Magic : The Sortering

Team 24

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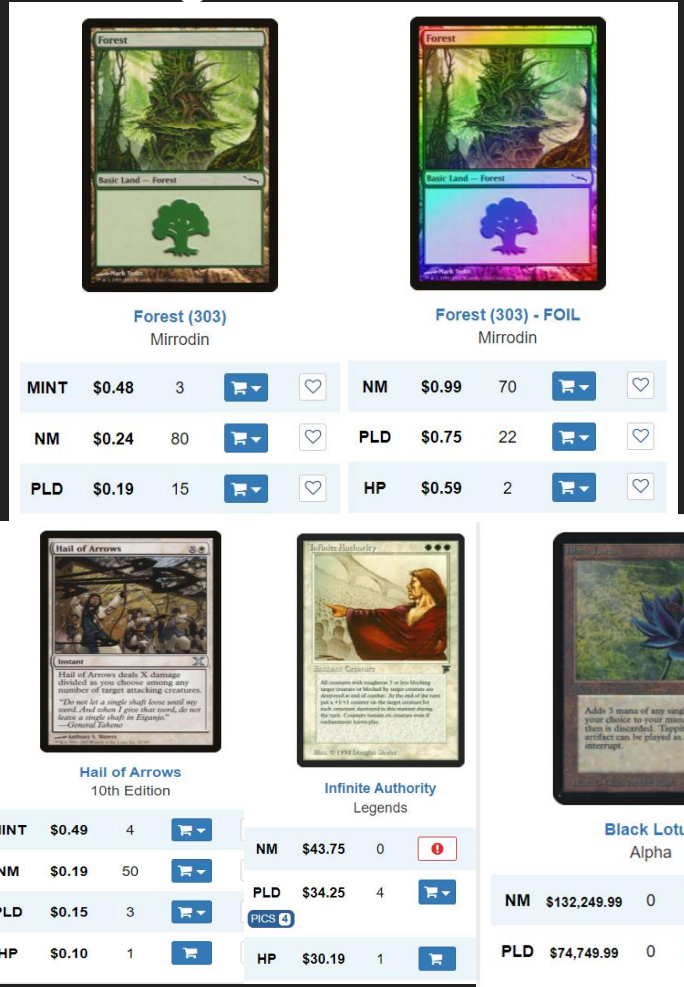
Background: Secondhand *Magic: The Gathering* cards market

Magic: The Gathering is a trading card game, where players collect cards and combine them into decks to play against each other, or simply collect for rarity (like baseball cards).

The Secondhand market for *Magic* cards is extensive [1].

The value of a given card is determined by its condition and rarity.

How is this condition determined and measured?



Background: *Magic* card condition rating

There are two major, complementary systems for analyzing card condition. Both are fairly inconsistent & subjective, though there are specific guidelines for each:

Qualitative [2]

- Mint: Almost no wear whatsoever
- Near Mint: Very little wear
- Lightly Played: Limited wear
- Moderately Played: Worn
- Heavily Played: Very worn
- Damaged: Worthless
- Cards that have been altered (e.g. signed) are generally not given a condition rating

Quantitative [3]

- 1-10 scale either on the card as a whole or on its individual parts (edges, surface, etc).
- May be mapped to a corresponding qualitative rating.
- Typically used by professional rating services.

Problem Statement

- Reselling lots of cheap cards has large returns, but is expensive and annoying to sort, especially when grading and checking for forgeries is involved.
- Solutions exist, but they’re not good enough, as they only do card ID.
- We’ll make a device that does everything needed.

Magic card sorters: *Roca Robotics*

User sets sorting criteria, including price (extracted from TCGplayer.com database)

Automatically fills spreadsheet with information about cards in each section [4]

Does NOT analyze quality

Price unpublished, suggested to be ~$25,000

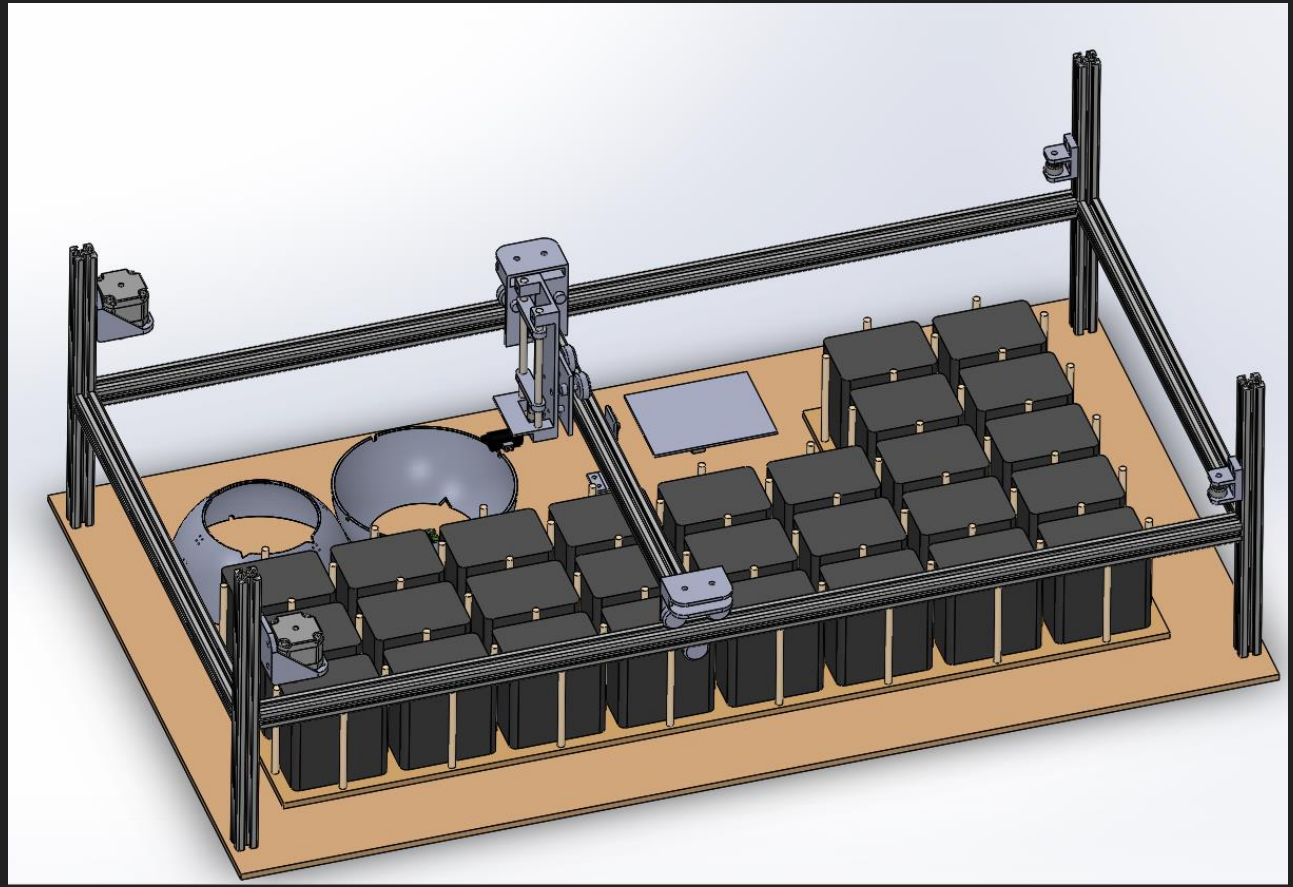
1000 cards in 2 hours (8.3 cards per minute)

Project Implications: Pick and place style is slow. Automatic cataloguing and user configuration is desirable. Clearly demand for this sort of device is high if stores will buy such an expensive, slow machine.

System Specifications and Verification

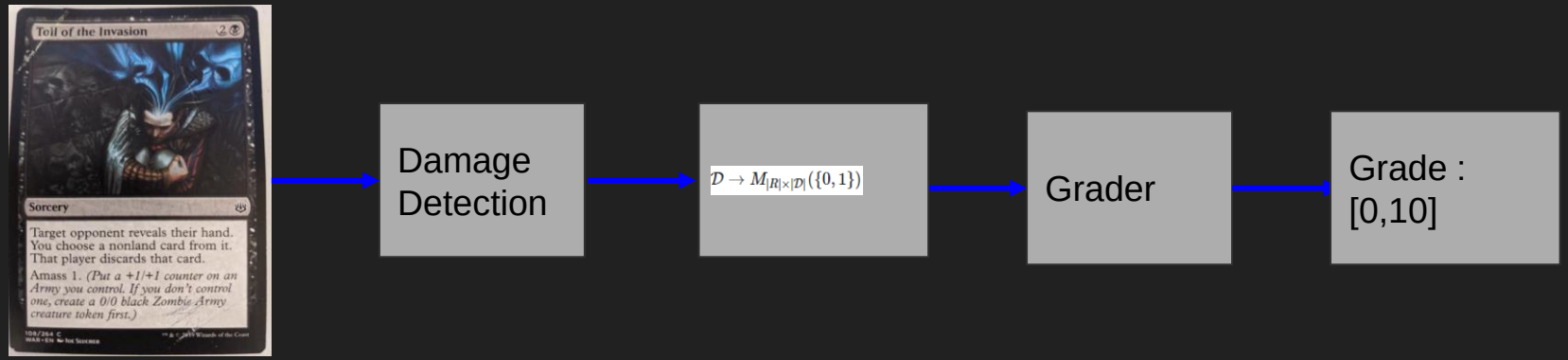
Item	Description/spec	Test Plan/Verification
Card Throughput	>5 cards/min, >1000 card capacity	Basic verification of speed and capacity.
Card Condition Grading	Catch signs of damage. Provide a valid grading based on that damage.	Demonstrate that solution identifies all damage visible to the human eye. Demonstrate that grading generally agrees with TCGPlayer guide.
Card ID	Machine must find the name of card as well as the set it comes from. >99% accuracy	Prove with 95% certainty that accuracy is >99%
Forgery Detection	Detect at least certain kinds/styles of fakes, with low false negatives for those kinds.	Input stack of real cards as well as some fakes, and catch more fakes than false positives.
Card Damaging	No noticeable damage to cards.	At first just use visual verification. Can be verified statistically once Card Conditioning fully works.
Jam Detection	System must pause if an anomaly occurs	Test both cases and make sure system pauses.
Output Bins	Need at least 5 software-configurable output bins	Demonstrate functionality.

Preliminary Design — General



Evaluator — Determining damage and assigning a grade

- Damage on the card needs to be detected for proper grading.
- Damage is considered anything different from the cards best condition.
- Our grader will look for:
  - Scratches - Anywhere for paint scratching off to a simple dent
  - Bends - Tearing to simple warping or fraying of edge
- Once damage is detected, map of damage is represented as a binary array which is fed into a grading function.



Evaluator — Testing the idea

- Went to M5 SMT lab, used Lynx Evo in dark setting
- Put damaged card under microscope, moved flashlight across card.
- Preliminary testing reveals that damaged areas has sudden sparkles and shadowing as light moved across.
- A test chamber will be created to confirm results.
- While we are confident in accuracy, computation speed and memory will be a concern.
    - Leaning towards using a single-board computer for image processing

Evaluator — Card Identification

- There are many existing projects that are capable of this with varying levels of accuracy [5]
- Generally accomplished with some form of perceptual hashing
  - Hashes for similar images will have a lower hamming distance than ones that are very different [6]
- Scryfall.com offers easy access to a database of cards with high quality images, making it ideal for this use case [7]
- Early testing has had encouraging results

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Feature Matching to Distinguish Similar Cards

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wrexial_images/wrexial_cmd_bottom.jpg
Good matches: 447
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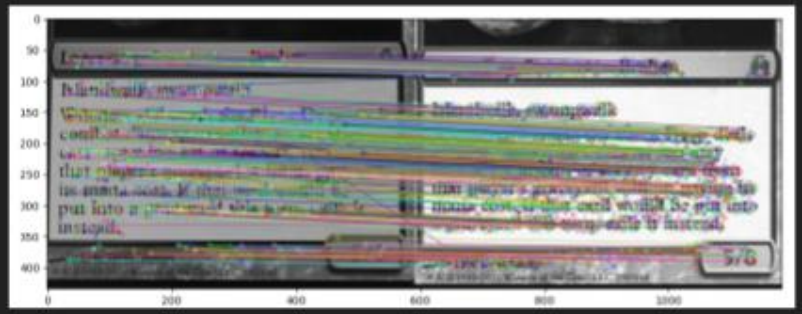

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Good matches: 754
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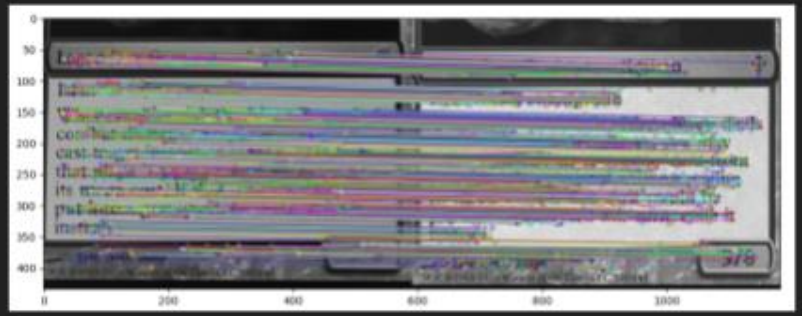

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wrexial_images/wrexial_cm2_bottom.jpg
Good matches: 68
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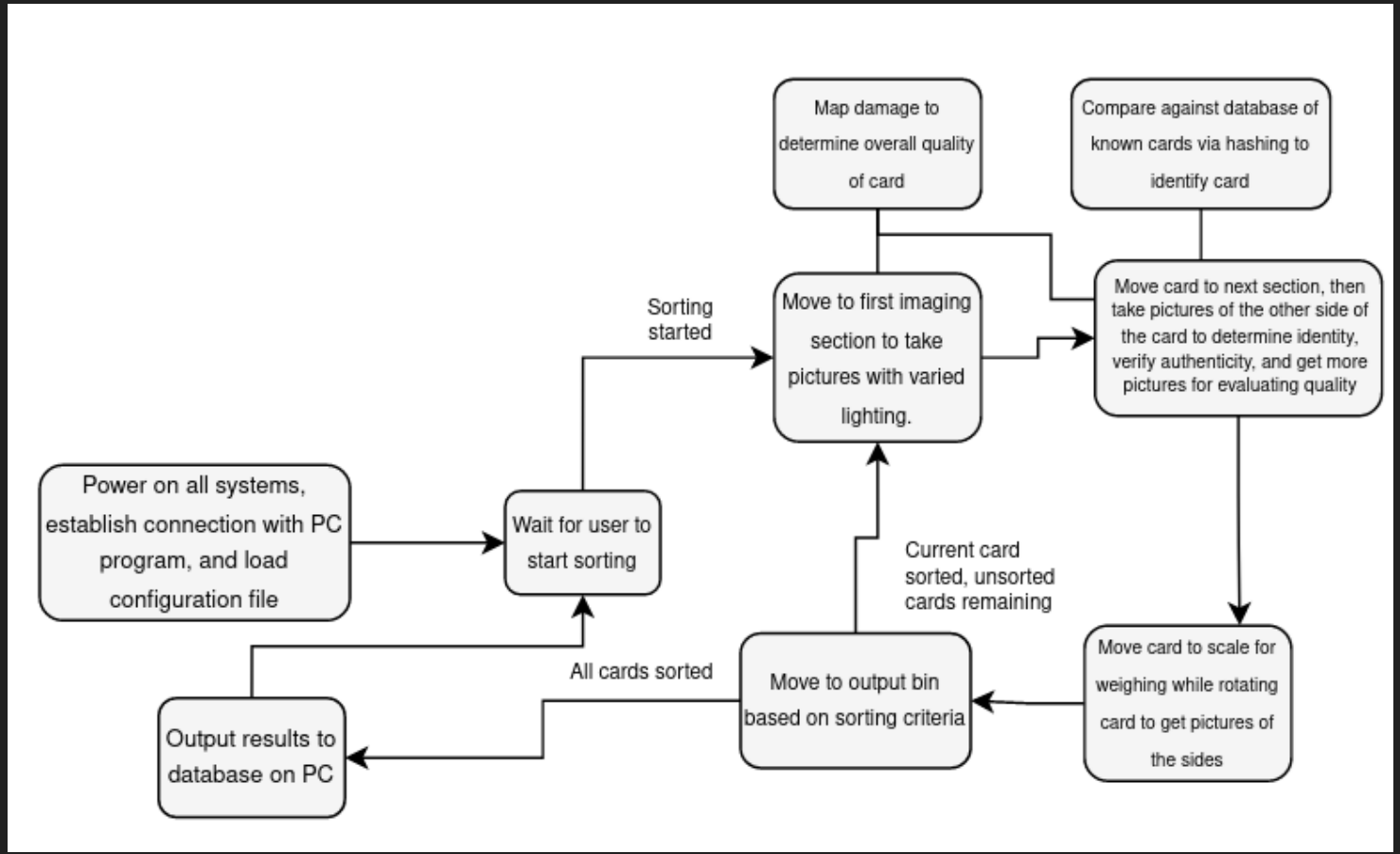
Evaluator — Forgery Detection

- Mass of real card> 1.7g, < 1.8 g
- 4 red dots in white part of green circle on back of card.
- Right amount of glossiness/reflectivity
- Correct print pattern

Software Diagram



MDR Deliverables

- **Mechanical**
  - Gantry system capable of picking up a single card from bins and carrying them to evaluation section.
- **Evaluator**
  - Prototype of visual card sensor that can successfully identify scuffs and damages to a card.
  - Scale that can weigh cards precisely enough to detect forgeries.
  - Prototype of Card ID, that can find the name of a card, as well as the set that it is from.

Project Expenditures

Item	Projected Cost
Early PCB Designs + parts	$60
PCB Design 2	$30
Enclosure & Structure (3D printing a lot)	$70
Gantry & Card handling	$50
Stepper Motors, servos, drivers, etc	$60
Power Supply	$30
Single-board computer	$100
Sensors & Lights	$100
Total	$500

Project Management

- Mechanical Lead - Gantry: Zalman Lipschitz
- Mechanical Lead - Evaluator: Liam Rees
- Software Lead: Malcolm Okaya
- Sensors Lead: Joseph Maloyan
- PCB Lead and Team Coordinator: Henry Powell

Sources

[1] “Singles”, Alpha-Beta-Unlimited. [Online]. Available: https://abugames.com/magic-the-gathering/singles. [Accessed 26-Sep-2021].

[2] “Card Condition Guide,” TCGPlayer. [Online]. Available: https://help.tcgplayer.com/hc/en-us/articles/221430307-How-can-I-tell-what-condition-a-card-is-in-.
[Accessed 26-Sep-2021].

[3] “About Beckett Grading Services”, Beckett. [Online]. Available: https://www.beckett.com/grading/about.
[Accessed 26-Sep-2021].

[4] “Roca - Robotic Card Sorter”, Roca. [Online]. Available: https://www.rocarobotics.com/. [Accessed 26-Sep-2021].

[5] E. Yoo, “mtg_card_detector,” *github.com*. [Online]. Available: https://github.com/hj3yoo/mtg_card_detector. [Accessed 27-Sep-2021].

[6] E. Klinger and D. Starkweather, “pHash,” *phash.org*. [Online]. Available: https://www.phash.org. [Accessed 27-Sep-2021].

[7] Scryfall, LLC., “Scryfall Search Reference.” *Scryfall, LLC*. [Online]. Available: https://scryfall.com/docs/syntax. [Accessed 25-Sept-2021].