Efficient self-assembly of just-barely 3D rectangles at temperature-1

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Self-assembly occurs when a disorganized system of pre-existing components forms to create an organized system in the absence of outside influences. This can describe processes on the macroscopic scale, such as the formation of galaxies and solar systems, or all the way down to the microscopic scale, such as the formation of bonded molecules within a solution of atoms (a subset of molecular self-assembly). Our study will focus on the theoretical realm of self-assembly within the field of computer science and mathematics, where we will apply algorithms, models, and theorems which are related to self-assembly.

We are proposing to study the problem of determining the minimum number of unique tile types needed to non-cooperatively self-assemble a 2 x k x N 3D rectangle-like shape in the abstract Tile Assembly Model. There is evidence to suggest that the tile complexity is . This is an open research problem.

**Project Description:**

Dr. Scott Summers and I will address the proposed problem of minimizing the needed number of tile types to self-assemble a, just-barely 3D, rectangle-like, shape using the abstract Tile Assembly Model (aTAM). This model was proposed by Erik Winfree in 1998, a leading researcher in the field of DNA computing and DNA nanotechnology. Our examination of the problem uses the aTAM to build a non-cooperative, temperature-1, tile set that mimics self-assembling DNA molecules at nano-scale. Since it is trivial to produce many copies of an existing DNA tile type, but difficult to produce unique tiles types, it is befinitial to find tile sets belonging to DNA patterns that require the minimum number of tile types. Our research project solves an open research problem related to an existing result from *Complexities for Generalized Models of Self-Assembly*, a paper in SICOMP 2005, by Qi Cheng, Gagan Aggarwal, Michael H. Goldwasser, Ming-Yang Kao, Robert T. Schweller, and Pablo Moisset de Espanés.

Our research will begin with a review of related research literature, including but not limited to: *Complexities for Generalized Models of Self-Assembly*, *The Program-Size Complexity of Self-Assembled Squares*, *Temperature 1 Self-Assembly: Deterministic Assembly in 3D and Probabilistic Assembly in 2D*, and *Complexity of Self-Assembled Shapes*. After gaining an adequate amount of background knowledge, we will begin outlining the structure of a research paper. Included in the paper will be an introduction that discusses the motivation for our research along with a broad overview of our findings. In our findings, we will mathematically define the nature of our model for self-assembly, which allows us to formally construct a proof of our proposed theorem. The paper will include a conclusion that proposes further questions and directions for research. After the paper is complete, we may explore ways to implement a procedure that will produce the proposed tile set as a proof of concept.

**Feasibility:**

Dr. Summers and I are both confident that the project is feasible to complete. Dr. Summers has also completed such projects before this and has based his approval of the project on its similarity with previous work. I would like to say that I am a fast learner when it comes to mathematics. I pride myself on being able to disassociate from presumptions in order to think outside of the box, as well as having an intuition for mathematical problem solving. I believe these statements can be backed up by any member of the teaching faculty in the UW Oshkosh Computer Science department and by my associated coursework. With that in mind, I believe that I have demonstrated a good work ethic. I often devote a large number of hours on challenging tasks because I don’t like to leave things unfinished. What makes me especially adept for this area of computer science is my (virtually complete) bachelor’s in mathematics. While many fields within computer science involve at least a small mathematical component, self-assembly seems to require a more thorough understanding of mathematics and proof techniques, of which I feel I am well qualified for.

**Deliverables:**

* My written contributions to the paper’s discussions, proofs, explanations, and theorems.
* A formal solution of the problem written in LaTeX with supporting text and figures.
* TAS files related to the testing and implementation of the solution.

**Project Timeline:**

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| **Time Period** | **Activity** |
| Week 1 | Reading the aforementioned research literature on the subject of self-assembly in preparation for exploration of the topic.  Also to complete exercises related to the readings in order to test proficiency. |
| Weeks 2-3 | Solving the research question by having meetings, formulating solutions, and constructing simulations. |
| Weeks 4-6 | Writing the research paper, which includes summaries, proofs, motivations, data, and figures. |
| Weeks 7-8 | While completing the research paper in time for the upcoming conference in week 6 is ideal, we have agreed that the integrity of the research must come first. In the event that our research does not meet this unusually short deadline, it’s only fair to continue the work to its completion over the following two weeks.  This period of time can also be used to continue exploration into the topic of our paper, perhaps for a further iteration and implementation, or to open up new branches of discovery for future endeavors and is left to the supervisor’s discretion. |

**Validation:**

Exercises in week 1 will be used to evaluate my learning and preparedness for the topic. The problem’s solution will be validated by a rigorous mathematical proof as well as an implementation of the derived algorithm as supporting evidence. Publication of the research may also be used as validation.

**Evaluation:**

The project will be graded by the practicum supervisor on the following criteria:

* Successful completion of the project.
* Regular adherence to the project timeline.
* Quality of written work.
* Contributions proportional to research team’s overall productivity.
* Written and oral communications skills.
* Appropriate levels of self-reliance.

**Expected Outcomes:**

My desire is to learn skills necessary for working in a professional and academic research setting while also learning about this particularly unique field of computer science. As stated prior, we wish to prove that the complexity for a just-barely 3D temperature-1 rectangle can be self-assembled with no more than tile types. After the paper is complete, we may implement the algorithm that returns said tile set. If the research is accepted, we will submit it to academic journals with expanded content.

[1] Matthew Cook, Yunhui Fu, Robert T. Schweller: Temperature 1  
Self-Assembly: Deterministic Assembly in 3D and Probabilistic Assembly  
in 2D. SODA 2011: 570-589

[2]Qi Cheng, Gagan Aggarwal, Michael H. Goldwasser, Ming-Yang Kao, Robert T. Schweller, and Pablo Moisset de Espan\_es, Complexities for generalized models of self-assembly, SIAM Journal on Computing 34 (2005), 1493--1515.