Design of an Analysis Environment for Planning Decision Support

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Summary

In this contribution, the design of an analysis environment is presented, that supports an analyst to come to a decision within a gradual collaborative planning process. An analyst represents a project manager, planner or any other person, involved in the planning process.

Today, planning processes are managed by several geographically distributed planners and project managers. Thus, complexity of such a process rises even more. Prediction of consequences of many planning decisions is not possible, in particular since assessment of a planning advance is not trivial. There have to be considered several viewpoints, that depend on individual perceptions. In the following, methods are presented to realize planning decision support.

1 Introduction

Success of a product strongly depends on efficiency of the planning process, which is of major importance. The course has to be set at a point in time where only diffuse knowledge of certain information is available. Making a decision at such a point can have severe impact on the development of the ongoing planning process. Typically, the process goes on with time and the goal is to achieve optimal planning advances. Such a planning advance is defined as the changeover from an "old" to a "new" planning state and is triggered by planning activities, like aforementioned planning decisions. As already mentioned, it depends on individual, mainly domain specific, viewpoints if a planning advance is considered to be satisfying or not. The challenge is to find the interdisciplinary optimum, which usully is a compromise. Many methods, defining assessment criteria and support solving problems, are typically applied in the field of sensitivity analysis. These methods have to be integrated in an analysis environment to show how and if planning decision support thus can be achieved.

Nowadays, planners, participating in a collaborative planning process, use computer applications, henceforth termed planner applications. Because of the heterogeneity of these applications a common shared product model is necessary. The Industry Foundation Classes (IFC), maintained by the International Alliance for Interoperability (see 1) is widely accepted in this field. It is designed to keep intderdisciplinary data of a construction object. Recent further developments, like the release of IFC2x2 in May 2003 seem to be a step forward to enable integration of the standard in current applications.

2 Related Work

The International Alliance for Interoperability released IFC2x2 as the actual version in May 2003. This release has significant changes to the prior IFC2x version (e.g. ST-4 extension for Structural Analysis Model and Steel Constructions, see 2). However, only few planner applications implement the actual version of standard, at the moment.

To serve business needs the product model has to be managed by model servers, that are capable of keeping consistency, multi-user access handling, etc. Among others, the EPM Technology (see 3) company is engaged in implementing these services. Their product, called

EPM Data Manager, provides powerful functionality to handle EXPRESS based product models. Also, the Institute of Applied Computer Science in Civil Engineering at the University of Technology Dresden developed a model server along with the iCSS project (see 4) to fulfill the postulated needs.

Extended functionality, like communication between the participants, project management, knowledge base services is obtained by cooperation platforms. Recently, several research projects were involved in developing those constructs. ISTforCE (see 5) and iCSS research projects have been ended. ArKos (see 6) is a new and actual project of several companies and research intstitutes.

To find more acceptance in practice much more functionalities have to be implemented in such platforms. For example, the previous services (in particular IFC model servers) were not able to grant access to partial models. Only either individual objects or the whole model could be exported. The Institute of Applied Computer Science in Civil Engineering at TU Dresden developed a global model subset definition schema (Weise et al. 2003) to define partial models. It is capable of representing a specific view of the model (for example the structural model, or the HVAC model). This is one important step to support collaboration of planners from different disciplines.

Collaboration and co-operation in a planning process implies combining different planner's applications. Data transfer between them can be achieved by using and "understanding" the underlying common shared product model. Unfortunately, the number of planner applications implementing such product models, in particular IFC, is not very high. Most of them support read access from IFC only. Exceptions are, among few others, mainly CAD-applictions like ArchiCad (see 7) or ADT (see 8) which produce IFC data in form of a STEP Physical File (ISO 10303-21 IS 1994). However, they mainly support the geometric model only.

3 Analysis Environment

The Analysis Environment needs to be capable to include workflow, involved planners and underlying product model data for a certain scenario. Such a scenario represents a configuration of a process chain, that may be partially modeled or different from the primal workflow. Furthermore, an analyst has to be supported to define, configure, stop and re-run the scenario.

Internal relations of the above aforementioned are depicted below in Fig. 3.1.

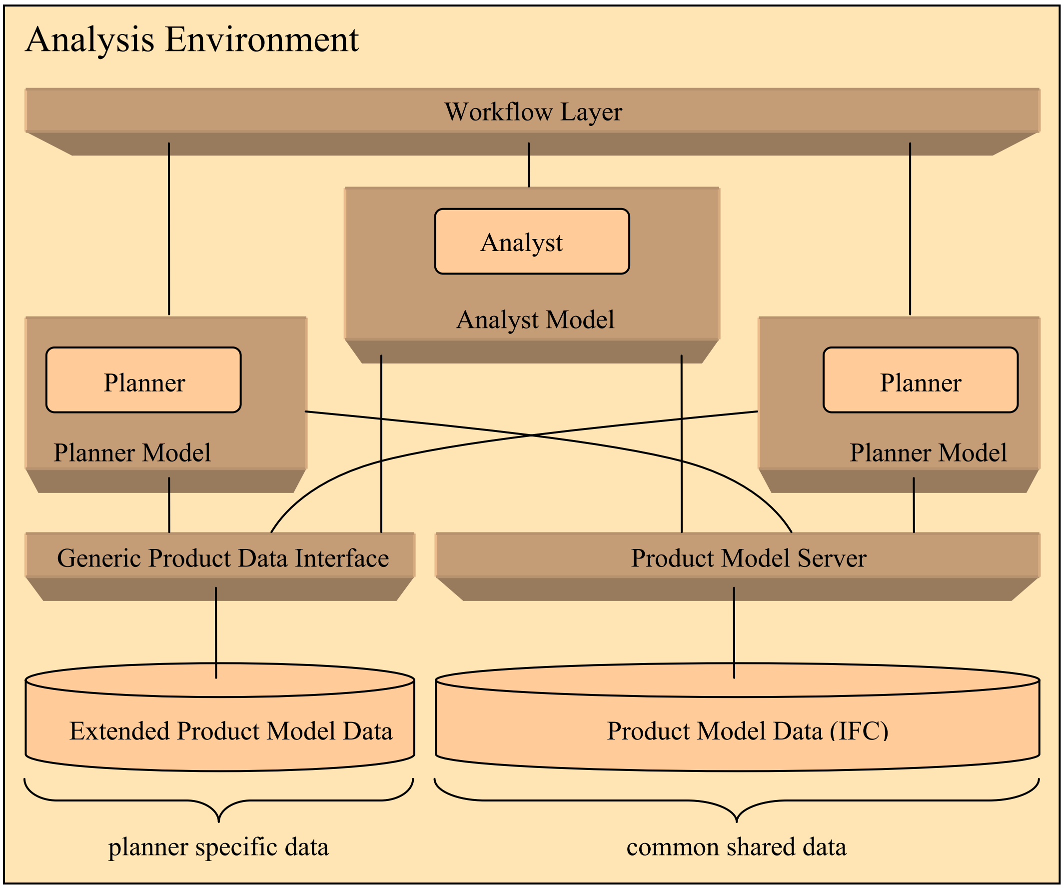


Fig. 3.1: Relations of the environments components

Heterogeneity and different demands of planner applications make generic interfaces highly essential. Therefore, they have to be represented by a generic model, that is vital for analysis environment internal communication via these interfaces. This enables interactions with workflow, data and comuncation management described below.

3.1 Analyst/Planner models

Planner models represent the contribution of a planner to the planning process, while analyst models extend them by adding controlling features to them and the workflow management. Underlying applications differ in being planner applications (e.g. structural analysis) for the planner models and analysis methods (see Sec. 3.1) for the other case.

Both possess similar data access methods. Thus, both are entitled to read/write planner specific extended product model data and common shared product model data.

Since the representational nature of the aforementioned kind of models, their functionality may be network distributed. A client implementation at the planner's site connects the "real" application to their corresponding representation within the address space of the analysis environment. Favoured communication technique is Remote Procedure Calling (RPC), so far. Alternatively, usage of software agents is considered. Locally (planner's site), the client implementation has to be adapted to the planner application or analysis methods.

Planner models are predominantly domain specific, but beyond that, heterogeneity of planner applications and their local environments renders them almost unique for every participating planner. Because they are domain specific, they benefit from applying partial model techniques, like those presented in (Weise, et al. 2003). For example, network traffic, due to the quantity of exchanged data, and integration into the local planner applications' data format are drastically simplified. On the other hand, partial models at best are derived from the underlying standardized product model (IFC in this case). This ensures data consistency to the greatest possible extent. But it also means that non-standardized data is excluded. For this reason, an extended product model concept (Sec. 3.2.2) is deployed.

In contrast, an analyst indeed may be interested in interdisciplinary data. Thus, a domain specific partial model is not to be considered for this issue. In fact, only attributes of certain objects within the product model (e.g. a wall thickness) matter. Hence, a kind of product model viewer is needed that enables selecting objects and choosing attributes, to identify them in the global model by characteristica, like globally unique identifiers.

Another complement between planner and analyst model is workflow interaction. While a planner is controlled by the workflow management, an analyst is able to influence it. So, workflow interactions are handled different for both models.

A variation of planner models are surrogate models. They represent a computer simulation of a planner's task. In some cases it is advantagous, using simulations instead of a "real" planner activity. Reasons may be an absence of a planner or if processing of his task everytime means high time and effort costs, when testing various scenarios. The derivation of the surrogate models realized by applying the statistical method *Kriging*. It is a procedure with an interpolative character and was originally developed by Sacks et al. and presented in (Sacks et al. 1989). Currently, at our Chair this method is implemented in MATLAB and is under further development (see 9).

3.2 Product Model Data

Data transfer between analyst and product data model ideally should be based on a product data model. This data variety depends on the definition of the product model. Thus, planner specific data may not be transferred along with the mentioned standardized product data model (IFC). Three reasons are responsible for this:

- The product model is still under development and certain features are not available yet.
- The planner specific data will not be part of the standardized model, because it is considered to be of no interest for other involved persons.
- Used planner applications may be unable to write their data back into the product data model.

In particular, for our purpose planner specific data indeed may be very interesting. This fact leads to the strategy to split the product data into two parts.

3.2.1 Common Shared Product Model Data (IFC)

The standardized IFC model is used for common shared data of the planned project. The question is how to (i) transfer the data to the planner, (ii) modify it and (iii) merge it back to the product data model.

Usually, a model server is responsible for accessing and keeping consistency of the global model. The target applications (see 10), that will be used at first for designing and testing this environment, are able to read IFC as ISO 10303 Part 21 – **S**tep **P**hysical **F**ile (SPF) format, which is currently the reason for taking the full IFC-Model for (i). Step (ii) clearly is left to the applications themselves and step (iii) is to be managed by an aforementioned model server. Because none of the above mentioned applications is capabale of writing IFC data, the model server supports currently only full model operations. For future development it is of major importance to improve this field.

3.2.2 Extended Product Model Data

The *Extended Product Model Data* concept is designed to contain data, that is not includable in the underlying product data model, in this case IFC. Access and management is controlled by a generic model data interface that provides generic methods for common operations, like *get*, *put, search,* etc. Its functionality is to be used by planner and analyst models.

For consistency reasons, with respect to the EXPRESS based common shared product model IFC, this concept is also modeled in EXPRESS. It contains basic generic object definitions that can be linked to the IFC objects by their globally unique identifier. This relation is unidirectional, which means, that extended product model data objects can reference IFC objects, but not vice versa. In that way no manipulation of the IFC schema is necessary and standardization is retained. The underlying data exchange format is based on XML.

For example, a feature not included in the IFC in this form is a kind of “maximum deflection” property of an object. This could be done either by using the IFC Property Definition Sets or simply via following XML-schema:

```
<PlannerApplication id="StructuralAnalysis" name="CARAT">
        ...
        <Displacements>
                <MaxDeflectionOfObject IFCobjectID="xghj!k289shjkhs" val="0.04"/>
        </Displacements>
        ...
</PlannerApplication>
```

Fig. 3.2 XML-Example

Of course, because the data format does not adhere to a standard and the defined objects are generic other analyst or planner models have to know about the data specification to use this information. This has to be made amendable by a well-kept documentation system.

3.3 Workflow

Typically, complexity of a planning process in AEC renders determination of the planners affected by another planner’s decision highly delicate. Since within this environment mainly partial processes are to be defined, there is a designated internal workflow management. It is defined by the analyst. He may use controls to change the sequence, stop the process or re-run the preassigned process chain of planner models during execution. Everytime a planner model’s computation has finished he gets notified and has the possibility to execute these controls.

The design pattern to realize this management system is the *Observer Pattern* (Cooper 1998) and is implemented in the workflow layer of the analysis environment.

3.4 Analysis Methods

In this section a short survey of the designated analysis methods is presented. Note, that the methods are only generally described. Precise statements on how they are being applied in the analysis environment are not made, since, at first, we need to realize the environment as a basis for data aquiration needed by following methods.

3.4.1 Sensitivity Analysis

Basically, sensititvity analsysis is concerned with the question how response *y* of a system varies, due to an alteration of the input parameters *x*.

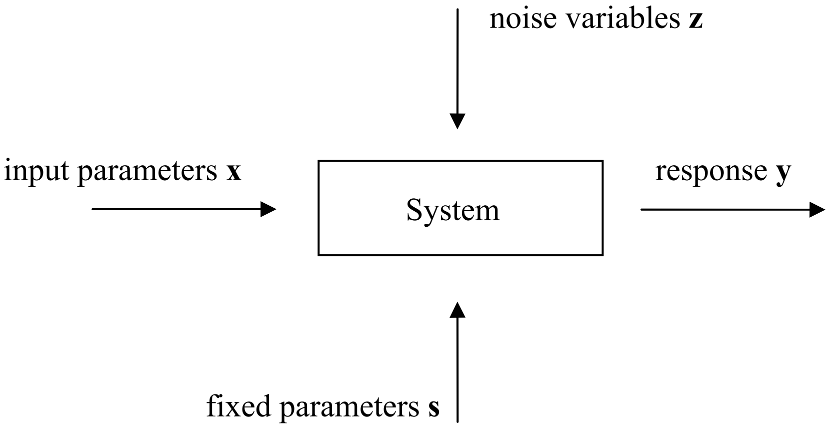


Fig. 3.3 System within a typical sensitivity analysis context.

Reasonability of a sensitivity analysis depends on the knowledge of the underlying system. Thus, it can be used to identify an unknown or predict the response of a sufficiently acquainted system.

Particularly, there is distinguished between screening methods, local and global methods. Screening methods are used to identify significant system parameters. One of the simplest applications of screening methods is the one-at-a-time (OAT) method. Their major limitation is the neglection of parameter interaction (Saltelli et al. 2000). Local sensitivities of a system are imagined at best as partial derivatives with respect to the input parameters. The system has to be known as a function to directly derive the sensitivities from. Otherwise, methods like finite-difference approximation support obtaining the slopes of the calculated system. Considering "real" systems, an analyst is faced with the influence of noise variables. They are uncertainties, like measurement errors, rounding errors, etc., and can't be controlled directly. Therefore, global methods of the sensitivity analysis are applied to cover the total scope of input parameters. The goal remains the same, namely to analyze the system alteration by variation of input parameters.

3.4.2 Response Surface Method

Starting from certain system information and educing to a corresponding function behaviour of significant input parameters is a task for *Response Surface Methods* (RSM). For example, supported by regression analysis, mostly linear or quadratic approximation is used. Aforementioned system information may be of experimental or numerical nature. The models derived in this way can also be used for system response prediction, as mentioned in Sec. 3.4.1.

RSM is strongly associated with *Design of Experiments* and *Robust Design* and is considered to be a major prerequisite of multidsciplinary otpimization.

3.4.3 Design of Experiments

Design of Experiments (DOE) is a methodology to choose the location of the sampling points, used to accomplish statistical experiments. To make an expedient statement of a statistically derived model a certain number of experiments is to be processed. This number can be controlled by using different designs (Box and Draper 1987).

3.4.4 Robust Design

Consider a system, like depicted in Fig. 3.2. Application can be thought of accomplishing a sensivity analysis, like described above, with directly influencable input and noise parameters. Achieved sensitivities refer to the noise parameters. Thus, input parameter sets can be determined, that minimize these sensivities and thereby the influence of the noise parameters to the system. Then, such a system is called to be robust (Taguchi 1986). For this reason, another expression for robust design is *Quality Engineering*.

3.5 Assessment of an Analysis

A result of an analyzed scenario are the output parameters the analyst receives partially from the product data model (IFC) and from the extended product model data, where they were stored by the planner models during the execution of the process chain.

As already mentioned an assessment depends on the individual perception of an analyst. Thus, a possibility to obtain a numerical interpretation of quality can be achieved by defining an objective function. Individuality is taken into account by the corresponding choice of parameters and their weighting by the analyst.

To get an idea about how an objective function could be, a simple abstract example is presented. Here, the used models are simulate planner models, because, at this stage of our work, we don't have a planner model based upon a planner's computation yet. They are chosen just to simplify the imagination of an assessment.

Example:
Assume there is a base plate of a working area. There is a fixed workplace at *W* and a heat radiating machine *M* with a decent weight. What would be a location for M so that a) the deflection of the plate and b) the temperature at the workplace are satisfying, in a way that a) the deflection is minimzed and b) the temperature is around 18°C?

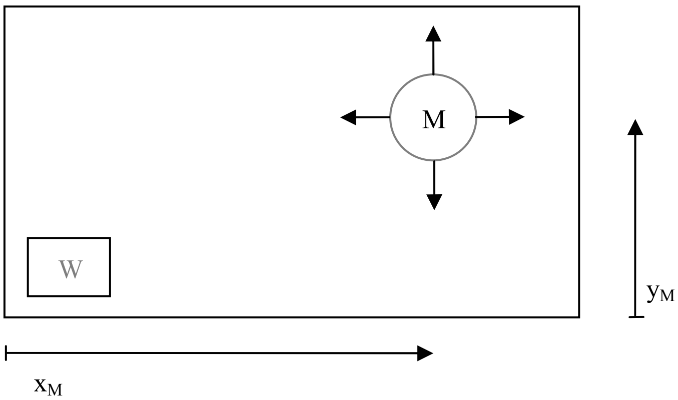


Fig. 3.4: base plate with workplace and machine

Considering two necessary planners models (structural and thermal analysis), that are evaluated as follows by the analyst after several input scenarios, where the location (x_M, y_M) of the heat source are the input parameters, that have been modified each time. The variables x_M, y_M are normalized and therefore dimensionless.

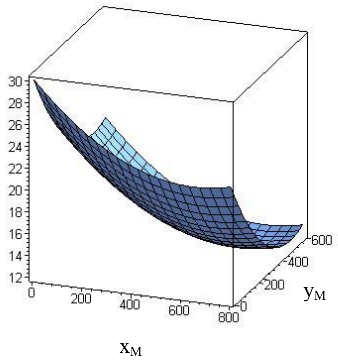


Fig. 3.5a temperature $T(x_M , y_M)$

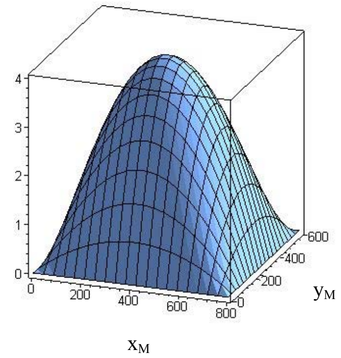


Fig. 3.5b deflection $w(x_M , y_M)$

The temperature is calculated at *W* and the deflection at the center of the plate.

An individual interpretation of the analyst by applying preference functions follows:

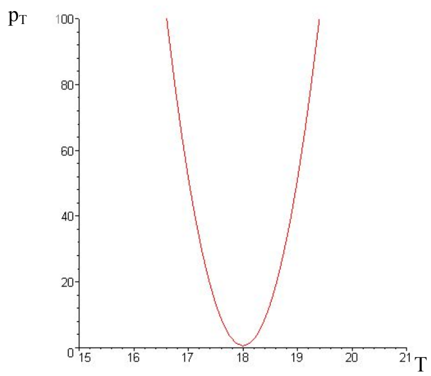


Fig. 3.6a preference $p_T(T)$

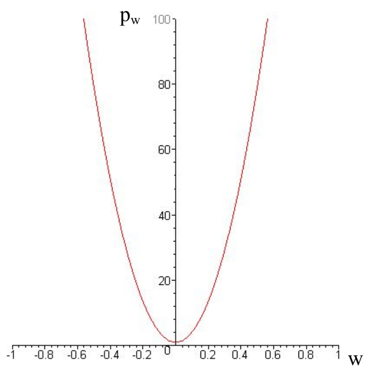
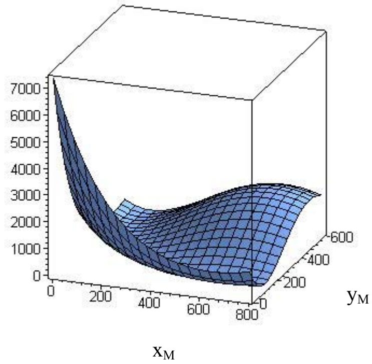


Fig. 3.6b preference $p_w(w)$

Preference functions allow assessment of quality for certain functions with respect to an optimum. The preference functions depicted in Fig 3.6 penalize $T(x_M , y_M)$ and $w(x_M , y_M)$ for deviation from their considered individual optimum values (e.g. T_{opt}=18 °C, w_{opt}=0 cm). Applied to the planner model functions ($T(x_M , y_M)$, $w(x_M , y_M)$) lead to Fig. 3.7.



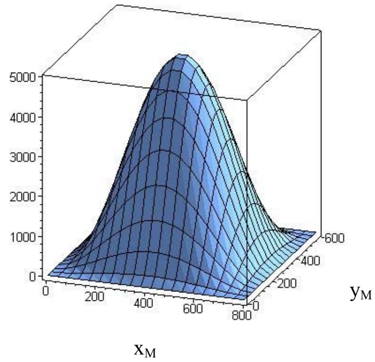


Fig. 3.7a $p_T(T(x_M, y_M))$ Fig. 3.7b $p_w(w(x_M, y_M))$

Combining the models, an objective function may be achieved as follows:

$$F(x_M, y_M) = w_T p_T(T(x_M, y_M)) + w_w p_w(w(x_M, y_M))$$

The parameters w_T and w_w are additional weighting parameters the analyst can choose freely to consider the importance of the planner models.

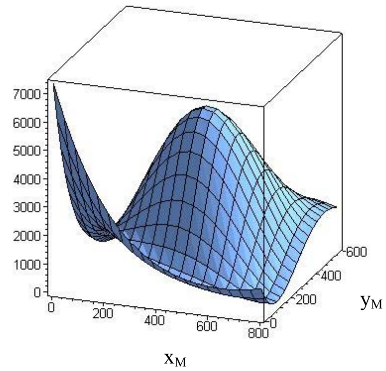
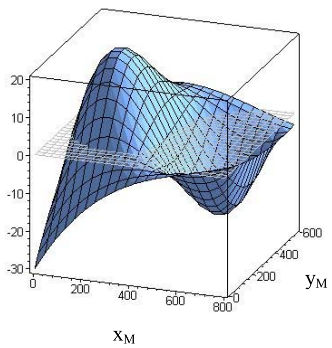


Fig. 3.8 objective function $F(x_M, y_M)$

An analyst may conclude the optimal location for *M*. Local minima of $F(x_M, y_M)$ represent best possible locations for his chosen set of weighting and penalty functions. The absolute minimum of the objective function depicted in 3.8 is $F_{min} = 1.499$, at $x_M = 800$ and $y_M = 126.849$. Thus he may consider to place *M* at this location.

Another way to interprete the objective function is considering the sensitivities depicted below. They are deduced by partial differentiation with respect to the input parameters x_M and y_M:



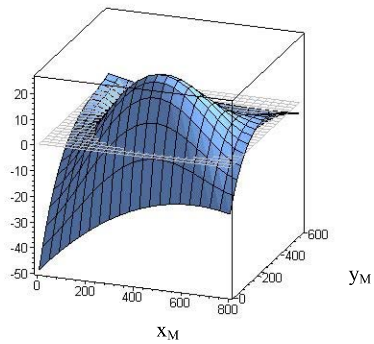


Fig. 3.9a $\partial F / \partial x_M$

Fig. 3.9b $\partial F / \partial y_M$

Here, an analyst may reason the slopes of the objective function. Thus, he gets an imagination about how severe an impact on his objective function will be, if he decides to change one of the input parameters x_M , y_M of his system. Clearly, he can also see if an input parameter would have no influence on a partial region of the input parameter space ($\partial F / \partial x_M = 0$, $\partial F / \partial y_M = 0$).

4 Conclusion

A general design is presented to support planning decisions on basis of sensitivity analysis in a heterogenous planning environment in structural engineering.

Still, a difficult problem is product model data management. Since almost no applications support the check-in of their local data to a common shared product model, our above described extended product model data concept will have to be used as workaround for this issue. For a manageable amount of different planner applications this is applicable, but beyond that the effort to keep track of the variable data format will become very high. Besides that, we seek cooperation with researchers of product model technology to develop a reliable solution for product model data transactions.

Anyhow we are confident that our approach, once implemented, will fulfill the postulated aims.

5 Acknowledgements

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6 Endnotes

1) International Alliance for Ineroperability. Project homepage available at http://www.iai-international.org/iai_international/

2) ST-4 Project "Structural Analysis Model and Steel Construction". Further information available at http://cib.bau.tu-dresden.de/icss/structural_papers.

3) EPM Technolohy. Further information available at http://www.epmtech.jotne.com/

4) iCSS - Integrated Client-Server System for a Virtual Enterprise in the Building Industry. Project homepage available at http://cib.bau.tu-dresden.de/icss/factsheet-en.html

5) ISTforCE – Intelligent Services and Tools for Concurrent Engineering. Project homepage availabe at http://www.istforce.com/

6) ArKos – Architektur Kollaborativer Szenarien (translated: Architecture of Collaborative Scenarios). Project homepage available at http://www.arkos.info/

7) ArchiCad. CAD application developed by Graphisoft. Further information available at http://www.graphisoft.de/

8) ADT – Architectural Desktop. CAD application developed by Autodesk. Further information available at http://www.autodesk.com

9) Dipl.-Ing. F. Jurecka is involved in implementing the Kriging method in MATLAB at the Chair of Strucutral Analysis, Technical University of Munich, see (Jurecka 2004).

10) Structural Analysis (Romberg et al. 2003) and life-cycle assessment (Neuberg et al. 2003) applications developed at the Institute of Computer Science in Civil Engineering, Technical University Munich.

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