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D20 Assessment of WP2 outcomes

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EXECUTIVE SUMMARY

This deliverable, D20 "*Assessment of WP2 outcomes*" is structured in four parts.

The first Chapter, "*Introduction*" shortly presents the WP2 main goal and scientific objectives, mainly consisting of development of innovative methodologies for VR-based collaboration within manufacturing engineering environments. The planned tasks of WP2 are oriented towards the development of methods and guidelines for collaborative working and presence modelling. Supplementary, new cooperative VR media for manufacturing collaboration and new methods for ergonomic modelling are planned to be developed and then evaluated. The WP2 main research activities are structured according the following tasks:

Task 2.1 - Methodologies for collaborative working modelling (IPA),

Task 2.2 - Methodologies for collaborative presence modelling (ITIA),

Task 2.3 - Methodologies for ergonomic modelling for worker safety and productivity (UNOTT),

Task 2.4 - Media for group presence based manufacturing collaboration (METAIO),

Task 2.5 - Integration with the IMS project (ITIA).

The Chapter "*Organisational overview*" shortly presents the "Technical workflow and relationships with other packages" and then the list of "Main outcomes of WP2", respectively the planned deliverables (D11, D12, D13, D18, D19 and D20).

The main outcomes of the WP2, presented in the Chapter "*Technical overview and main outputs*" represent a list of five deliverables, four of them having the delivering date the Month 12 (D11, D12, D13 and D19) and a single one has been postponed to Month 24 (D18) since it contains the guideline for the implementation (a sort of handbook for supporting companies to introduce the new technologies in their processes). The performed research activities under the above mentioned tasks are presented according the following structure: task research objectives, used research methods, achieved results and the concrete form of them, the deliverables, through their executive summaries and conclusions.

In "*Conclusions*" are assessed the main achievements and are highlighted the weaknesses or/and the not as expected fulfilled activities.

1. INTRODUCTION

The overall objective of WP2 entitled “Methodologies and media for future collaborative manufacturing” is the development of innovative methodologies for VR-based collaboration within manufacturing engineering environments. The research activities of WP2 are oriented towards the development of methods and guidelines for collaborative working and presence modelling. Both modelling methods will find their roots in established methods for task and presence modelling but will be widely enlarged to CVEs to take into account the special needs and capabilities of cooperative VR. Additionally, new cooperative VR media for manufacturing collaboration and new methods for ergonomic modelling are planned to be developed and then evaluated.

The activities of WP2 are structured in five main tasks, as follows:

Task 2.1 - Methodologies for collaborative working modelling (IPA), aiming at identifying the state-of-the-art of task and collaborative task modelling and elaboration of innovative methodologies for evaluating the level of collaboration in CVE.

Task 2.2 - Methodologies for collaborative presence modelling (ITIA), focused on developing innovative presence quantification methods and tools and identifying the *presence* influence factors in CVEs.

Task 2.3 - Methodologies for ergonomic modelling for worker safety and productivity (UNOTT), oriented towards the development of ergonomic modelling technique aiming increasing the worker safety and productivity within an manufacturing enterprise.

Task 2.4 - Media for group presence based manufacturing collaboration (METAIO), aims to identify the requirements for new media for the implementation of collaborative virtual environments (D19). The development of guidelines for the usage of this collaborative media will be covered at a later stage in the project (see postponed D18 delivery date), to be able to create a sort of handbook for the application of the DiFac CVE.

Task 2.5 - Integration with the IMS project (ITIA) represents the activity aiming at linking the DiFac project with the IMS-DiFac consortium. This has not yet started since the IMS project is still under definition.

2. ORGANISATIONAL OVERVIEW

2.1. Technical workflow and relationships with other packages

In Figure 1 is presented the technical workflow of WP2, respectively the dependencies and relationships with other workpackages of the DiFac project. As is illustrated, the WP2 uses as main inputs the results of WP1, respectively the gaps of VR solutions and systems for Digital Factory and identified requirements of collaborative manufacturing. These represent a huge support to elaborate and develop new and innovative methodologies and performance indicators for evaluating the collaboration, presence and ergonomics in CVE. As well, a guideline for using the current solutions is provided, and the needs and gaps for new media are recommended. These outputs are representing valuable basis for the planned activities of the WP3 and WP4.

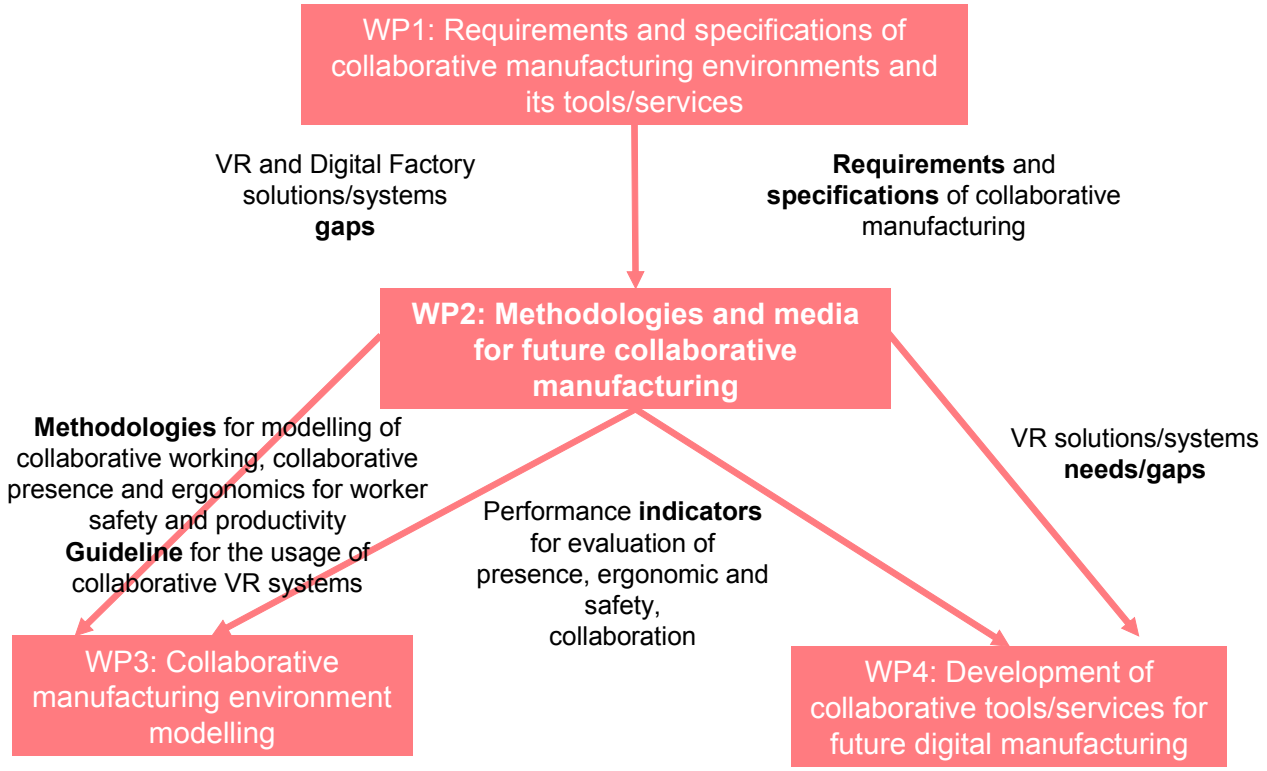

Figure 1. Technical Workflow of WP2

2.2. Main outcomes of WP2

The main outputs of the WP2 are structured in six deliverables, shortly presented in the Table 1, through several relevant information.

Del. No.	Deliverable name	WP No.	Lead partner	Person-months	Nature	Diss. level	Delivery date
D11	Methodologies for work modelling within CME	WP2	IPA	10	R	RE	9
D12	Methodologies for presence modelling within CME	WP2	ITIA	9	R	RE	9
D13	Methodologies for ergonomic programming, observation and analysis	WP2	UNOTT	11	R	RE	9
D18	Guideline for the usage of collaborative VR systems in VM	WP2	LMS	5	R	PU	**24**
D19	New media for collaborative virtual manufacturing	WP2	METAIO	7	R	PU	12
D20	Assessment of WP2 outcomes	WP2	IPA	1	R	PU	12

Table 1. WP2 List of Deliverables

3. TECHNICAL OVERVIEW AND MAIN OUTPUTS

In the amended text of the DiFac project, WP2 is presented as follows:

> "*The objective of WP2 is to define methodologies for VR-based collaboration within manufacturing engineering environments. In order to achieve this DiFac will develop methods and guidelines for collaborative working and presence modelling. Both modelling methods will find their roots in established methods for task and presence modelling but will be widely enlarged to CVEs to take into account the special needs and capabilities of cooperative VR. Furthermore DiFac will use the knowledge and understanding of VR-based manufacturing engineering in combination with the state-of-the-art in collaborative virtual environments to identify, develop and evaluate new cooperative VR media for manufacturing collaboration and new methods for ergonomic modelling*".

Corresponding to the performed activities, all planned deliverables have been passed the required steps towards the final submission. In the following, each of these tasks and the corresponding deliverables are presented through main goal, used research methods for goals achieving, results and the executive summary and conclusions of their corresponding deliverables.

3.1. Task 2.1: Methodologies for collaborative working modelling

Goal:
Development of innovative methodologies for modelling of work processes, based of existing collaborative tasks and technological CVE state-of-the-art

Method:

- analysis of existing task and collaborative task modelling methods, of their approaches and requirements analysis of VR and CVE methods specific capabilities, adaptation, extension and enhancement towards collaborative tasks and DiFac application scenarios.

Results:

- state-of-the-art of task and collaborative task modelling,
- innovative task modelling and business process re-engineering methods,
- object and topic of D11: Methodologies for work modelling within CME.

Executive Summary:
The main scientific goal of the DiFac project represents the development of an innovative Collaborative Manufacturing Environment (CME) for the next generation digital manufacturing. This platform aims to support group work in an immersive and interactive way, for concurrent product design, prototyping and manufacturing, as well as worker training. The collaboration represents one of the main three pillars of the DiFac platform, the collaborative work modelling. Evaluation is one of the research directions on which the efforts have to be directed. The Deliverable D11 "Methodologies for work modelling within Collaborative Working Environments" represents the concrete output of the activities performed into the task 2.1, having as goal the identification of the state-of-the-art methodologies for work modelling and evaluation in collaborative virtual environments.

The report is structured into two main parts: 1) Foundations of collaborative task and business process modelling and 2) New approach and methodology for collaborative work measurement.

The first part presents the state-of-the-art, challenges and potential solutions, related to the main points: Tasks and Processes. These two entities, task and process, are introduced through several recognised definitions, modelling techniques and methodologies. The collaborative aspects are taken into consideration by highlighting and presenting the specific methodologies which support the modelling of the collaborative tasks and processes. The modelling of collaborative work in production enterprises, in the field of product development, is detailed regarding the required level of collaboration. This is approached from the perspective of the two research fields, Simultaneous and Concurrent Engineering, which are shortly presented and compared. Additionally, the business process modelling for collaborative processes is analysed from the perspective of the organisational structure of a manufacturing enterprise, as well.

The second part presents a new methodology of measuring and evaluating the level of collaboration in virtual environments. Subsequently referred to as the "DiFac flow model", the method is based on the "Flow"

methodology, and enhances Hoffman and Novak's (1996) model of flow in computer-mediated environments with several new constructs as engagement, control, involvement and trust, collaboration, presence, sense of progress, and collaborative presence and behaviour. The "DiFac flow model" aims at measuring the collaboration in the DiFac platform by several experiments, evaluated through the research instrument of type questionnaire, for which the first draft is presented as well. Its refinement and final form represents the future work, while it requires the synchronisation of this activity with the content of the deliverable D12, focusing on evaluating the presence in virtual environments and D13 aiming at classifying and creating user guides for VR systems and tools.

The two annexes, respectively Annex A "Survey of commercial solution for business process modelling" and Annex B "Definitions of Flow" complete the presented concepts in Chapters 1 and 2 by clarifying several aspects in details.

The results presented in the framework of this deliverable represent the output of the activities performed in Task 2.1, which, in harmonisation with the results of all tasks corresponding to the WP2 "Methodologies and media for future collaborative manufacturing" are intensively used in the future activities planned for the WP3 "Collaborative Manufacturing Environment Modelling" and WP4 "Development of Collaborative Tools/Services for Future Digital Manufacturing".

Conclusion:

The aim of this deliverable is to collect the most important methodologies for work modelling within collaborative working environments and to set up a new methodology for evaluating the level of collaboration in virtual environments. The deliverable is the direct output of the activities performed in the Task 2.1 of WP2 and the results presented in the document will be further used in WP3 "*Collaborative Manufacturing Environment Modelling*" and WP4 "*Development of Collaborative Tools/Services for Future Digital Manufacturing*".

The document is divided into two main parts. The first part includes a state-of-the-art on task and process modelling while the second part introduces a new approach for the evaluation and measurement of collaborative work.

A detailed analysis of existing *Task Modelling* and *Process Modelling methodologies* was performed and summarised. As the collaboration represents one of the main three pillars of the DiFac platform, special emphasis was given to the collaborative aspect of the task and process modelling. From the point of view of task modelling and on the base of the extensive literature review we can state, that both task modelling and collaborative task modelling approaches are new research fields. Nevertheless there are several different methodologies, but none of them can be regarded as a widely used standard.

A comprehensive analysis about the required level of collaboration was performed in the field of product development. This was approached from the perspective of the two research fields, *Simultaneous and Concurrent Engineering,* which were shortly presented and compared. The business process modelling for collaborative processes was analysed in more detail and special highlight was given from the perspective of the organisational structure of a manufacturing enterprise.

The collection of the state-of-the-art task and process modelling methodologies represents a valuable base of the modelling activities related to the DiFac digital components: Factory Constructor, Prototype Designer and Training Simulator. As an example, the modelling activity of the Layout Planning, one of the envisioned services offered by the Factory Constructor, employs a specific modelling method which can be selected from the set already collected and analysed into the framework of Task 2.1 and into this deliverable.

A new method based on the "*Flow*" methodology was introduced in the second part of the deliverable. This new approach named "*DiFac flow model*" aims at the evaluation and measurement of collaboration in virtual environments. It is a further enhancement of the Hoffman and Novak's (1996) model of flow in computer-mediated environments with several new constructs, as engagement, control, involvement and trust, collaboration, presence, sense of progress, and collaborative presence and behaviour.

The new "*DiFac flow model*" will be further used in WP4 and WP5 and aims at measuring the collaboration in the DiFac platform. In the evaluation phase, a questionnaire based assessment will be applied for which the draft is also defined in the last part of this deliverable. The final questionnaire will be created after the final synchronisation of the activities in WP2.

The overall objective of developing this methodology has two faces: the first one represents the modelling of flow experience in collaborative virtual environments. The second one represents the validation of the model by evaluating the collaboration in several virtual environments, first of all the DiFac platform. We suppose that this model and methodology, together with its corresponding investigation instrument a DiFac

questionnaire, is useful and valuable for the manufacturing and ICT academic community and for ICT companies which produce VR tools and platforms for collaborative manufacturing.

The deliverable also includes two annexes. Annex A is the "*Survey of commercial solution for business process modelling*" and is a complement for the first part, while Annex B is the "*Definitions of Flow*" that further clarifies the basic terms of the initial "Flow" methodology.

As a conclusion, the state-of-the-art in modelling technologies for manufacturing tasks and processes together with the developed methodology, represent precious and helpful sources of knowledge for modelling the DiFac components, Factory Constructor, Prototype Designer and Training Simulator, and for the evaluation of the collaboration as one of the main features of our DiFac platform.

3.2. Task 2.2 - Methodologies for collaborative presence modelling

Goal:
Development of innovative methodologies for presence quantifying and identifying of new factors influencing the presence

Method:

- state-of-the-art and analysis of presence quantification methods and tools (interviews, psycho-physical, physiological, performance measures),
- state-of-the-art and analysis of presence influence factors (sensory, control, distraction and realism factors none-CVEs,
- extension/enhancement of presence quantification methods and tools and influence factors aiming at reflect the collaboration aspects.

Results:

- innovative DiFac presence quantification methods and tools
- new knowledge about influence factors for CVEs
- object and topic of D12: Methodologies for presence modelling within CME

Executive Summary:

This report is deliverable D12 "Methodologies for Collaborative Presence Modelling"; part of the WP2 where the requirements in the three pillars of the project are analyzed and the methodology for the measurement is foreseen. In particular the task 2.2 has investigated and found out methodologies for the measure of the Presence in Collaborative Virtual Environments. This state will be denominated as "Social Presence".

The deliverable starts from an **analysis of the Social Presence** in literature, deepens the definitions and investigation of the D4 deliverable.

The text passes then to the **technological side** of Social Presence giving a list of hardware and software that can make the Presence easier. A second list tries to give an evaluation of such technologies.

A chapter about the **measurement methodologies** wants to recall the main differences between subjective and objective measurements, introducing the reasons of the selection of our method. Actually a more detailed analysis has been presented in the previous deliverable.

The core content of the deliverable is the explanation of the theory we want to use as performance indicator: **the Flow**. Explanation of the link between Flow and Presence introduce the reader to the methods for measures.

The last chapter contains the **second questionnaire in Presence field**. The presentation of the methodology, the areas investigated with the questionnaire and the way of detection of the Social Presence. Last paragraph illustrates the innovation of such a method and the advantages of it with an image.

Conclusion:

Giving performance indicators for a VE before having the environment is not so easy.

Based on the literature there's no a certain and common method for measuring the Presence, and the measurement of Social Presence could be even more difficult. The idea of merging the classical Presence

measurement and the Flow theory it's innovative. The results will be giving us not only a numerical value, but will assure the quality of the experience.

Having an Optimal Experience means assurance about the efficiency in learning, and, in general, in completes the task you should perform during the virtual moment.

It's not possible now having a list of specific questions. We are waiting the developing phase of the specific environment. In the meantime the methodology will be tested in different situations, starting from very real and practical (as reading a book, or writing), passing through various level of immersion in VE (videogame, internet) till the immersive collaborative environment presented by DiFac.

3.3. Task 2.3 - Methodologies for ergonomic modelling for worker safety and productivity

Goal:

Development of innovative ergonomic modelling methods through integration of the two current existing approaches for human work modelling within VEs (entire scene modelling including human vs. single-person immersive environment)

Method:

- requirements analysis of human work modelling (position, ergonomics, layout of workplace, playback, observation, …),
- conception of innovative methods for ergonomics modelling.

Result:

- methodologies for ergonomic programming by implicit pre-execution system approach (architecture) for observation and (both subjective and tool-based) analysis
- benefits: the behavioural simulation enhancing the digital manufacturing modelling, from nominal to exceptional situations
- object and topic of D13: Methodologies for ergonomic programming, obs. and analysis

Executive Summary

D13 "Methodologies for Ergonomic Programming, Observation & Analysis" was produced as part of task T2.3 within work package 2 of DiFac (IST-5-035079). The aim of the task was to develop and describe the methodologies for ergonomic assessment within a digital factory for human-oriented production.

There are two separate, but related, objectives for ergonomic programming, observation and analysis within DiFac; one is to harness the power of collaborative virtual reality (VR) systems for workplace assessment, concerned mainly with identifying and eliminating physical ergonomics issues; the other is to simulate human behaviour for factory layout analysis and for use during training.

D13 describes the approach used to develop the methodologies, which began with a review of the presence, collaboration and ergonomics requirements arising from the WP1 deliverables: D2 "Definition of work groups and patterns in CME" D3 "Ergonomic requirements for human safety and productivity" and D4 "Presence requirements for group work in a rich VE". Thereafter, existing methodologies for workplace assessment are described, concluding that digital human modelling (DHM) is the most appropriate approach for the digital factory. The generic DHM methodology has been adapted to include the identified presence, collaboration and ergonomics requirements, and to overcome the cost and time constraints of dispersed groups of vested parties, through collaborative working practices. Additionally, opportunities arising from DiFac technologies are identified, in particular, the possibility for improved ease of programming an avatar, opportunities to benefit from the tacit knowledge of workers and improved analysis through the visualisation facilities of VR/VE (virtual environments).

For simulating human behaviour, two methodologies have been developed. Research into state-of-the-art human behaviour modelling revealed that the infancy of this discipline and innovation of the DiFac approach means there are few established methodologies for introducing realistic behaviour into virtual simulations. Therefore, the first human behaviour methodology describes how this will be achieved for DiFac throughout

the modelling and development phases. Thereafter, a methodology was developed which describes the ways in which the completed DiFac human behaviour simulations will be used for training and factory layout analysis, once again capitalising on the power of collaborative VR, and addressing the presence, collaboration and ergonomics requirements.

D13 summarises what is required to apply each of the methodologies, and what can be expected as a result of their application. For workplace ergonomics this is likely to be a high validity assessment of the ergonomics of a proposed digital workplace with advanced means of demonstrating the results. For human behaviour simulations the outcome will be rich simulations of workers' behaviour and reactions (for normal to exceptional events) which can be used to improve industrial processes, or during training.

The appendices include examples of the application of the methodologies, demonstrating their benefit and contribution to the digital factory and supplementary literature for further detail.

To conclude, D13 has focussed the outcomes of WP1 into methodologies which will be used throughout the development of DiFac in WP3 "Collaborative Manufacturing Environment Modelling" and WP4 "Development of Collaborative Tools/Services for Future Digital Manufacturing".

Conclusion:

The aim of D13 was to propose methodologies for ergonomic programming, observation and analysis which could be applied within DiFac. The main objectives of the task were to research the potential of virtual environments to address identified requirements for ergonomics assessment, and also to define the methodologies for modelling human behaviour with the aims of improving industrial operations and training users with constructive simulations. These objectives were completed with the generation of three methodologies, which are illustrated and described within D13.

The approach used for developing the methodologies is presented in the first chapter, which begun with a review of the WP1 deliverables to identify relevant presence, collaboration and ergonomics requirements. These requirements were grounded with a literature review to illustrate research into the three interwoven domains.

A subsequent analysis of the existing approaches for ergonomic programming, observation and analysis was conducted, and are summarised. These approaches were analysed to identify opportunities to utilise the innovative technologies and methods of DiFac to address the presence, collaboration and ergonomics requirements. Thus, the resultant methodologies are built upon a firm foundation of presence, collaboration and ergonomics, and are innovative not only due to this unique approach to their development, but also due to the collation of cutting edge VR/VE tools and methods. Furthermore, research into state-of-the-art studies revealed that the very notion of modelling behaviour in factory simulations is innovative. It should be noted that there are few examples of this in current literature and therefore the DiFac approach will provide a useful and interesting addition to current knowledge. The aim is to enhance the richness and validity of simulation software by addressing the lack of human behaviour in existing tools.

Thereafter, an illustrated description of three methodologies is presented. The workplace ergonomics methodology focuses on using VR technologies for programming, observation and analysis. Further innovation to that described above comes from the use of VR technologies to enhance the quality and validity of the evaluation. Typically, DHM assessments are conducted using desktop systems; WP1 identified several opportunities for the use of collaborative systems, and the benefits of 3D visualisation technologies to enhance these assessments. Additionally, programming the DHM using immersive tracking systems utilises VR technologies to enhance the accuracy and speed of programming avatars for ergonomics analysis.

As mentioned, modelling human behaviour in factory simulations is a new and emergent discipline, and therefore this required the development of a new methodology for incorporating human behaviour in simulation software. This will be used by the DiFac developers during work packages 4 and 5.

Subsequently, a methodology for factory layout planners and trainers to use the human behaviour simulation tools was generated, again made innovative by highlighting opportunities to use DiFac tools and approaches to address the presence, collaboration and ergonomics requirements. Furthermore, opportunities to utilise VR visualisation technologies in behavioural simulations are identified, hereby increasing the accessibility for different groups of people, but also improving the richness of the experience.

For both workplace ergonomics and behaviour simulation tools, innovative collaborative working practices should enable dispersed groups of workers to contribute, analyse results and develop alternatives, thus negating the hindrances of geography and improving the speed and efficiency of the factory design process – fundamental requirements of group presence and collaborative working. There are few VR/VE applications

which actively apply development on a good base of ergonomics, presence and collaboration. In providing DiFac with carefully considered methods it is hoped to provide effective and efficient applications which meet the needs and requirements of the user.

Finally, the appendices provide examples of using human behaviour simulations in training, and in decision making. There is also supplementary text from the overview of current approaches for human behaviour modelling. An example is made of an ergonomics workplace assessment, illustrating how the proposed DiFac methodology could be applied.

To conclude, D13 provides the methodologies for ergonomics programming, observation and analysis that will be used to focus the development of DiFac throughout WP3 (Collaborative Manufacturing Environment Modelling) and WP4 (Development of Collaborative Tools/Services for future digital manufacturing).

3.4. Task 2.4 - Media for group presence based manufacturing collaboration

Goal:

The goal of T2.4 is the identification of detailed needs for future CME media based on the existing state of the art hardware and software (D19). Furthermore this task should provide guidelines for the usage of collaborative VR systems types. As mentioned before this aspect was postponed to WP4, to be able to create a concrete handbook for the usage of the actual DiFac CME components (D18).

Method:

- Review of the DiFac application scenario (requirements and methodologies identified and developed in WP1 and WP2),
- Collection of state-of-the-art collaborative approaches and media (existing software systems and hardware devices),
- Analysis of exsting media with respect to DiFac requirements and identification of needs for future CME media

Results:

- State-of-the-art media review and needs for new media, D19: New media for CME
- Design and use guidelines for VR systems, D18 => postponed to month 24

Executive Summary:

This report is deliverable D19 “New media for collaborative virtual manufacturing” which was created as part of task T2.4 within work package 2 of the DiFac project (IST-5-035079).

Throughout this document previously identified requirements for the DiFac application scenarios will be opposed to existing media, hardware and software available for digital manufacturing tasks. Based on identified gaps in pillar quality of collaboration, presence and ergonomics and missing functionalities for fulfilling all the requirements, approaches for new media for future collaborative manufacturing will be presented.

Chapter 1 is an introduction to the subject of the DiFac framework, its components and the identified application scenarios.

In chapter 2 the requirements for a DiFac collaborative manufacturing environment are presented. These requirements are based on the results of previous work in the DiFac project. Three different aspects of requirements are discussed: First the needs for the pillar components presence, collaboration and ergonomics will be summarized. In addition functional requirements for the components representing the three digital activities, Prototype Designer, Factory Constructor and Training Simulator are described. And finally methodologies developed in the tasks 2.1 and 2.2 are presented, as performance indicators for evaluating the quality of the pillar realization.

Chapter 3 discusses state of the art CMEs by presenting existing hardware and software for collaborative manufacturing. To classify this state of the art media for the DiFac project, chapter 3 closes with a mapping of the existing tools to the three DiFac digital activities.

After the specification of state of the art media, this media is evaluated based on the previously defined requirements. Chapter 4 presents this evaluation by analysing the pillar quality needs and by comparing the required functionalities for the digital activities with the services available through state of the art media. The main deficits for the DiFac collaborative manufacturing environment are summarized in chapter 4.5.

Based on this evaluation and the deficits identified in the previous sections, approaches for new CME media can be presented in chapter 5. Possible innovations for the DiFac framework can thus be implemented in terms of enhancing the pillar quality for the overall system, by adding additional functionality to the different modules and through improving the comprehensive collaborative framework.

The document closes with a conclusion resuming the state of the art for CMEs and summarizing the possibilities for future collaborative media.

Conclusion:

The aim of this deliverable is to oppose already identified requirements for the DiFac CME with the functionality provided by existing media (hardware and software), available for digital manufacturing.

CME requirements were presented in terms of pillar requirements for collaboration, presence and ergonomics extracted from previous work in this project, mainly deliverables D1, D2 and D3. In addition the functional requirements of the end-users were considered to collect a list of services that need to be offered by the DiFac framework.

As a next step existing media for digital manufacturing was described. State of the art media was presented in the fields of

- Communication
  - SW for (remote/distributed) communication
  - HW for visual and audio input/output
- Collaboration
  - User management
  - Knowledge management (data/document management, management of access, sharing and versioning)
  - Project management
- CAD and simulation
- VR/AR worlds
  - Visualization systems
  - Tracking systems
  - Interaction devices

Finally chapter 4 connects the information collections of chapter 2 (requirements) and chapter 3 (media) by analysing the latter according to the needs defined in the former. Through this analysis, a number of already achievable results within the DiFac CME could be identified. In addition the evaluation revealed the main gaps and challenges for the future CME media that needs to be developed in this project

4. CONCLUSIONS

Methodologies for future collaborative manufacturing

The development of an innovative Collaborative Manufacturing Environment (CME) for next generation's digital manufacturing is the aim of the DiFac project. This platform aims at supporting group work for concurrent product design, prototyping, manufacturing and worker training, in an immersive and interactive way. The Deliverable D11 "Methodologies for work modelling within Collaborative Working Environments" presents the precise output of the activities performed in task 2.1, aiming at identifying the state-of-the-art methodologies for work modelling and evaluation in collaborative virtual environments.

The report is divided into two main parts: 1) Foundations of collaborative task and business process modelling and 2) New approach and methodology for collaborative work measurement.

The first part describes the state-of-the-art, challenges and potential solutions, related to the main points: Tasks and Processes. By highlighting and presenting the specific methodologies, which support the modelling of the collaborative tasks and processes, the collaborative aspects are taken into consideration. In the field of product development, the modelling of collaborative work in production enterprises is detailed regarding the required level of collaboration. This is derived from the perspective of two research fields, namely Simultaneous and Concurrent Engineering. Additionally, the business process modelling for collaborative processes is analysed from the perspective of the organisational structure of a manufacturing enterprise.

The second part presents a new methodology of measuring and evaluating the level of collaboration in virtual environments. Subsequently referred to as the "DiFac flow model", the method is based on the "Flow" methodology, and enhances Hoffman and Novak's model of flow in computer-mediated environments. The "DiFac flow model" targets on measuring the collaboration in the DiFac platform by several experiments, for which the first draft is presented as well. Its refinement and final form represents the future work, while it requires the synchronisation of this activity with the content of the deliverable D12, focusing on evaluating the presence in virtual environments and D13 aiming at classifying and creating user guides for VR systems and tools.

Annex A "Survey of commercial solution for business process modelling" and Annex B "Definitions of Flow" complete the presented concepts in Chapters 1 and 2 by clarifying several aspects in detail.

The results show the output of the activities performed in Task 2.1, which, in harmonisation with the results of all tasks corresponding to the WP2 "Methodologies and media for future collaborative manufacturing" are intensively used in the future activities planned for the WP3 "Collaborative Manufacturing Environment Modelling" and WP4 "Development of Collaborative Tools/Services for Future Digital Manufacturing".

Methodologies for presence modelling

There are many existing methods for evaluating and quantifying Presence in Virtual Environments. The main classification is between the objective and the subjective methodologies. DiFac decides to use one of the most qualified questionnaires by Witmer & Singer, named the Presence Questionnaire (PQ) mixed with an innovative approach using the Flow theory and the Flow Questionnaire (FQ).

The Flow status in doing a specific duty has specific characteristics: skill, challenge, control, engagement, control, interactivity, involvement and trust, sense of progress. Living all these characteristics mean experience an optimal status and a high level of involvement and Presence.

Since the methodology is innovative in its use for virtual reality, ITIA is going to start a validation of the methodology. The validation path will take some months and some steps are foreseen for reaching a methodology accepted by the scientific community.

- The first step will verify the structural relation between Presence and Flow construct, through a software called EQS (June 2007). In this first study we administer a VR ambient, all the subjects answer to a questionnaire to evaluate the sense of Presence and Flow.
- The second study is to verify the Presence and Flow questionnaire built through first study (June/Dec 2007). We administer at every subject a battery of "experiences" (watching TV, play with a videogame on PC, play with interactive videogame, a session in a VR). We expect to measure high level of presence and flow when the experience is more interactive and immersive.
- The third study is to verify at different levels of the manipulate variable (media-interaction) the different score of Presence and Flow. We build a VR ambient in three different version in terms of quality and interaction. We expect to have an overall score of Presence and Flow in the group with high media quality and interaction mode, in according to the theories.

The definitive questionnaire will measure the level of Presence and Flow in Virtual environment, and it will be used during the validation phase of the DiFac environments.

Methodologies for ergonomic modelling for worker safety and productivity

The aim of task 2.3, and deliverable D13, was to generate and describe methodologies to improve worker safety and productivity within the digital factory. This was achieved by developing two application methodologies: one to benefit from the power of collaborative VR tools for workplace assessment, which concentrates mainly on the physical ergonomics aspects of safety and productivity; the other to model realistic behaviours for programming autonomous software agents, which will ultimately be used for factory layout evaluation and for training. For the latter, an additional methodology was generated which explains the process of taking established behavioural phenomenon, and moving them toward programmable algorithms, which will remain within the realm of the DiFac developers, whereas the other two methodologies will be accessible by the DiFac end users.

The methodologies addressed the requirements for presence, collaboration and ergonomics generated within work package 1, thus conforming to the fundamental DiFac principles. Furthermore, unique and innovative opportunities to enhance the application of the methodologies through the use of collaborative VR equipment are identified.

D13 describes the expected outcome of applying the methodologies: for workplace ergonomics this should include a timely, yet high validity, assessment of a proposed workplace; for behaviour simulations the outcome will include realistic representations of avatars, which can be used to generate more realistic predictions of manufacturing throughput, or can populate virtual environments for use in training.

Media for future collaborative manufacturing

With respect to media for future collaborative manufacturing, deliverable D19 aimed to identify concrete needs for hardware and software components to meet the requirements for group-presence based virtual and collaborative manufacturing. The analysis of existing state-of-the-art media revealed that most of the the functional requirements identified by the end-users can be covered by existing media, either by adding some additional functionality or by connecting several tools to form one comprehensive workflow. But with respect to the pillar requirements (the needs for presence, collaboration and ergonomics), state-of-the art media offers rather poor possibilities.

It will thus be a main goal of the DiFac project to provide a set of software tools, methodologies and guidelines for building Virtual Factory applications by taking into consideration the collaboration, presence and ergonomics issues. The media will not be created from scratch. Instead the most suitable existing software and hardware components will be selected and enhanced from a functional as well as from the three pillars point of view, to realize three comprehensive suites for collaborative manufacturing (the 3 digital activities components).

5. REFERENCES

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