Statement of Research

My research interest is the processing and handling of geometric content. Currently, I am focused on the study of computational models to design and study geometric interlocking assemblies. Understanding interlocking is a significant activity across disciplines. It could be for simple Ikea assembly instruction, imperative understanding of viral capsids, sophisticated architecture designs, or ambitious engineering megastructures. My Ph.D. thesis focused on the generation of Topological Interlocking Configurations, an interlocking model based on the blocks' shape and alignment. My long-term goal is to formulate models that describe interlocking instances given an initial geometric domain.

Before working on geometry, I had the opportunity to explore and contribute to different research projects. Such experiences tailored my interest in becoming a researcher and looking for multi-disciplinary research opportunities. In this statement, I describe my initial research contributions, along with three projects that show my previous, current, and future goals on my search for a deeper geometric understanding of interlocking assemblies and other forms of geometric content.

Background: My Research Experiences Before Focusing on Geometry

My first research experiences occurred in teaching settings while considering the source code plagiarism problem among students learning algorithms and programming. I proposed a code detection model based on a modification of the Greedy String Tiling algorithm to relax the comparison between code from two different sources [1]. My proposed model aligns the comparisons with the code plagiarism spectrum defined by Parker and Hamblen [2]. The model helped instructors to collect evidence of suspected plagiarism among students in actual teaching settings.

As an instructor, I explored the student's engagement with course evaluation activities as part of their learning experience. I hypothesize that students fully engage with activities akin to real professional scenarios. To test this idea, I worked with local software development companies and designed programming projects that resembled actual day-to-day work. My students on Mobile App Development courses worked on such projects and interacted with the developers as part of their activity requirements. The results suggest that students had a positive reception of this methodology as they perceived "*the experience gave them a closer context to what to expect after graduation*." I shared and discussed these experiences during the World Engineering Education Forum 2013 [3] [4].

My contributions to the project “Low-Cost Smart-Home Environments Based on Embedded Systems” include writing the grant proposal and being a lead researcher. We obtained funds (around

USD 7K) to pay young researchers' stipends and buy devices. While executing the project, my first goal was to identify the evolution of smart-home environments proposed for research and commercial purposes. I classified the trends in system architecture, applications, user interfaces, and growing interests in the field [5]. Then, we designed a managing system to control selected household devices while maintaining user profile preferences and handling schedule tasks per device.

Before a full commitment to my geometric work, I considered research trends on data analysis. I formulated a linear model to measure users' influence in recommender systems. The model estimates the influence of a user and its impact on a business. A user's influence is the out-degree of their activity and social attributes on the platform. The effect on a business is the collective influence received in a period. To mitigate the impact of older reviews in the measurements, I included a time-effectiveness attenuation coefficient in the model. We tested the results using the data from Yelp's 2015 Dataset Challenge and successfully identified the most influential users and the most influenced businesses in the dataset [6].

Parallel to my Ph.D. work, I joined Purdue's Rosen Center for Advanced Computing as a research assistant in research hub platforms. I designed and proposed data-related components for "*cross-domain, self-serve platform[s] for data and computing that supports the entire end-to-end research investigation process*" [7]. The components are capable of data representation, visualization, and analysis of multi-dimensional hierarchical datasets. Such datasets could be case-oriented (e.g., datasets based on experimental cases and units) or ad-hoc (e.g., datasets based on non-structured collected data). My proposals worked successfully on projects from different disciplines, including Environmental Science, Nutrition Science, Computational Chemistry, Forest Science [7] [8] [9], Pharmaceutical Science [10], Thymic Malignancies and Pediatric HIV studies, and Civil Engineering [11].

Project 1: Generation of Topological Interlocking Configurations from a Geometric Approach

My Ph.D. research, advised by Dr. Christoph Hoffmann, focused on generating Topological Interlocking Configurations (TICs) based on free-form geometric domains. A TIC is an assembly where the kinematic constraints result from the shape and alignment of the blocks. Such a concept disregards the use of joinery, adhesives, or any other bonding mechanism between blocks. Although TICs were

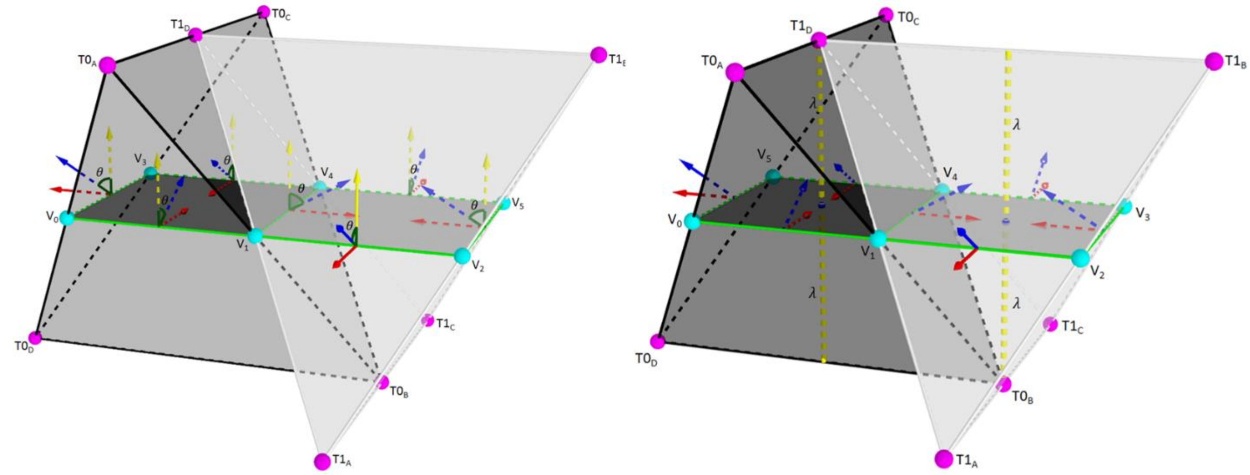

Figure 1. TIC generation parameters. Left: traditional method using angles. Right: Proposed method using distances [15].

conceived as planar assemblies made of convex shapes, recent research venues aim to design and analyze free-form configurations based on convex or concave blocks [12] [13].

The traditional TIC generation method requires an exhaustive parameter search to find angles that generate aligned blocks without overlapping [14]. I proposed using distance parameters between the geometric domain and each block's top and bottom sections [15] (see Figure 1). My proposed methods generate TICs in a single iteration over a given geometric domain, significantly improving performance over the traditional generation method. After designing a TIC, the method determines the force magnitudes (compression, tension, and tangential) to maintain the structure's static equilibrium state. I included the structure feasibility analysis by Withing *et. al.* [16] as part of the TIC generation framework (see Figure 2). The generation methods optimize the parameters such that the required tension forces are minimum.

TICs have gained interest in architecture and engineering since they offer a non-monolithic material capable of withstanding random block failure [17] and carrying transverse mechanical loads through the structure [18]. My proposed methods expand our understanding of the generation process and can be adapted to deal with intrinsic geometric domain features such as curvature and lack of symmetry. These features are of interest due to the connection between block geometry and internal load paths. I have discussed and published my results in IUTAM [19] and IEEE GMAX [20] conferences.

Project 2: Multi-Step Generation Methods for Both Convex and Concave Interlocking Shapes

The discussed generation methods could only design antiprisms, a subset of shapes that hold the topological interlocking principle. We know other solids are suitable to define TICs [21]. Researchers

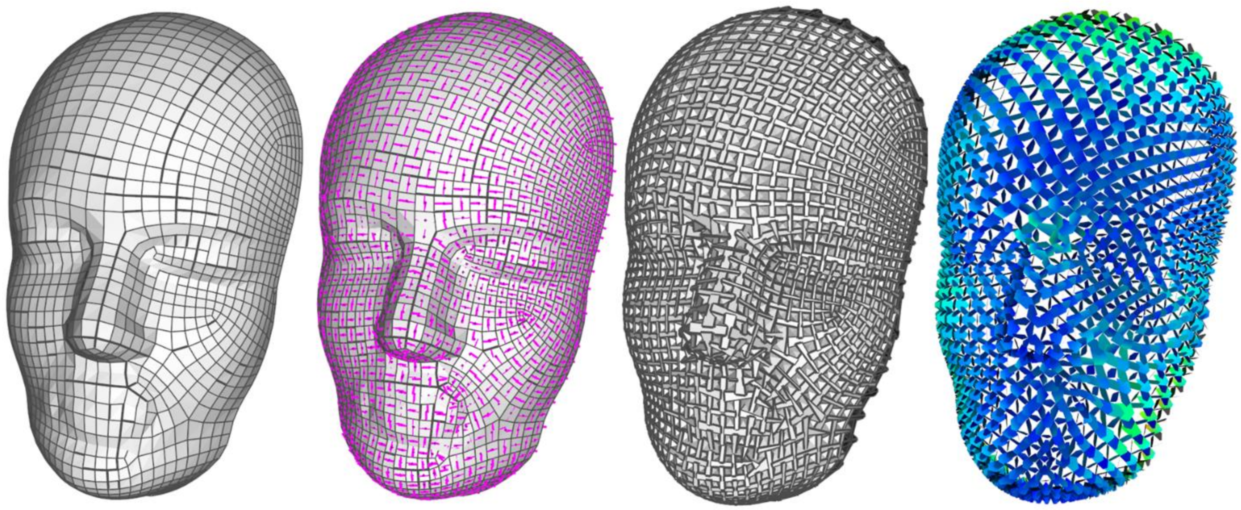

Figure 2. Proposed TIC generation workflow. From left to right: Geometric domain, Generation parameters, Assembly definition, Contact interfaces with minimum tension force distribution.

have also found concave polyhedra that comply with such interlocking principle. Up to this date, there is no unified generation method that designs both convex and concave shapes TIC blocks.

My work in progress describes any topological interlocking block as multi-step evolution sequences [22] [23]. The method starts with a seed polygon and considers its evolution to represent the respective block's vertices. Each evolution step is a parametric process that translates and reshapes a polygon into an n-polytope, with n = 0, 1, or 2. Evolution sequences occur along both orientations of the seed polygon, which provides flexibility to design elaborated interlocking shapes. Parallel to block generation, I consider the evolution requirements to create shapes that comply with the topological interlocking principle. I define such requirements in terms of uniform and reciprocal evolution sequences. Using this approach, I can describe any topological interlocking shape, including concave blocks.

Project 3: Interlocking Based on Embedded Surfaces, and Differential Growth

My current results and experience provide me with the tools necessary to approach sophisticated interlocking mechanisms besides topological interlocking. My long-term goal for the interlocking topic is to provide computational insights to more complex scenarios by focusing on geometric features of the blocks and the initial domain.

We can expand the design of the blocks by embedding non-planar surfaces on their faces. This approach's purpose is twofold: to provide unique pattern matching between incident blocks and impose additional kinematic constraints at the contact interface level. By doing this, we can design blocks with organic interfaces between them (e.g., Osteomorphic brick [17]). There are applications using similar blocks in medicine and engineering fields to generate moveable interlocking joints and periodic interlocking structures.

Finally, some geometric domains are defined using differential growth to describe nature-inspired geometries (e.g., biomimetic structures). I intend to explore interlocking configurations and other geometric settings where shape and constraints result from growing systems. I propose to approach such structures using parametrized geometric variations over time. The study of computational biomimetic structures is a growing trend in physical chemistry and materials engineering [24].

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