Algorithmic Molecular Self-assembly of Fractals by Cotranscriptional Folding*

Yusei Masuda, Shinnosuke Seki, and Yuki Ubukata

Department of Computer and Network Engineering, University of Electro-Communications

RNA sequences immediately start folding upon itself as they emerge from the RNA polymerase enzyme (*cotranscriptional folding*). Geary, Rothemund, and Andersen have recently demonstrated the capability of cotranscriptional folding to manufacture an RNA molecule of an intended shape (rectangular tile) at nano-scale [Geary et al., *Science*, 345(6198):799-804, 2014]. Using a novel computational model of cotranscriptional folding called the *oritatami system* [Geary et al., Proc. MFCS 2016, LIPIcs 58: 43:1-43:14, 2016], we shall initiate the theoretical study on algorithmic self-assembly of shapes by cotranscriptional folding.

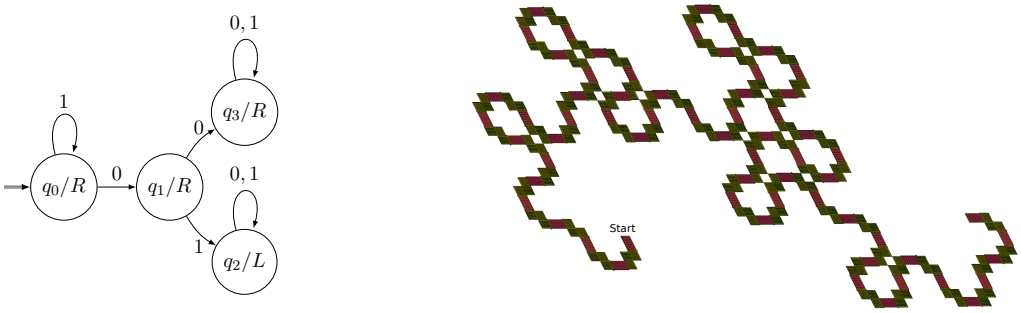

Figure 1: Heighway dragon. (Left) A DFAO that outputs a turtle program for Heighway dragon. (Right) The 6th iteration of the Heighway dragon folded by the proposed oritatami system.

Algorithms and computation are fundamental to molecular self-assembly as illustrated in their enormous success in DNA tile self-assembly. The Heighway dragon is a fine starting example in order to cut to the heart of algorithmic self-assembly by cotranscriptional folding because it is traversable algorithmically. An algorithmic way to traverse it is to feed a turtle program with the binary *automatic sequence* RRLRRLLRRRLLRLL ... as a direction to turn, whose i-th bit (starting from 0) can be obtained by giving a binary representation of i from LSB to the DFA with output (DFAO) in Figure 1 (Left). Our oritatami system combines the existing binary counter and copier modules with two modules: one implements the DFAO and computes the direction to turn from the current count i, which is propagated through a red line segment consisting of a counter and copiers; the other (green L-shaped block) bends the count i leftward or rightward according to the direction just computed. The 6th iteration of the Heighway dragon, i.e., the first $2^6 - 1$ turns of it, folded by the proposed oritatami system is shown in Figure 1 (Right). The system architecture is generic and works for an arbitrary finite portion of the Heighway dragon.

*This work is in part supported by JST Program to Disseminate Tenure-Tracking System, MEXT, Japan, No. 6F36 and by JSPS KAKENHI Grant-in-Aid for Young Scientists (A) No. 16H05854 to S. S.