3D Printed Models for Teaching Data Structures

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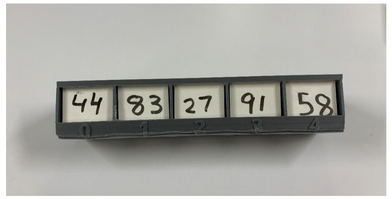
Introduction

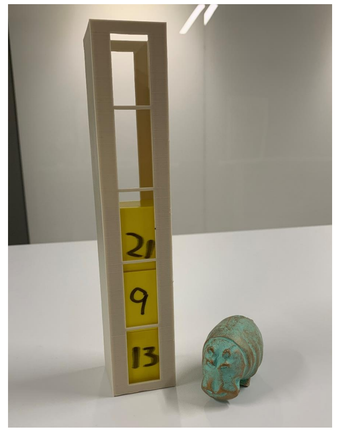
The data structures course is a fundamental course in Computer Science education. It describes and compares the different structures that can be used to store data in memory. The course typically covers arrays, stacks, queues, hash tables, trees, and graphs at least. The emphasis is on the different features of each and when it is most suitable to use it. And therefore, students need to visualize the data structures in memory and how they are used. This is traditionally done by showing diagrams and animations of the data structure being used. For example, a stack having data pushed and popped from it, or a binary tree changing shape with data insertion and removals.

Methodology

We designed a set of 3D printed models that represents the different data structures. They enable students to better visualize them in memory, and to compare the structure of consecutive and non-consecutive memory allocation. This is particularly useful for explaining data structures with pointers such as linked lists and trees. Students were involved in the design of the 3D structures and the actual printing process. Four basic data structures were designed and printed during the spring 2020 semester: arrays, stacks, queues and linked lists. The data and memory addresses was represented as cubes with numbers printed on them that are inserted into the 3D frames representing the memory locations.

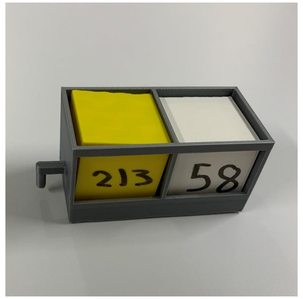
Consecutive Allocation

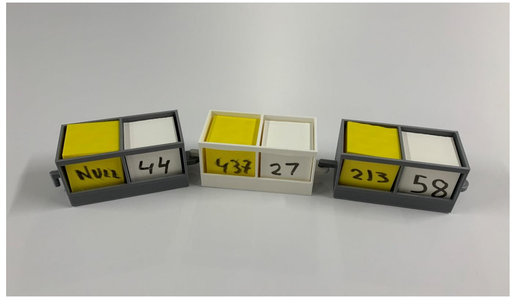




Consecutive structures are build as a rectangle with cubes to insert in the slots and opening in the back to easily slide them in and out. On the left is an array with index number, in the middle is the queue with openings on both sides and directional arrows. On the right is a stack with a top opening only and back opening for easily moving the blocks.

Linked List





The Linked list consists of connecting nodes with hooks and eyes built in. The white cube is the data part and the yellow cube is the address of the next node. Nodes with more data cells were also built to show that not all nodes has one data item in it. The hook and eye can be replaced with a rope to emphasize that consecutive spots in memory are not needed.

Future Work

The students found the structures very useful and stated so in the course evaluations. The next challenge is the 3D design for a binary tree that can support the addition and removal of nodes. Several ideas were discussed using arrows, ropes and hooks, and the implementation of them will be built and compared in the fall 2020 semester. A complete data structure demo set will be published as an instruction aid for data structures courses in high schools and colleges.

References

1. J. Ali, "A visualization tool for Data Structures course," *2009 2nd IEEE International Conference on Computer Science and Information Technology*, Beijing, 2009, pp. 212-216, doi: 10.1109/ICCSIT.2009.5234389.
2. Y. Chen and P. Chang, "3D printing assisted in art education: Study on the effectiveness of visually impaired students in space learning," 2018 IEEE International Conference on Applied System Invention (ICASI), Chiba, 2018, pp. 803-806, doi: 10.1109/ICASI.2018.8394384
3. Z. Liu, H. Jia and S. Han, "Research on the Teaching Method of Combining the Theory and Practice in Data Structure Course," *2008 The 9th International Conference for Young Computer Scientists*, Hunan, 2008, pp. 2501-2506, doi: 10.1109/ICYCS.2008.330.
4. Y. Sun and Q. Li, "The application of 3D printing in mathematics education," 2017 12th International Conference on Computer Science and Education (ICCSE), Houston, TX, 2017, pp. 47-50, doi: 10.1109/ICCSE.2017.8085461.
5. Y. Sun and Q. Li, "The application of 3D printing in STEM education," 2018 IEEE International Conference on Applied System Invention (ICASI), Chiba, 2018, pp. 1115-1118, doi: 10.1109/ICASI.2018.8394476.

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