CPP Research Proposal: Sketching Static and Dynamic 3D Models

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1 Introduction / Problem Statement

Sketching is a wonderful and rewarding activity for all ages and for a wide variety of purposes [Loomis and Ross 2014]. For example, artists use sketching to express a situation or a mood, children and adults sketch to give their interpretation of reality, and scientists and engineers create sketches in order to understand concepts and to design new objects and mechanisms. However, extending sketching to 3D content creation is not trivial because of the lack of depth information in a typical 2D sketch – this hinders creating complex 3D objects.

Recent computing technology, such as tablets, digital pens, and high-resolution displays has enabled a new breed of digital sketching tools. However, almost all previous sketching tools assume the object being drawn is static in nature. A few approaches have been proposed for designing a mechanical object, but these methods either assume an articulated model is provided as input or require explicitly specifying the mechanical details of the joints. There is no previous work that provides an interactive digital sketching interface to create an object with moving parts that may undergo user desired motions!

2 Goal

In this project, we will pursue a novel sketching interface to intuitively model static and dynamic 3D objects. Our methodology incorporates concepts from sketching, procedural modeling, and deep learning. In particular, we augment traditional sketching by including a computing system that can automatically complete, and parameterize, the object being sketched. This can help to reduce the sketch time. More interestingly, the user can trivially alter the parameters after sketching and produce entirely new variants of the sketched object without actually having to sketch it again! A key component is a deep learning engine that is trained to recognize the intent of the users from a coarse sketch. We are the first to propose the combination of deep learning and procedural modeling for 3D content creation, and a preliminary version of this approach was presented at this past year’s ACM SIGGRAPH Conference [Nishida et al. 2016]. We were informed it was the highest ranked paper (ACM SIGGRAPH, the leading conference in our research area, does not give best paper awards but papers do obtain scores during review).

Going forward, we are extending our approach to support jump-starting the sketch process with a photograph (an exciting option we recently submitted to this year’s SIGGRAPH conference) and to support sketching dynamic objects (e.g., objects with mechanical joints and linkages). In particular, during this next year we will explore sketching a dynamic content that includes moving parts (e.g., mechanical engine part, folding chair, and folding bicycle). While several approaches have been proposed to reduce the user effort for designing a mechanical object, these approaches still require the user to provide an articulated 3D model as input (e.g., [Coros et al. 2013]), or explicitly specify the mechanical details of the joints during design (e.g., [Koo et al. 2014]). Also, most of those sketching approaches do not prevent collisions between moving parts. To address these limitations, our goal is to allow the user to design a dynamic 3D content without having to specify the mechanical details, such as selecting a joint type, specifying the geometry of the joint, designing the necessary linkages, and/or detecting collisions during the motion. Instead, the designer uses a sketching interface to draw an object in different poses, implicitly specifying the motion of the object. Figure 1 shows an example workflow -- mechanical details are not provided in the user sketches, instead our approach automatically infers those details. Our computational approach to solve this problem will combine inverse procedural modeling and machine learning techniques. We anticipate a working software sketching application and several major publications within 1 year.
3 Methodology

Given a user sketch of an object in at least two poses, our proposed approach automatically generates a collision-free mechanical structure that achieves the implicitly-defined motion with only a single degree of freedom. Given a sketch, our approach automatically extracts an initial estimate of the kinematic diagram as a first step. Primitive shapes drawn by the user are detected by our deep learning technique and are considered links of the kinematic diagram. However, the connectivity between the links and types of joints are not provided by the user. Then, our optimization process uses a Markov Chain Monte Carlo (MCMC) algorithm to randomly change the graph structure by adding one of a predefined set of linkages and changing some parameters of the linkages in order to find a collision-free mechanical structure that achieves the user-specified motion. While the search space for this optimization is huge, we will define a finite set of linkages (e.g., four-bar linkage and six-bar linkage) and of joints (e.g., hinge, slider, and ball joint) in order to make the problem tractable. The four-bar linkage and six-bar linkages are widely used linkages that have a single degree of freedom. By combining these linkages and joints, just about any kind of complex motion can be achieved. To evaluate the proposed graph structure during the optimization process, we will define a score function that takes into account the similarity of the resulting motion to the user sketches, any collisions during the motion, and the complexity of the linkages. The output of our approach is a collision-free 3D articulated model with appropriate joints/linkages that achieves the user-specified motion.

4 Schedule, Budget, and Student

During this CPP grant we expect to produce an algorithm and software deliverable implementing our approach described in Section 3. For the sketch interpretation part, we will extend our previous paper, which has already been accepted at ACM SIGGRAPH, to solve the inverse problem for finding an appropriate kinematic structure. We request one year RA support for the student on the project, Gen Nishida, and funds to purchase a new computer-graphics-equipped computer workstation ($2500). Gen is an extremely bright C.S. PhD student, that lead the SIGGRAPH paper (top US publication outlet) and has another previous journal publication as well to Computer Graphics Forum (top European graphics journal).

References