Alex Negrini (ajn3205@rit.edu)
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Origami Designing - Part 1: Analysis

Rational

Foldabots is a private start-up that conducts research in micobots, or robots which are constructed and operated at a minuscule scale. These robots are typically designed to be foldable, which allows them to be leveraged for multiple unique use cases. Foldabots have collaborated with a variety of different disciplines, including healthcare, aerospace engineering, and structural engineering. As the primary feature of these robots are them being foldable, they take significant inspiration from origami, or the art of folding paper which has had a significant amount of backing within the scientific community.

Foldabots has been operated as a start-up for the past 4 years, whose average employee has been with the company since its formation. 6 months ago, they have received multiple large investments, which provides the company with the necessary resources to grow. This entails hiring additional engineers, both in the junior and senior positions. Recently, as Foldabots has started onboarding new employees, it became apparent that they do not have the necessary background or experience in designing complex foldable structures to effectively collaborate with the current employees. This is despite the new-hires' appropriate general engineering skills and capabilities. This was further emphasized when these new-hires starting to participate in ongoing projects with engineers who have more experience with these types of structures. Thus, new-hires struggle in understanding, learning, and advancing the projects they are assigned to, which greatly impacts both the quality of work and its efficiency across aspects of all new-hire roles within Foldabots.

Students

Students include newly-hired, currently onboarding employees, and any additional engineers which Foldabots may hire in the future. These new roles significantly vary from junior, entry-level positions to senior positions. As students are selected for employment based on their technical abilities, it can be assumed that the typical student possess a strong engineering skill set as well a potentially a research skill set. As this company works in a niche area of research, it is assumed that students will not have prior experience in creating complex, foldable designs or have any origami-related skills. The typical student is interested in advancing research in a previously unexplored area, which is relevant as it indicated that they are invested in learning more about the technology currently being used and developed, particularly foldable technologies and the principles behind them.

Actuals

Students have sufficient engineering experience, potentially with research experience, and are qualified for a traditional engineering role. They are invested in learning new technologies, but have yet to gain knowledge or experience with the niche area of research involving origami-based microbots or the science or art of origami that would significantly improve their rate of learning, efficiency of work, and quality of work.

Optimals

Students have a sufficient baseline knowledge with foldable structures, particularly both how they are both used and created. This, combined with engineering and research experience, will allow students to be able to effectively participate in and advance research in microbots with experienced employees and advance one's personal understand and learning within the field.

Performance Discrepancy

There is a discrepancy in both the ability to complete current work and continually advance research in the field of microbots. This includes having the understanding and capability to participate in current projects, as well as to continually learn and adapt to the evolving field of research. The latter differs from simply the ability to do work, as it implies the personal capability to leverage experience with foldable structures to better test and explore novel concepts and ideas within this area of research.

Need

As new-hires are selected for more long term roles to be able to advance more long-term projects, having a short instructional program at the beginning of employment may be beneficial for multiple reasons. These benefits include both the potential increase in quality of work directly after course completion, as well as the ability to continually advance research more efficiently and effectively with the increasing amounts of knowledge built off of what was gained in the course. Both the proposed long term and short term benefits make the monetary risk of developing and deploying the program as well as the risk of diverting employees' time away from their current work less significant.

As the type of work of developing foldable structures is frequently engaged in by engineering new-hires and remains a consistent, stable portion of what is required as part of the job's roles, an instructional program or electronic learning program would specifically be appropriate for the implementation of any instructional system. This is also supported by the assumption that most, if not all, new-hires will not have the necessary experiences or skills with complex foldable structures. In addition, the lack of motivations in learning new technology can primarily be ruled out as a key factors in a performance discrepancy, as the students were interested to accept a position in niche technological research. As part of the job, students were provided will the same relevant software and tools as current, experiences employees, which rules out the lack of proper tools and materials as a key factor. Finally, a lack of practice of skills is insignificant, as the usage of these skills are a primary aspect of the engineering role. Despite the students being new-hires, there is not a persistent lack of practice which can be identified as a key factor for a performance discrepancy.

Terminal Objective

Given three square sheets of paper, a writing utensil, and access to an illustrative/design software, the student should be able to conceptualize, design, and collapse a particular model based off of a description.

Conceptualizing involves constructing a valid tree diagram from a model's description. The total length of all sections must not exceed 16, each flap must be a whole number length, the number of flaps must be accurate, and the location of flaps must contain at most 1 misplacement. Iterations from the initial conceptualization are allowed.

Designing involves creating a flat-foldable crease pattern which contains a minimum of 2 box-pleating techniques and a minimum of 2 circle-packing design techniques. Box-pleated components must have no sections whose grid size is smaller than 1/16 of the size of the paper. Circle-packed components must have less than or equal to 10 packed circles. This resulting crease pattern must contain less than 10% of vertices which are not locally flat-foldable, however the crease pattern must be globally flat-foldable given the general location and angles of all of the edges (not the type of fold), with or without adjustments to the initial crease pattern from folding. The crease location and angles on the crease pattern are not required to be exactly, mathematically accurate, but they must resemble the general structure of a collapsible model. As this is an iterative process, there is no time limit.

Folding involves the successful collapse of the crease pattern. No additional folds need to be completed after the collapse of the base to further resemble the model description. There is no time limit.

Objectives List

1. Terminal Objective
    1.1. Given a sheet of paper and a writing utensil, the student should be able to list and describe at least 80% of the main categories of origami and other related art forms.
        1.1.1. From memory, the student should be able to verbally compare and contrast the definitions for all the origami-related art forms. (terms include: origami, kirigami, quilling, papercraft, etc.)

1.1.2. Given a sheet of paper and a writing utensil, the student should be able to list and describe at least 80% of the main categories of origami. (categories include: modular, tessellation, wet folding, etc.)

1.2. Given instructional diagrams to a simple-to-intermediate origami model which use the Yoshizawa–Randlett diagramming system (such as the dragon by Jo Nakashima) and a single 15 cm^2 square sheet of paper, students should be able to successfully fold the model within 30 minutes.

1.2.1. Given a sheet of square paper, the student should be able to demonstrate all 5 of the basic folding steps for origami diagrams. (valley fold, mountain fold, fold and unfold, rotate paper, flip paper)

1.2.2. From memory, the students should be able to identify the fold steps of at least 80% of the instructional iconography-diagram pairs from Yoshizawa–Randlett origami diagramming system. A pair consists of a diagram and its associated iconography to describe a folding step.

1.2.3. Given a sheet of 15 cm^2 square paper in a pre-folded state (as all folds can not be made directly from a flat sheet of paper), the student should be able to execute singular, simple (non-compound) folding steps that have paired iconography in the Yoshizawa–Randlett system. They should be able to successfully execute the at least 16 of the 18 types of simple folds.

1.2.4. Given a sheet of 15 cm^2 square paper in a pre-folded state (as all folds can not be made directly from a flat sheet of paper), the student should be able to execute compound folds (compound folds do not have any paired iconography in the Yoshizawa–Randlett system). They should be able to execute primitive versions of all 3 of the named compound folds (squash, rabbit-ear, petal folds).

1.3. Given a crease pattern with a single vertex, the student should be able to assess flat-foldability with at least 90% accuracy.

1.3.1. From memory, the student should be able to accurately clarify all of the rules and structure of a crease patterns.

1.3.2. Given a sheet of paper and a writing utensil, the student should be able to illustrate diagrams for at least 6 of the 7 Huzita-Tarori axioms.

1.3.3. From memory, the student should be able to assess potential flat-foldability of a crease pattern with a single vertex according to the Maekawa-Justin theorem with at least 90% accuracy. (potential as is if it does not follow the theorem, it is not flat foldable)

1.3.4. From memory, the student should be able to assess potential flat-foldability of a crease pattern with a single vertex according to the Kawasaki-Justin theorem with at least 90% accuracy.

1.3.5. From memory, the student should be able to assess potential flat-foldability of a crease pattern with a single vertex that satisfies both the Maekawa-Justin theorem and Kawasaki-Justin theorem according to the Big-Little-Big Angle theorem with at least 90% accuracy.

1.4. Given a sheet of paper and a writing utensil, the student should be able to construct a tree diagram for a particular model's description. The total length of all sections must not exceed 16, each flap must be a whole number length, the number of flaps must be accurate, and the location of flaps must have at most 1 misplacement.

1.4.1. From memory, the student should be able to identify the validity of a tree diagram at least 90% of the time.

1.4.2. Given a sheet of paper and a writing utensil, the student should be able to construct a tree diagram from a set of written specifications including number of flaps, length of flaps, and location of flaps. The number and length of each flap must be accurate, and the location of flaps must have at most 1 misplacement.

1.4.3. Given a sheet of paper and a writing utensil, the student should be able to create a list of specifications from a conceptual model's description. The total length of all sections must not exceed 16, each flap must be a whole number length, and the described location of flaps must have at most 1 inaccuracy.

1.5. Given a square sheet of paper and a writing utensil or an illustrative/design software (such as Inkscape), the student should be able to design a box-pleated crease pattern for the base of a model with certain specifications in the form of a tree diagram within 1 hour. The resulting crease pattern must be of grid size 16 or less and must contain less than 10% of vertices which are not locally flat foldable.

1.5.1. From memory, the student should be able to identify each type of crease within a box-pleated crease pattern of grid size 16 or less with at least 80% accuracy. (ridge, hinge, axial creases)

1.5.2. Given a sheet of paper and a writing utensil, the student should be able to construct a tree diagram for a specific box-pleated crease pattern of grid size 16 or less. The number and length of flaps in the tree diagram must be accurate, and the location of flaps must have at most 1 misplacement.

1.5.3. Given a separate square sheet of paper and a writing utensil or an illustrative/design software, the student should be able to design a full box-pleated crease pattern of grid size 16 or less from a crease pattern with only ridge creases within 45 minutes. The resulting crease pattern must contain less than 10% of vertices which are not locally flat-foldable.

1.5.4. Given a box-pleated crease pattern and a square sheet of paper, the student should be able to accurately collapse the structure within 30 minutes.

1.6. Given a square sheet of paper and a writing utensil or an illustrative/design software (such as Inkscape), the student should be able to design a circle-packed crease pattern for the base of a model with certain specifications in the form of a tree diagram, within 1 hour and 15 minutes. The resulting crease pattern must have less than or equal to 10 packed circles and must contain less than 10% of vertices which are not locally flat-foldable. The crease location and angles on the crease pattern are not required to be exactly, mathematically accurate, but they must resemble the general structure of a collapsible model.

1.6.1. Given 4 sheets of 15 cm^2 square paper, the student should be able to accurately construct the set of traditional origami bases (kite, fish, bird, frog).

1.6.2. From memory, the student should be able to identify and locate each type of circle-packing technique used in a circle-packed crease pattern with less than or equal to 10 packed circles with at least 80% accuracy. (techniques include non-uniaxial bases and quadrilateral molecules)

1.6.3. From memory, the student should be able to identify and clarify the packed polygons in a circle-packed crease pattern with less than or equal to 10 packed circles with at least 80% accuracy. A successful identification includes accurately clarifying each line-segment side length of the packed polygon.

1.6.4. Given a sheet of paper and a writing utensil, the student should be able to construct a tree diagram for a specific circle-packed crease pattern with less than or equal to 10 packed circles. The number and length of flaps in the tree diagram must be accurate, and the location of flaps must have at most 1 misplacement.

1.6.5. Given a square sheet of paper and a writing utensil or an illustrative/design software, the student should be able to design a general circle-packed crease pattern with less than or equal to 10 packed circles from a circle-packed crease pattern with only packed polygons within 1 hour. The resulting crease pattern must contain less than 10% of vertices which are not locally flat-foldable. The crease location and angles on the crease pattern are not required to be exactly, mathematically accurate, but they must resemble an accurate general structure of a collapsible model.

1.6.6. Given a circle-packed crease pattern and a square sheet of paper, the student should be able to accurately collapse the structure within 45 minutes.

Objectives Hierarchy