An Analysis of More Efficient Methods of Wrapping Presents

[redacted]
12th grade, aged 17
[redacted]

Research Sponsor: [redacted]

School: [redacted]
Administrator: [redacted]

We below, certify that this grant proposal is a true and accurate representation of the research intentions of the student.
Signature of the researcher: [redacted]
Signature of mentoring teacher or scientist: [redacted]
Signature of school administrator: [redacted]

Signature of mentoring teacher or scientist:
Signature of school administrator:

Review only

Introduction

I am sure everyone has experienced having to wrap a present but not having enough wrapping paper. This happened to me one day. I thought I had plenty of paper, but the present didn't fit. Knowing that the hypotenuse of a rectangle is longer than its sides, I rotated the present to lie along the hypotenuse of the paper, but still couldn't fully wrap the present because the traditional method of folding edges tucked away too much paper. So I tried to find a different way to fold edges, and found that I could now cover the entire present. This made me think that the traditional way of wrapping presents may not the most paper efficient way to do it, but rather the method that is easiest to teach, as it doesn't involve irregular angles. It is worth finding a more efficient method because all of that extra paper adds up. 81% of Americans wrap 6 or more gifts just during the holiday season, and all that paper just gets thrown away afterwards, so finding a way to wrap presents more efficiently would be both good for wallets and the environment (3M).

I will use mathematical modeling of wrapping crease patterns to compare 2 alternate methods to the traditional method of wrapping presents to determine how much less paper they use, and in what situations they are more efficient than the traditional method. I believe the alternate methods will show the most improvement with flatter boxes because the taper of the corners of the paper mean that when a box is tall, more paper gets wasted in internal folds in order to have the same amount of paper on the top face of the box. For this same reason, I expect the alternate methods to be worse than the traditional method on cube-like boxes. I also think my alternate method will use less paper than the Santos alternate method because mine allows for variable box angle with respect to the paper where Santos always uses 45 degrees.

Literature review

Santos, s. [Sara Santos]. (2012, Dec, 5). Maths of Christmas Wrapping - The One Show. Video file retrieved from https://www.youtube.com/watch?v=_5Mkslq4T7w.

This video shows the equation and fold sequence for an alternate wrapping method created by Sara Santos. The fold sequence is almost identical to my alternate method. However, the equation assumes a 45 degree angle where a variable angle is likely more efficient. To confirm this, I added it to the study

Biegert, M. (2016, December 28). Gift Wrapping Math. Retrieved from http://mathscinotes.com/2015/11/gift-wrapping-math/.

This website contains a derivation of Santos's equations that shows various dimensions of the paper in terms of box a b and c. I will build off this to create my crease pattern models for the alternate methods.

Gottsegen, G. (2015, December 15). How to Wrap a Present Like a Pro. Retrieved from https://www.wired.com/2015/12/how-to-wrap-a-box/.

This is a good explanation of what I consider the traditional wrapping method, so I will follow it when traditionally wrapping for repeatability.

The Science of Wrapping. (2007, December 4). Retrieved from https://www.le.ac.uk/ebulletin-archive/ebulletin/news/press-releases/2000-2009/2007/12/nparticle.2007-12-6.html.

This study came up with an equation for minimum area of paper needed using the traditional wrapping method: A1 = $2(ab+ac+bc+c^2)$ (A1 = area, and a b & c are box dimensions where $a \geq b \geq c$.) I will use this to confirm my method of deriving the area equations because if my traditional method equation lines up with this, it it safe to assume my alternate method equations are also correct as they will be derived by the same process.

Mei. [Charles Fung]. (2011, Dec, 15). Diagonal gift wrapping. Video file retrieved from https://www.youtube.com/watch?v=AR4ZWFvVseU.

In this video, I found that the method I though I discovered already exists. I will follow this folding sequence for the sake of repeatability.

Christensen, L. [Lars Christensen]. (2015, Feb, 18). Quick Inventor Tip : Parameter & Equations. Video file retrieved from https://www.youtube.com/watch?v=52iHEMOAq4Y.

This video showed me how to set parameters and equations in autodesk inventor sketches. I will use them to create a model in inventor that can create a crease pattern given box dimensions.

3M. “WRAP” SHEET Survey reveals Americans’ Gift-Wrapping Habits. (2003, June). http://solutions.3mthailand.co.th/3MContentRetrievalAPI/BlobServlet?locale=en_WW&lmd=1253742644000&assetId=1180618676597&assetType=MMM_Image&blobAttribute=ImageFile

This page contains the wrapping paper statistic I refer to in the introduction.

Roodnitsky, M. (2017, October 26). [Google hangouts interview].

I did not know how to solve my area equations because they have 3 independent and 1 dependant variable. Mary is taking Calculus 3 now, where she works with equations in higher dimensions, so I asked her for help. She helped me figure out how to solve my equations, offered to perform the calculations, and introduced me to Geogebra 3d graphing

Procedure

- Creating a crease pattern for the folding methods
  - Find a medium sized box (largest side length should be about 12 in) with fairly sharp corners, where each side is a different length
    - If no box is available, build one with cardboard
  - Record the box's dimensions
  - Wrap the box using the alternate method described by Mei
  - Carefully unwrap
  - Wrap the same box using a different piece of wrapping paper and the method Santos describes
  - Wrap the same box using different piece of wrapping paper and the traditional method described by Gottsegen. This is the control
  - Carefully unwrap
  - Copy the crease patterns into a notebook
    - It does not need to be exact, just close
- Optimizing the crease patterns
  - Label which creases are constrained by box dimensions
  - Re-draw the crease pattern so that all constrained creases are at their minimum length while still covering the box
    - Should be exact and to scale
  - Confirm full that full coverage still exists by trying the new pattern on the box used to create the original patterns
    - If full coverage does not exist, adjust the pattern
  - Find the length and angle of all non-trivial creases and angles.
  - Repeat for the other 2 patterns
- Modeling the crease patterns
  - Sketch out the 3 crease patterns in Autodesk Inventor
  - Re-define all non-trivial folds and angles in terms of initial box dimensions a, b and c, where $a \geq b \geq c$
    - Use the dimensions Biegert came up with as a starting point.
    - Check that the dimensions created by the models line up with the recorded dimensions
  - Put in a few random values for a, b and c to make sure everything is constrained correctly
    - If it not, add or adjust constraints
- Equations
  - Using the re-defined crease lengths, create equations for the area of paper needed for wrapping given a box's dimensions.
    - The answer for traditional method should be $A_{trad} = 2(ab+ac+bc+c^2)$. If it is not, evaluate for mistakes.
  - Calculate $A_{tra\,d}$ - A_{alt} and A_{trad} - A_{sant} using Geogebra 3d calculator.

            - The alternate methods are more efficient than traditional in places where the functions are positive.
                - If it is mostly positive, my hypothesis that alternate is better than traditional is correct
            - Take a picture of the graphs
        - Calculate A_{sant} - A_{alt} using Geogebra.
            - My alternate method is more efficient than Santos's where the function is positive
                - If it is mostly positive, my hypothesis that my method is better than Santos's is correct
            - Take a picture of the graph
- Analysis
    - Solve for where each equation = 0, where each pair of methods use the same amount of paper, to define the inequalities shown by the graphs
    - Record the equations of the resulting inequalities
    - Find the minimums and maximums of each equation
        - If there is a maximum in $A_{tra\ d}$ - A_{alt} where c=0 and a minimum where a=b=c, my hypothesis on what situations the alternate method is better for is correct
    - Record the dimensions and numerical difference in paper usage for these points
    - Plug minima and maxima into the models to determine why one method is better than the other in that situation and what relationship between box dimensions creates that situations

Holly Showalter, my supervisor, is a science teacher, not a math teacher, so she will only be giving me feedback on my grant request and final report.

Mary Roodntsky, a classmate of mine, will assist with calculations because she is currently taking calc 3.

Budget

Item	cost	quantity	Provider
Initial box	0 (can be found or built)	1	[redacted]
Wrapping paper	0 (already have it)	1 small roll	[redacted]
Autodesk Inventor	0 (Free for students)	1	[redacted]
Geogebra	0 (online)	NA	NA

This study requires a box and wrapping paper to create the initial crease patterns with as well as Autodesk Inventor to create the crease pattern models and Geogebra to help analyze the data.

Approval Form (1B)

A completed form is required for each student, including all team members.

1. To Be Completed by Student and Parent

a. Student Acknowledgment:

- I understand the risks and possible dangers to me of the proposed research plan.
- I have read the Intel ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
- I have read and will abide by the following Ethics statement

Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and the Intel ISEF.

Student's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)
[redacted]	[redacted]	11-13-17

b. Parent/Guardian Approval: I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Parent/Guardian's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)
[redacted]	[redacted]	11-13-17

2. To be completed by the local or affiliated Fair SRC

(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. Required for projects that need prior SRC/IRB approval BEFORE experimentation (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/ Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

SRC/IRB Chair's Printed Name

Signature

Date of Approval (mm/dd/yy) (Must be prior to experimentation.)

OR

b. Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval.

This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the Intel ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

SRC Chair's Printed Name

Signature

Date of Approval (mm/dd/yy)

3. Final Intel ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair
I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all Intel ISEF Rules.

Regional SRC Chair's Printed Name	Signature	Date of Approval
State/National SRC Chair's Printed Name *(where applicable)*	Signature	Date of Approval

Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: [redacted] Grade: 12

   Email: [redacted] Phone: [redacted]

   b. Team Member: ______ c. Team Member: ______

2. Title of Project:

   An Analysis of More Efficient Metods of wrapping presents

3. School: [redacted] School Phone: [redacted]

   School Address: [redacted]

4. Adult Sponsor: [redacted] Phone/Email: [redacted]

5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes ☒ No Tentative start date: 12-15-2017

6. Is this a continuation/progression from a previous year? ☐ Yes ☒ No

   If Yes:

   a. Attach the previous year's ☐ Abstract **and** ☐ Research Plan/Project Summary

   b. Explain how this project is new and different from previous years on ☐ Continuation/Research Progression Form (7)

7. This year's laboratory experiment/data collection:

   12-15-2017 — Actual Start Date: (mm/dd/yy)

   1-15-2018 — End Date: (mm/dd/yy)

8. Where will you conduct your experimentation? (check all that apply)

   ☐ Research Institution ☒ School ☐ Field ☐ Home ☐ Other: ______

9. List name and address of all non-home and non-school work site(s):

   Name: ______ ______

   Address: ______ ______

   ______ ______

   Phone/email ______ ______

10. **Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions and attach to this form.**

11. **An abstract is required for all projects after experimentation.**

Checklist for Adult Sponsor (1)

This completed form is required for ALL projects.

To be completed by the Adult Sponsor in collaboration with the student researcher(s):

Student's Name(s): [redacted]

Project Title: An Analysis of More Efficient Methods of wrapping presents

1. [x] I have reviewed the Intel ISEF Rules and Guidelines.

2. [x] I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.

3. [x] I have worked with the student and we have discussed the possible risks involved in the project.

4. [ ] The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:

NA

- [ ] Humans
- [ ] Vertebrate Animals

Potentially Hazardous Biological Agents

- [ ] Microorganisms
- [ ] rDNA
- [ ] Tissues

5. [ ] Items to be completed for **ALL PROJECTS**

- [ ] Adult Sponsor Checklist (1)
- [x] Student Checklist (1A)
- [x] Research Plan/Project Summary
- [ ] Approval Form (1B)
  - [ ] Regulated Research Institutional/Industrial Setting Form (1C) (when applicable; after completed experiment)
  - [ ] Continuation/Research Progression Form (7) (when applicable)

Additional forms required if the project includes the use of one or more of the following (check all that apply):

- [ ] **Humans,** including student designed inventions/prototypes. (Requires prior approval by an Institutional Review Board (IRB); see full text of the rules.)

NA

  - [ ] Human Participants Form (4) or appropriate Institutional IRB documentation
  - [ ] Sample of Informed Consent Form (when applicable and/or required by the IRB)
  - [ ] Qualified Scientist Form (2) (when applicable and/or required by the IRB)

- [ ] **Vertebrate Animals** (Requires prior approval, see full text of the rules.)

NA

  - [ ] Vertebrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required.)
  - [ ] Vertebrate Animal Form (5B) - for projects conducted at a Regulated Research Institution. (Institutional Animal Care and Use Committee (IACUC) approval required prior experimentation.)
  - [ ] Qualified Scientist Form (2) (Required for all vertebrate animal projects at a regulated research site or when applicable)

- [ ] **Potentially Hazardous Biological Agents** (Requires prior approval by SRC, IACUC or Institutional Biosafety Committee (IBC), see full text of the rules.)

NA

  - [ ] Potentially Hazardous Biological Agents Risk Assessment Form (6A)
  - [ ] Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.
  - [ ] Qualified Scientist Form (2) (when applicable)
  - [ ] The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protists, archae and similar microorganisms, for projects using manure for composting, fuel production or other non-culturing experiments, projects using color change coliform water test kits, microbial fuel cells, and projects involving decomposing vertebrate organisms.

NA

- [ ] **Hazardous Chemicals, Activities and Devices** (No SRC prior approval required, see full text of the rules.)
  - [ ] Risk Assessment Form (3) (have up with potentially hazardous biological agents.)
  - [ ] Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

[redacted] — Adult Sponsor's Printed Name

[redacted] — Signature [redacted]

1-13-17 — Date of Review

[redacted] — Phone

[redacted] — Email