint venture (Cagliano, et al., 2000).

2.2 Types of collaborative efforts involving CAD/CAE/PLM

Most of the established design collaboration solutions are aimed at closed communities with very little public file sharing anticipated (Rama and Bishop, 2006). In computer supported cooperative work in design the trend is the integration of technologies (Horvath, 2012), supported by the development of advanced design and engineering systems, often extended with VR. Any portal supporting design based collaboration is typically a general entry point into the software framework used during the entire lifetime of the collaboration lifecycle, including collaboration brokering, orchestration of task, set-up and closure of collaborative sessions (Benölken et al., 2010). The Platform based section of the Portal we envisage would function in a similar fashion. Regarding the structure collaborative platforms are classified as (Fuh and Li, 2005; Song et al., 2010): Thin server/strong client, strong server/thin client and peer-to-peer. Generally the protocols have not been standardized, in terms of architecture, function or implementation (Horvath, 2012). There are three dominant modes of collaboration control (Tay and Roy, 2003): Complete collaboration (peer to peer), Master-Slave division and the organization where everyone sees everything but has control over only their own part. We are proposing a structure in which each entity has complete control over their own contents, but which favours data sharing and is more conducive towards complete collaboration. Collaboration platforms which combine the knowledge exchange and design visualization usually consist of a few layers facilitating different types of activities (Yingxia and Nan, 2010; Benölken et al., 2010; Lee et al., 2010). Commercial collaborative CAD/CAE/PLM systems largely focus on model sharing and annotation among designers, but not on the concurrent communication between them (Lee et al., 2010) and both syntax and semantics cannot usually be transferred (Fuh and Li, 2005; Raposo et al., 2009). Research is being performed in the real-time collaborative design which would enable transfer of the parametrically defined models in a neutral format between the PLM and CAD applications (Song et al., 2010; Hwan, et al., 2009) attempting to resolve the problem using STEP, XML, VRML, X3D and Xj3D technologies (Tian et al., 2007; Wright and Madey, 2009; Fuh and Li, 2005; Yingxia and Nan, 2010; Whitfield et al., 2011), as well as OMG (Object Management Group) specification. Our model focuses on concurrent communication among designers and users, and the provision of right information at the right time. It is less concerned with the visual presentation, although that may become a factor in the later stages.

2.3 Network integration

Design based collaboration assumes the data transfer between distributed locations; therefore it is necessary to establish a file transfer protocol. Most enterprises have firewalls set up which severely limits options for data transfer and therefore most collaboration models have opted for secure hosting and IP based VPN tunnelling as the data transfer method (Wang et al., 2009; Grow, 2012; Benölken et al., 2010). Data exchange is yet to be completely standardized especially since the volumes of data being transferred could grow geometrically and no current solution offers a robust mechanism to manage this change in volume. The data exchange for the solution presented in this paper ranges from Portal requested and facilitated service provision with minimal exchange of data to the integration of two geographically distributed Platforms communicating with each other using the portal minimally or not at all, but exchanging large amounts of data. Large amounts of data could be exchanged through a VPN connection using a specific port in the firewall, allowing the users to retain complete control over what they share and who with, while still providing seamless support for data exchange.

3 FINDINGS FROM THE EUROVIP SURVEY

Through the maritime associations' and EuroVIP project partners' contacts a survey was distributed to the companies of all profiles in the European maritime industry (80% of which with no ties to the project) in order to discover the current common operational collaboration modes and priorities for the companies in the industry. A questionnaire included 41 questions covering technology and service collaboration, data and information exchange issues and 128 replies were received from associations, companies and research institutions in the maritime sector from Belgium, Denmark, France, Germany, Lithuania, Netherlands, Portugal, Sweden, Turkey, and UK. 69 were used for further analysis due to completeness of information. It was discovered that collaboration plays a considerable role in company business. The proportion of companies participating in collaborative business partnerships are given in the Figure 1. Each graph gives a graphical representation of the percentage of all companies taking part in service or technology exchange.

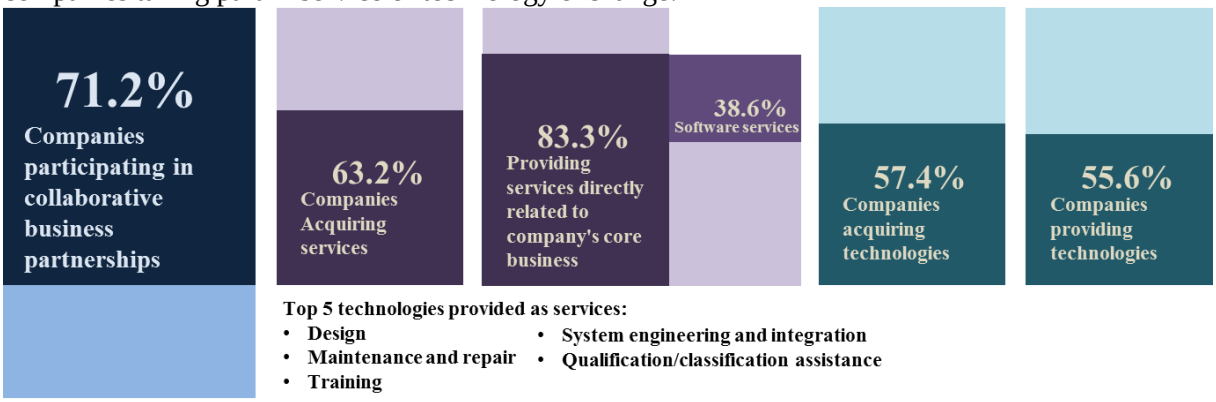

Figure 1. Role of collaboration and service/technology acquirement/provision in the European maritime community (survey information)

None of the companies were found to produce all of their own components and subsystems, and the highest portion of them (32%) purchased between 21% to 41% of components they sell. Data exchange is an integral part of the Model. Currently within an organisation, data is typically exchanged using email, shared server or physical file transfer. Between organisations email, postal service, physical transfer, and fax are used. This shows that the organisations are familiar with the standard practices for data exchange, however it is noticeable that they are only used within each organisation, and between organisations data exchange practices are quite out-dated. This is a challenge to be tackled in the proposed solution.

Analysing the data regarding the ways companies promote themselves and obtain information about other companies, although the internet, personal visits to potential customers, responding to calls for tender and informal contact were identified as top four methods to promote business, personal visits to potential customers and responding to calls for tender were identified as most effective. This way a provider was usually found within between one and three months of search.

It was concluded that over 60% of the companies in the sector either provide or acquire services or technologies, with the emphasis on design therefore developing a model for operational collaboration was deemed a worthwhile effort. Companies reported the need for the reliable information sources on technology/service quality, compliance with employed standards, and the importance of the price and timescale of provision. It was highlighted that technology can be transferred or provided/acquired as a service which should be accounted for in the solution proposed.

4 DEVELOPMENT OF THE COLLABORATION MODEL

The Model was created to provide a framework and support for design related activities. It abstracts the service and technology collaboration modes between enterprises in a variety of possible configurations. The Model is too complex to include in its entirety in this paper; instead a simplified scheme illustrating the main sections and their connections is given in Figure 2. Model defined collaboration modes are implemented through the combination of the Portal and the Platform. The

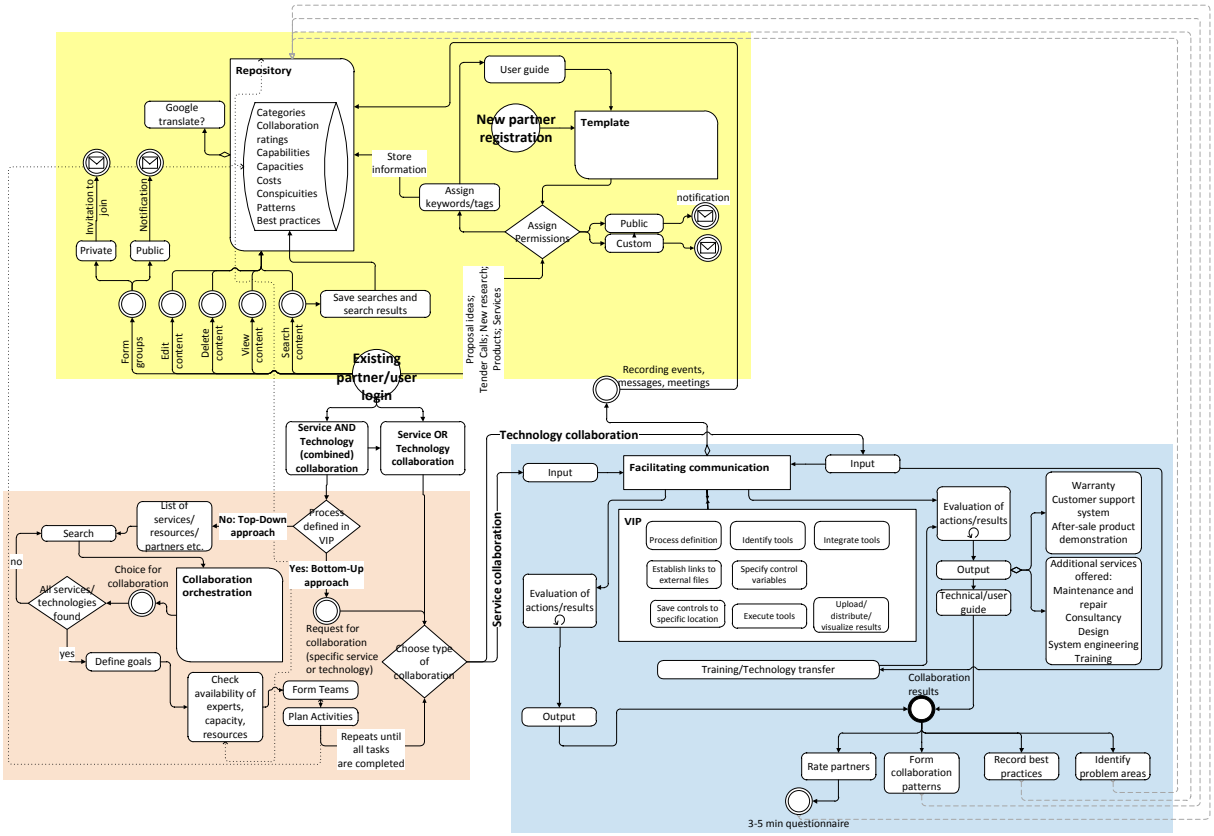

Figure 2. Operational Collaboration Model

Portal is a web based solution supporting information, services and technologies exchange in the maritime sector as the basis for collaboration forming, knowledge exchange and technology transfer. It is comprised of the Business Directory (a main database containing relevant information about the technologies, services, research activities, expertise etc.); the EuroVIP network which provides various communication facilities (from instant messaging to group forming, event tracking, news, updates etc.); and a variety of easily accessible collaboration tools (groups, calls for collaboration, service collaboration etc.). Functionality is being developed within the Portal to provide "smart search" enabling the "user" to timely identify the specific technology or service they might need in a given context and start the collaboration accordingly. The Portal is being populated using appropriate channels within the maritime community. To maintain the appropriate privacy levels where needed, while still fostering the collaboration in areas which are less sensitive with regards to data privacy practices, the control over the addition of the each piece of the each organisation's information is their own responsibility. Once assigned these permissions would be consistent throughout the Portal. Information registered in the Portal is made available to search and browse through during the collaboration negotiation and forming processes, therefore the keywords/tags using the shared terminology will be assigned to it enabling the contextual storage. This in turn makes it possible for the search to be contextualised for design environment – search for the same term yields different results depending on the context. Post collaboration, the entries will be rated to support the development of trust in the community. Evaluation will be performed using both the rating facility and a simple and brief questionnaire, taking no more than 5 minutes to complete in order to increase the response rate. The questionnaire's content should minimize the subjective effects of the collaboration experiences (Swoboda, et al., 2011) and the effects project results might have on the satisfaction levels/trust, while ensuring the conspicuity - validity of information provided by the members about their capabilities, capacities and costs (Afsarmanesh et al., 2009). Successful collaboration patterns developed during the collaborative efforts would ideally be recorded and reused later as guides for collaborations established on the similar principles.

University of Strathclyde has developed the Platform in a succession of EC funded projects (VRShips - FP5, VIRTUE FP6 and SAFEDOR FP6) (Whitfield et al. 2011, Whitfield et al. 2012). The main purpose was to offer support for integrated design with regards to the through-life design of ships by

providing an integrating environment through the provision of data and task level management and co-ordination enabling different Computer Aided Design and Engineering (CAD/CAE) tools to be integrated and operated in a unified and holistic manner. It allows distributed organisations with different design and analysis tools, including both commercial and bespoke locally developed tools, to be integrated together and perform distributed design processes. Currently the Platform is available for installation, download and use for EuroVIP project partners. VPN connection between units is used for secure data transfer.
Four different levels of collaboration are envisaged for the Portal/Platform coupling, each anticipating different levels of utilization for both facilities, depending on the levels of the interaction collaborators wish to have, levels of technical design support needed, security requirements and the quantity and the type of the design information exchanged (for details please see Section 5).

5 IMPLEMENTATION BETWEEN THE PLATFORM AND THE PORTAL

5.1 Collaboration modes

Initially three possible modes of collaboration supported by the Model were envisaged – Service collaboration, Technology collaboration and Combined collaboration (roughly equal parts service and technology collaboration). However the discussions with the EuroVIP project partners and the experiences with the implementation of the Model so far have shown that almost all collaboration configuration modes are combined in that they consist of both service and technology collaboration combined in different ratios, depending on the specificities of the design process and its requirements. There are four collaboration modes defined (Figure 3), and the main parameter distinguishing between these modes of collaboration is whether they are more operational or technology based which is mirroring the ratio of operational or technical level of collaboration mechanisms employed in the process. In all four modes both Platform and Portal are used and integrated to a certain level. Seamless communication between the operational and technical levels of collaboration would ideally be achieved by the end of the project.

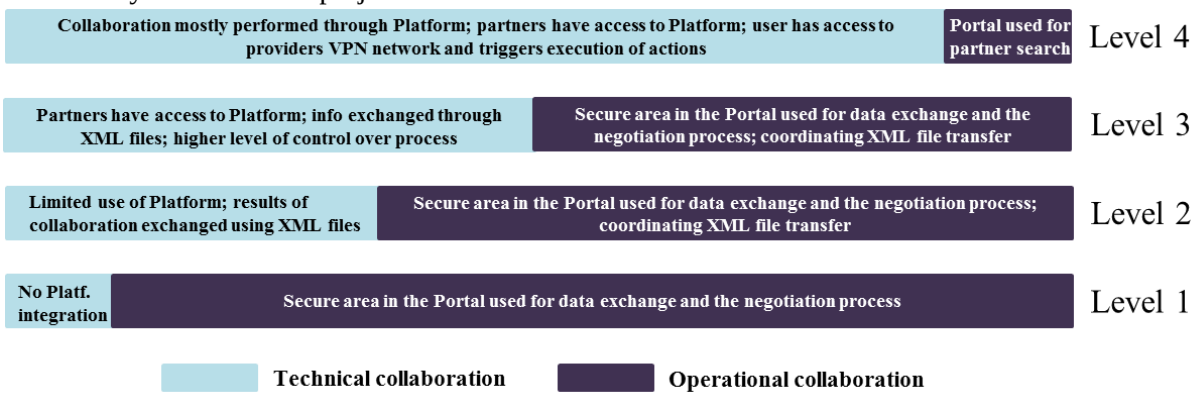

Figure 3. Four collaboration modes illustrating the ratio of technical and operational collaboration employed in each level

5.1 *Collaboration configuration*

Collaboration can be configured in two ways: Top-down or Bottom–up (graphically presented in the bottom left shaded area in Figure 2). Top-down collaboration is the collaboration type in which companies have a design project and a process (not necessarily set up using the Platform beforehand) ready in-house, but they are looking for service providers to complete the processes. They could input their key information in the Portal, find service providers, form a process using the Platform, link services to the software in the Platform and then move the work to it. If the companies are already using the Platform and have established design processes, but would like to find suppliers for some functions or replace the capability which has become unavailable for instance, they would engage in Bottom-up collaboration. This way the model is used to fill in the voids in the process. In the case of the bottom up collaboration the collaboration itself is more straightforward, and once the decision of the collaboration partner is made the collaboration is reduced to either the simple service or technology collaboration.

Essentially, both types of collaboration are foundered in finding the right partner for collaboration and then negotiating the terms of collaboration that all sides are happy to comply with and get the most benefit from. Theoretically the company could search for one or multiple services/technologies; or for service /technology providers to execute the entire process. They could either simply search the database for a suitable match or search through the published calls for collaboration for future or existing projects. Once a match is found and clear requirements and constraints are defined the process of collaboration options orchestration can start. It is an iterative process, and could offer just one result or a number of options, depending on the nature of the project, number of service providers and their capabilities, as well as the requirements and constraints themselves. Either organisational, control or content modes of collaboration might be prioritised and the options available for the collaboration orchestration might be influenced by that (Options section at the bottom of the Figure 2). Options are assessed using the primary and secondary factors. Negotiation between the potential collaborators will focus on all of the relevant points regarding the design requirements and specifications and capabilities, capacities and cost to fulfill them. The negotiation process can be supported through the communication mechanisms embedded in the Portal or it could be performed outside independently.

6 CASE STUDIES AND EVALUATION

Six case studies are planned to be performed in the following 12 months to demonstrate a variety of combinations for the operational and technical collaboration. The purpose of these case studies is to show how the collaboration means promoted in the EuroVIP project (including the Platform and the Portal) could facilitate predominantly design technology transfer into SMEs. Partners involved in the project will collaborate with each other remotely most of the time and locally in two workshops planned to implement the studies and ensure their progress. Appropriate metrics will be identified for the analysis, including items such as cost, efficiency, and time reductions. Two evaluation questionnaires will be distributed for feedback. Input of the questionnaire will be used to analyze the results and identify the best practice of collaboration.

The preparation for the case studies is currently underway and the main guidelines for all studies have already been defined. Data will be collected to reflect the use of the Platform and the Portal through the comparison of the operation while first not using and then using the two facilities, as well as how either of the options influences the workflow. For the Platform, most of the data collected relates to the technical collaboration aspects such as error reduction through automation, data consistency. It is mostly objective and quantifiable. For the Portal, most of the data collected relates to the operational collaboration aspects such as database searches and making contact through the web portal, which outputs less quantifiable data, relying more on the subjective observations of the users.

Six different scenarios will be played out:

1. A company looking for a replacement for one component of their design process, bottom-up approach;
2. A company using the Portal for selecting suppliers, bottom up or top down approach;
3. A company using the web portal to assemble experts for the planned design project, top-down approach;
4. A company combining a number of newly developed techniques into a single complex process in the Platform;
5. A company performing a multi-disciplinary analysis of a new ship hull being designed, with all tools using their own visualisation solutions;
6. A company using the Platform capable of remote execution of an internal company tool using the ticket system and subsequent billing procedure.

All facilities for the case study implementation are already in place.

7 DISCUSSION

The survey analysis has shown out-dated practices and this solution is an attempt to modernize the processes employed in the European maritime industry and enable it to overcome the limitations of geographical location at no expense on the quality of the design work performed and its outputs. We believe it will also improve the information and data exchange practices and to an extent standardize the requirements for the most frequently applied collaboration modes. In the previous applications of the Platform the time and cost savings as well as the significant reduction of user generated errors has been proven. We are attempting to achieve similar effects within collaborative distributed design. The

case studies will, once completed, provide the quantified data to confirm or deny this. It has been reported that simply finding the right partner takes from one to three months. We believe this time period will be significantly shortened and enriched by adding a variety of easily accessible options for actual collaboration forming following the partner matching, and the evolutionary collaboration support throughout the collaboration lifetime.

Through the Platform and the Portal coupling the European maritime online presence is achieved and a community is being built. The rating and evaluation facilities supported by the best practices collection and the recording of lessons learnt are intentionally designed to build the trust between the companies and increase the likelihood of collaboration forming. The Portal communication facilities are strongly based on groups, which would ideally be used to interlink a number of sections and ensure continuous flow of information about the companies, current projects, finalized projects, collaboration patterns, innovative design solutions, best practices, and potential problems collaborators have encountered.

For the solution to become fully applicable for the majority of the European maritime companies a number of facilities mentioned in this paper require further refinement (e.g. "smart search", tag suggestion, collaboration negotiation). The method of presenting collaboration evaluation rates in the Portal is a sensitive issue, since most users are expected to be commercial entities interested in maintaining good reputation. On the technical side the current solution supposes the VPN connection and the firewall issues currently tied with it and XML file exchange which means that the prompt for file upload/download is needed. Therefore it is not seamless and requires interaction with the portal which will be resolved once the Portal-Platform link is fully established.

8 CONCLUSION

Once completed the collaboration solution presented here should be able to provide the competitive advantage through the creation of new networks, forging new collaborations and partnerships to take advantage of design advances and innovation. It aims to provide net based, multi-disciplinary, cross-company, cross-domain, cross-system and cross-technology design collaboration with integrated distributed design capability. It is currently being tested in the maritime environment, but it is in no way limited to it and is applicable to any engineering design sub category. The Model aims to improve the supporting aspects of the engineering design such as knowledge exchange and technology transfer. Six case studies currently being developed will demonstrate the capabilities of the Model in the maritime industry as well as the Portal and the Platform implementation benefits and help identify areas where further development is needed.

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REFERENCES

Afsarmanesh, H., Camarinha-Matos, L. M., and Msanjila, S. S. (2009) On Management of 2nd Generation Virtual Ogranisations Breeding Environments. *Annual Reviews in Control*, Vol. 33, No. 2, pp. 209-219.

Benölken, P., Wewior, M., & Lang, U. (2010) A Virtual Workspace for Distributed Design and Engineering Tasks. *Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom), 2010 6th International Conference*, Chicago, October 9-12 2010, IEEE, pp. 1-9.

Cagliano, R., Chiesa, V., & Manzini, R. (2000) Differences and Similarities in Managing Technological Collaborations in Research, Development and Manufacturing: A Case Study. *Journal of Engineering and Technology Management*, Vol. 17, No. 2, pp. 193-224.

Fuh, J. Y., & Li, W. D. (2005) Advances in Collaborative CAD: The-State-of-the-Art. *Computer Aided-Design*, Vol. 37, No. 5, pp. 571-581.

Gajda, R. (2004) Utilizing Collaboration Theory to Evaluate Strategic Alliances. *American Journal of Evaluation*, Vol. 25, No. 1, pp. 65-77.

Gambetta, D., (2000) Can we trust trust?. In (2000) *Trust: Making and Breaking Cooperative Relations*, Oxford, pp. 213-237.

Garisson, D. R. (2009) Communities of Inquiry in Online Learning. in Garisson, D. R. (2000) Encyclopedia of Distance Learning, Hershey, PA, IGI Global, pp. 352-355.
Germani, M., Mandolini, M., Mengoni, M., & Peruzzini, M. (2012) Platform to Support dynamic Collaborative Design Processes in Virtual Enterprises. *International Journal of Computer Integrated Manufacturing*, pp. 1-18.
Gitt, W. (1989) Information: The Third Fundamental Quantity. *Siemens Review*, Vol. 56, No. 6, pp. 2-7.
Grow, J.D., Sirdevan, S.M., Sisco, P.A., Beck Jr, P.R., Ludke, E.R, Calderaro, M.A., (2012) *Methods and Systems for Electronic Data Exchange Utilising Centralised Management Technology*, USA US2012/0233206.
Horvath, I. (2012) Recent Developments in Computer Supported Cooperative Work in Design: From Group Collaboration Through Global Connectivity to Informing Apobetics. *IEEE 16th International Conference on Computer Supported Cooperative Work in Design*, Chicago, 2012, IEEE, pp. 2-13.
Hwan, K. J., Youn-Kyoung, J., & Do, N. S. (2009) Product Information Exchanges Between CAD/PDM Systems and the Collaboration Portal System Using PLM Services. *World Congress on Computer Science and Information Engineering*, Los Angeles, 2009, IEEE, pp.718-721.
Jeoungkun, K., Soongeun, H., Jinyoung, M., & Heeseok, L. (2011) Antecedents of Application Service Continuance: A Synthesis of Satisfaction and Trust. *Expert Systems with Applications*, Vol. 38, No. 8, pp. 9530-9542.
Katzy, B. R., & Dissel, M. (2001) A Toolset for Building the Virtual Enterprise. *Journal of Intelligent Manufacturing*, Vol. 12, No. 2, pp. 121-131.
Koney, K., & Bailey, D. (2000) *Strategic Alliances Among Health and Human Services Organisations: From Affiliations to Consolidations*. Sage Publications.
Lander, M. C., Purvis, R. L., McCray, G. E., & Leigh, W (2004) Trust-building Mechanisms Utilized in Outsourced IS Development Projects: A Case Study. *Information and Management*, Vol. 41, No. 4, pp. 509-528.
Larsson, A., Ericson, A., Larsson, T., Isaksson, O., & Bertoni, M. (2010) Chapter 9: Engineering 2.0: Exploring Lightweight Technologies for the Virtual Enterprise. In D. Randall, & P. Salembier. (2010) *From CSCW to Web 2.0: European Developments in Collaborative Design* , Springer, pp.173-191.
Lee, H., Kim, J., & Banerjee, A. (2010) Collaborative Intelligent CAD Framework Incorporating Design History Tracking Algorithm. *Computer Aided Design*, Vol. 42, No. 12, pp. 1125-1142.
Meyer, K., & Thieme, M. (2010) Activating the Innovation Potential of SME: The Bottom-Up-Approach. *48th Annual Meeting of the Association for Computational Linguistics*, Uppsala, Sweden, July 11-16, 2010, The Association for Computer Linguistics, pp. 3-16.
Peterson, N. L. (1991) Interagency Collaboration Under Part H: The Key to Comprehensive Multidisciplinary, Coordinated Infant/Toddler Intervention Services. *Journal of Early Intervention*, Vol. 15, No. 1, pp. 89-105.
Popplewell, K., Stojanovic, N., Abecker, A., Apostolou, D., Mentzas, G., & Harding, J. (2008) Supporting Adaptive Enterprise Collaboration through Semantic Knowledge Services. *Enterprise Interoperability*, Vol. 3, pp. 381-393.
Rama, J., & Bishop, J. (2006) A Survey and Comparison of CSCW Groupware Applications. *SAICSIT*, Gordon's Bay, Cape, South Africa, October 9-11 2006, pp. 198-205.
Raposo, A., Soares, L., Wagner, G., Corseuil, E., & Gattass, M. (2009) Environ: Integrating VR and CAD in Engineering Projects. *Computer Graphics and Applications*, Vol. 29, No. 6, pp. 91-95.
Shephard, M. S., Beall, M. W., O'Bara, R. M., & Webster, B. E. (2004) Toward Simulation Based Design. *Finite Elements in Analysis and Design*, Vol. 40, No. 12, pp. 1575-1598.
Song, X., Dou, W., & Zhu, J. (2010) Implementation of Collaborative Design System Upon Heterogeneous CAD Systems Using a Feature-Based Mapping Set. *14th International Conference on Computer Supported Cooperative Work in Design*, Shanghai, China, 2009, Curran Associates, pp. 510-515.
Swoboda, B., Meierer, M., Foscht, T., & Morschett, D. (2011) International SME Alliances: The Impact of Alliance Building and Configurational Fit on Success. *Long Range Planning*, Vol. 44, No. 4, pp. 271-288.
Tay, F. E., & Roy, A. (2003) CyberCAD: A collaborative Approach in 3D-CAD Technology in a Multimedia-Supported Environment. *Computers in Industry*, Vol. 52, No. 2, pp. 127-145.
Thimm, H., & Rasmussen, K. B. (2009) An Information Support Service for Moderators of SME

Company Networks. *Management Research News*, Vol. 32, No. 9, pp. 846-857.
Thomson, A. M., & Perry, J. L. (2006) Collaboration Processes: Inside the Black Box. *Public Administration Review - Special Issue*, Vol. 66, No. s1, pp. 20-32.
Tian, L., Chen, J., Wang, Q., Hao, W., & Tong, B. (2007) CoDesign Space: A Collaborative Design Support System in a Network Environment. *International Journal of Computer Integrated Manufacturing*, Vol. 20, No. 2-3, pp. 265-279.
Tounsi, J., Habchi, G., Boissière, J., & Azaiez, S. (2011) A multi-agent knowledge model for SMEs mechatronic supply chains. *Journal of Intelligent Manufacturing*, pp. 1-19.
Wang, Y., & Yu, X. (2009) Research on Distributed Cooperative CAE Analysis Platform Construction. *2nd IEEE International Conference on Computer Science and Information Technology*, Beijing China, 2009, pp. 244-247.
Whitfield, R.I., Duffy, A.H.B., York, P., Vassalos, D., Kaklis, P. (2011) Managing the exchange of engineering product data to support through life ship design. *Journal of Computer-Aided Design*, 2011, Vol. 43, No. 5, pp. 516-532.
Whitfield, R.I., Duffy, A.H.B., Gatchell, S., Marzi, J., Wang, W. (2012) A collaborative platform for integrating and optimising Computational Fluid Dynamics analysis requests. *Journal of Computer-Aided Design*, 2012, Vol. 44, No. 3, pp. 224-240.
Wright, T. E., & Madey, G. (2009) A Survey of Technologies for Building Collaborative Virtual Environments. *The International Journal of Virtual Reality*, Vol. 8, No. 1, pp. 53-66.
Wulan, M., Dai, X., & Popplewell, K. (2010) Collaboration Knowledge Ontologies to Support Knowledge Management and Sharing in Virtual Organisations. *Enterprise Interoperability*, Vol. 4, pp. 179-186.
Xiong, L., & Liu, L. (2002) Building Trust in Decentralized Peer-to-Peer Electronic Communities. *International Conference on Electronic Commerce Research*, Montreal, 2002
Yingxia, J., & Nan, H. (2010) Collaboration CAD Design Based Virtual Reality Modeling Language in Heterogeneity Assembly Environment. *Advances in Wireless Networks and Information Systems*, Vol. 72, pp. 435-441.
Zimmerman, M., Bronsart, R., & Stenzel, K. (2005) Knowledge Based Engineering Methods for Ship Structural Design. *International conference on computer applications in shipbuilding*, Busan, Korea, 2005