ABSTRACT

Despite the evolution of technologies intended to facilitate and optimize product development processes and foster collaboration, effective reuse of 3D models remains one of the biggest challenges in the area of Computer-Aided Design. Whether a manufacturer is designing a new commercial aircraft or a household appliance, engineering teams often start with existing designs and adapt them to new cases, rather than designing every product from scratch. Nevertheless, CAD model reuse is not effectively supported by conventional CAD packages, as much of the burden related to reusability lies on the CAD user.

It has been shown that CAD model reusability largely depends on a proper definition and communication of the geometric design intent, which are usually expressed implicitly within the CAD model. This implicit representation makes it difficult for CAD users interacting with a CAD model to understand how and why the model was created in a specific manner. This is especially true for models being reworked by designers that are not the original creators of the models. The inability to understand and modify existing CAD models negatively affects reusability and hinders the collaborative design process. The problem becomes more relevant in model-based engineering environments, where 3D models are used as the main shared data source for all engineering activities throughout the product life cycle.

Recent research has explored the potential of 3D annotations as tools to carry design intent information. The focus of this doctoral research is to study the effectiveness of 3D CAD annotation techniques to support the explicit representation and communication of design intent, and to analyze the impact of these techniques in the alteration and reutilization of 3D models in a product design context.

Literature shows that a good and structured methodology is an essential step to create parametric models that are reusable and can be altered easily. However, when models reach a certain level of complexity in terms of number of features and interdependencies, additional mechanisms must be established so design intent can be communicated effectively in an explicit manner. In this regard, a comparative study was conducted to determine the complexity of three professionally accepted modeling methodologies. These methodologies represent a group of well tested and documented methodologies that are currently available to the public. An efficient modeling methodology can provide a competitive advantage in industrial settings so companies are often reluctant to make this information public. An experimental software system was developed to examine the internal structure of parametric CAD models according to a set of complexity metrics.

Recent studies have suggested the use of 3D annotations as a method to embed design information in the model's geometry and make part of the design knowledge explicitly available. An exploratory study was performed to examine the formal annotation practices defined by model-based standards such as ASME Y14.41-2012 and ISO 16792:2006, and their implementation in current CAD systems. A series of experimental studies were conducted to evaluate the effectiveness of existing textual annotation mechanisms defined by current standards and analyze their impact in model alteration tasks. Effectiveness is analyzed in terms of the ability of the annotation to communicate design information to CAD users so CAD model alterations are performed correctly and efficiently. Results show that annotated models provide significant benefits when performing activities that require a direct manipulation of the model's geometry, but more advanced annotation mechanisms than those defined by current standards are necessary.

An extended annotation model that builds on current standards is introduced. The architecture of a new software system to communicate geometric design intent information explicitly by overloading and extending the scope of the current annotation instruments is presented. This system introduces a new broader type of model annotation where design information is represented both internally within the 3D model and externally, on a separate repository; and a new Graphic User Interface (GUI) embedded within the CAD environment to support the interaction of CAD users (designers and engineers) with the information. Integration of the proposed solution with existing Product Lifecycle

Management systems as well as additional tools such as an annotation history module and an annotation-based communication tool for collaborative environments are presented. Experimental results show a statistically significant benefit of using the proposed software architecture in terms of CAD alteration times and correctness of the models after modifications in different design scenarios, suggesting the use of this annotation model as a valuable approach to improve design intent communication.