
RecycleRight

Capstone Presentation



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Meet the Team



**Summer
McGrogan**



**Annie
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Agenda

Project Overview

Problem, Impact

01

Our Solution

Product Demo, User Journey

02

Technical Deep Dive

Datasets, Model Pipeline, Exploration and Results

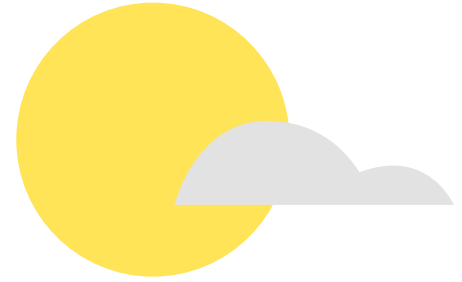
03

Summary

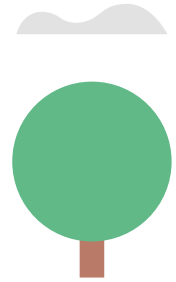
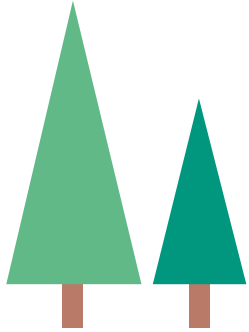
Key Takeaways, Roadmap

04

01



**Project
Overview**



Problem

Recycling confusion is a leading factor in waste being recycled improperly, with many recyclable items ending up in landfills due to improper disposal



Unclear recycling instructions



Variations in recycling guidelines across localities



Perceived complexity

User Recycling Behavior (Survey)

Findings:

- A large majority of people recycle, but are not looking up local information themselves
 - **97%** of users recycle
 - **75%** of users have not seen their local recycling guide
- Average confidence in deciding what to recycle: **3.29/5**
- Level of interest from users surveyed in recycling assistance: **4.4/6**
 - **75%** of users were interested
 - **50%** were interested or very interested

User Recycling Behavior (Survey)

What are people getting wrong about recycling?

- 78% of people said they would throw a detergent jug away
 - Recyclable
- 66% of people said they would throw a hot beverage sleeve away
 - Recyclable
- 44% of people said they would recycle shredded paper
 - Cannot be recycled

Problem: People are making mistakes and need additional help to make correct recycling decisions

Impact



Environmental Protection - Reduces landfill waste, conserves natural resources, lowers pollution, and saves energy by minimizing the need for raw material extraction and production

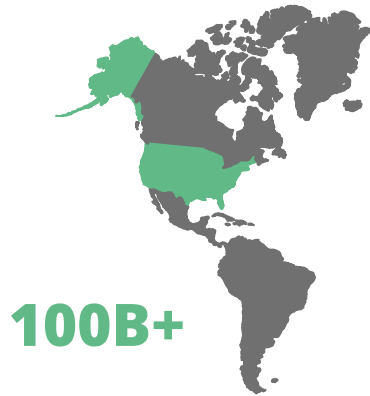


Economic - Saves costs, creates jobs, and supports industries by providing recycled materials, boosting both local and global economies.



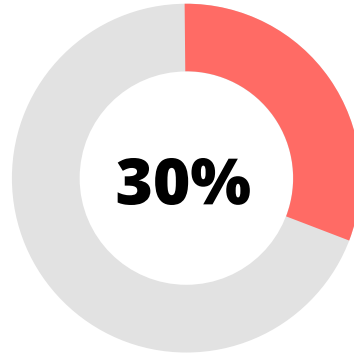
Social & Community - supports climate action, and promotes sustainable development by conserving resources and reducing pollution for future generations.

Impact by the Numbers



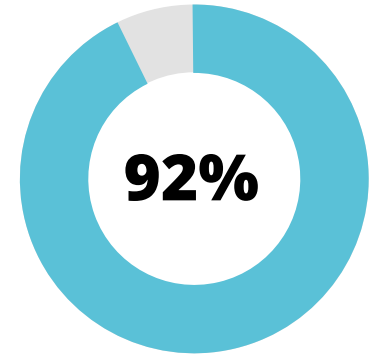
Market Size

The market size of whole selling of recycled material in the US is over \$100 billion.



Current Situation

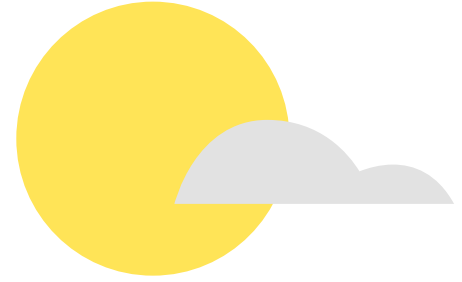
Only 30% of recyclable materials are successfully recycled.



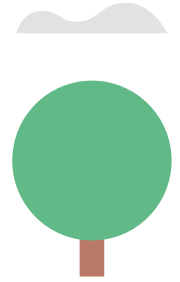
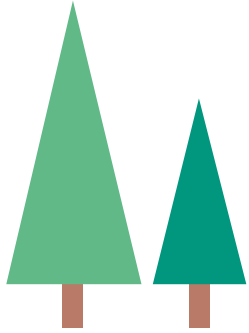
Participation

92% of Americans believe that recycling is important.

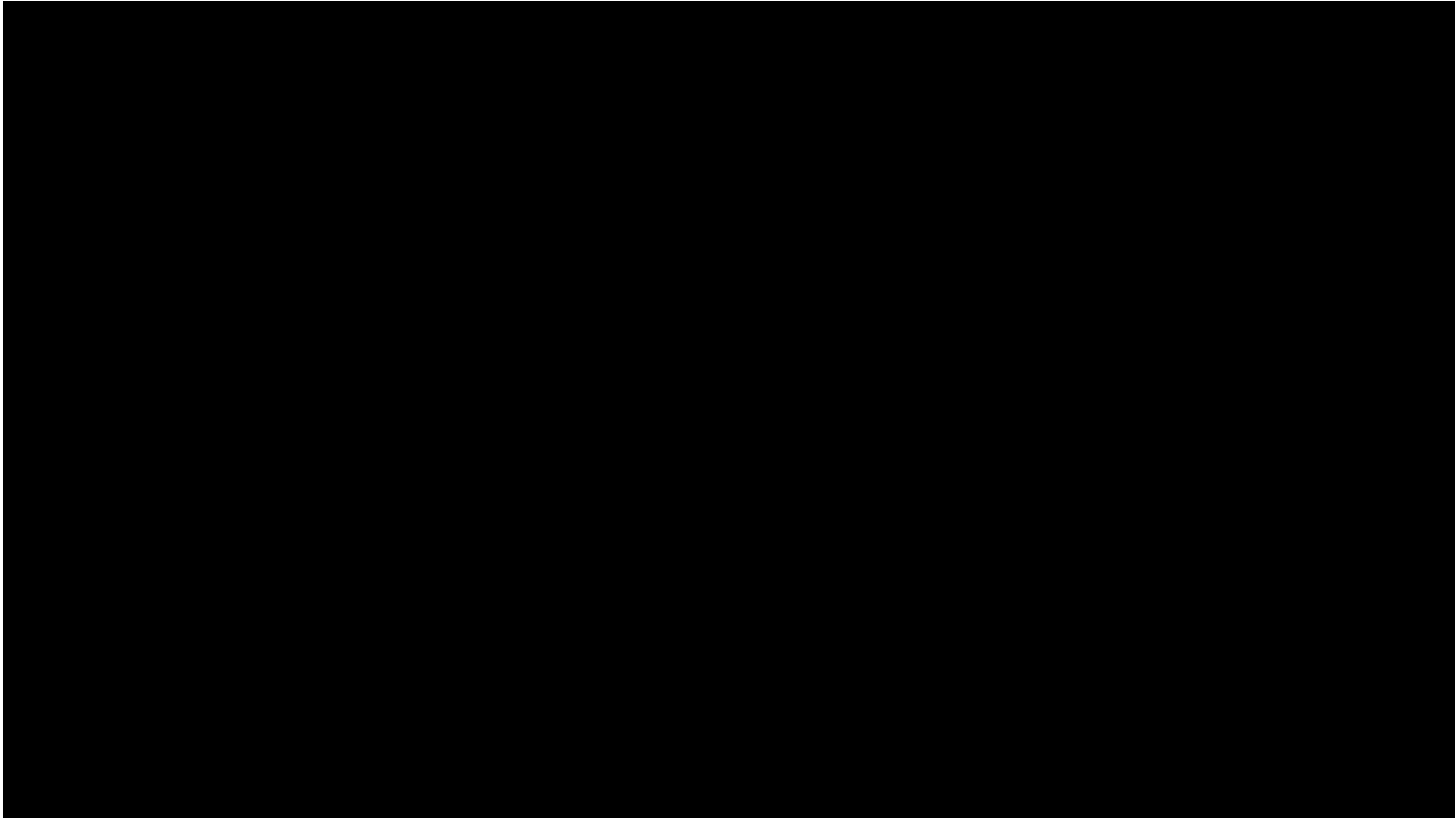
02



Our Solution



MVP Demo



MVP User Journey

Consume an item
with single-use
packaging



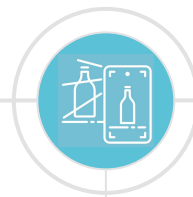
Don't know which bin
the waste item goes to
<11 classes>



Download our app
(first time user)
<web app>



Snap a photo of the item
and upload to the app,
select location
*<location: Cook County,
Palm Desert, Boston>*



Get item type and
recycling instructions

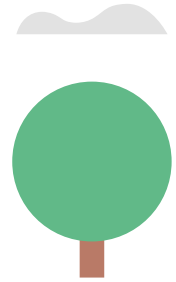
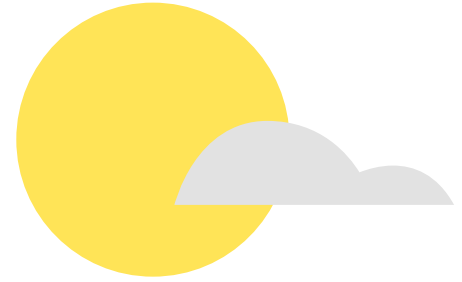
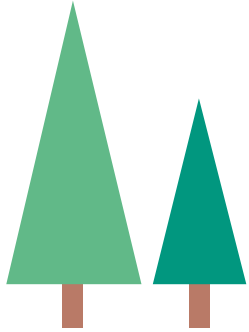


Recycle it
correctly!



03

**Technical
Deep-dive**



Dataset: Train

Recycling Guides:

- Cook County, Illinois
 - Verbose
 - Sentence-based
- Palm Desert, California
 - Concise
 - Bullet list
- Boston
 - List with examples



Portland State: Recyclables

- boxes, glass bottles, soda cans, water bottles
- 300 test per class

Kaggle Dataset: Mixed

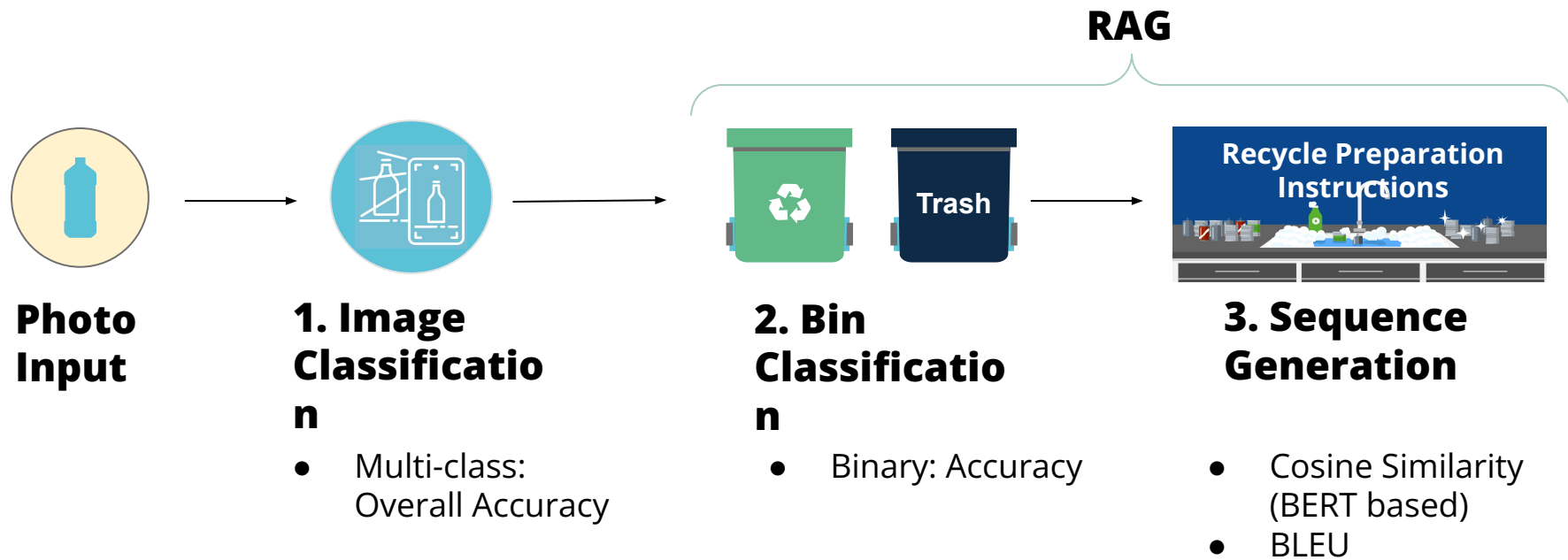
- 30 categories of recyclables and non-recyclables
 - Selected: Aluminum cans, paper cups
- 250 real-world images per class

Dataset: Test

- Did our own data collection with an expanded number of classes
- 4 different light conditions in 84 images
 - Bright natural lighting
 - Bright indoor lighting
 - Dim indoor lighting
 - Dim indoor lighting with flash



Model Pipeline



Model Result: Quantitative (Test)

Model	Stage 1 - Image Classification				Stage 2 - Bin Classification				Stage 3 - Sentence Generation	
	Accuracy	Precision	Recall	F1	Accuracy	Precision	Recall	F1	Cosine Similarity (BERT)	BLEU
Baseline (ResNet)	0.42	0.37	0.42	0.33	N/A					
LLaVA 1.5 (LoRA)	0.48	0.26	0.45	0.30	N/A					
LLaVA 1.5	0.80	0.86	0.82	0.75	0.98	1.00	0.93	0.61	0.52	0.22
LLaMA 3.2	0.61	0.71	0.61	0.61	1.00	1.00	1.00	1.00	0.82	0.06

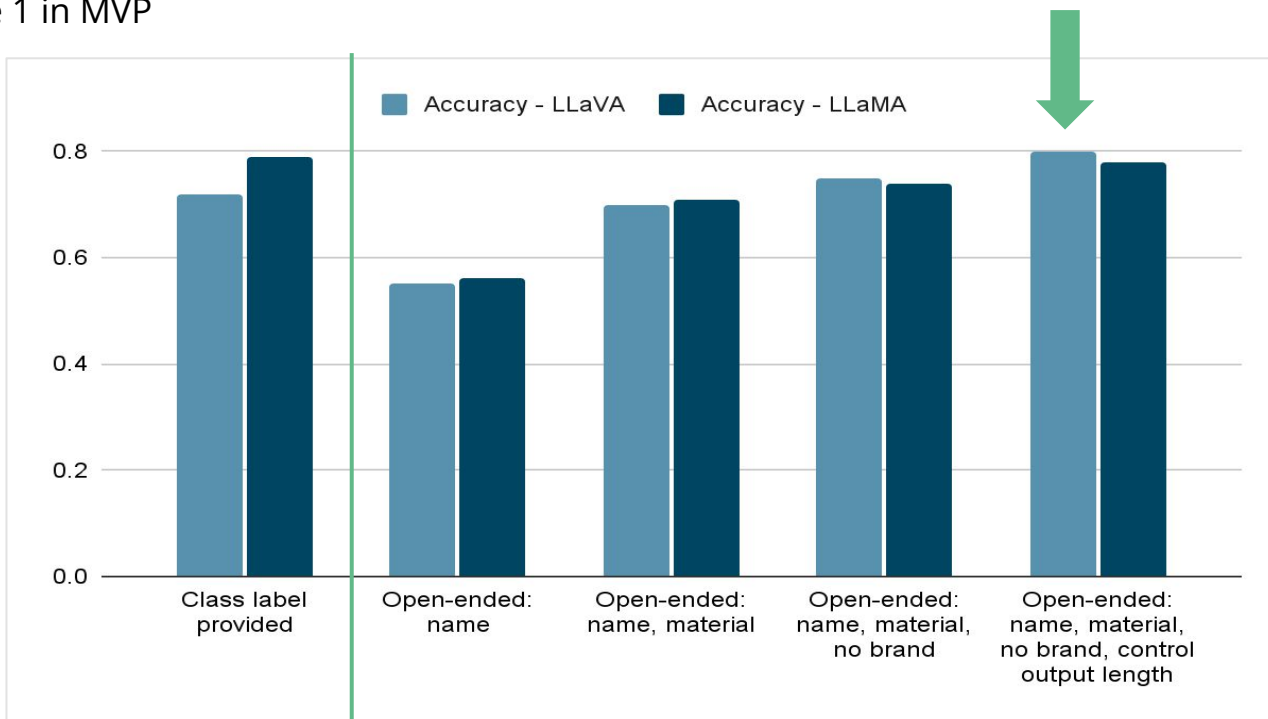
Model Result: Qualitative (Test)

Model	Stage 3 - Sentence Generation		
	Relevancy	Fluidity	Coherence
LLaVA 1.5	3.95/5	4.56/5	4.46/5
LLaMA 3.2	3.49/5	4.81/5	4.71/5

Findings: Sentences included accurate details but would sometimes add unnecessary steps that creates vagueness

Experimentation: Prompt Eng

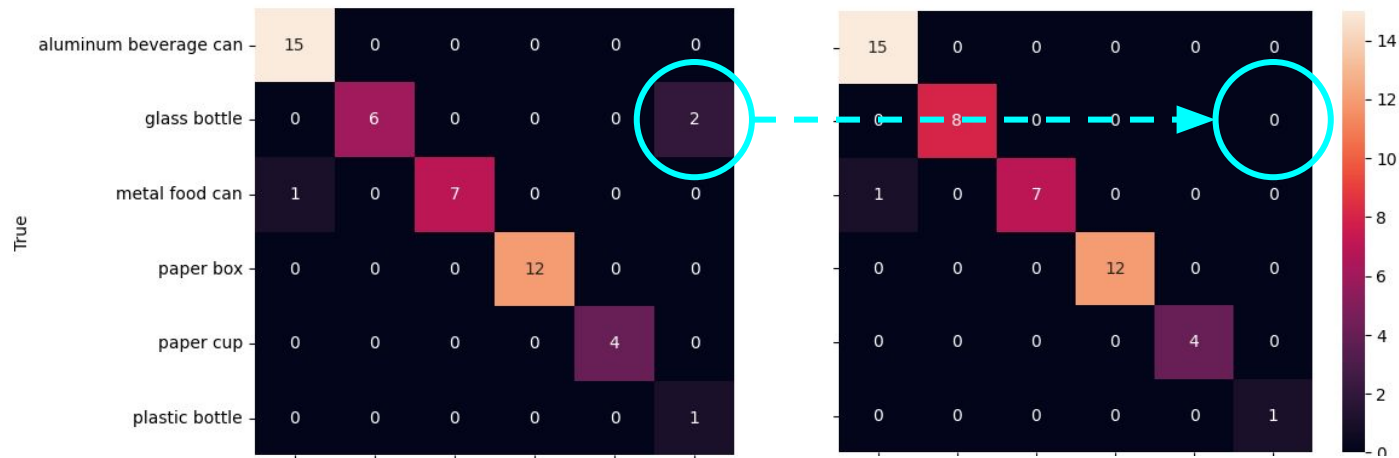
Decision: Use LLaVA with open-ended prompt (name, material, no brand, control output length) for Stage 1 in MVP



Experimentation: Fine Tuning

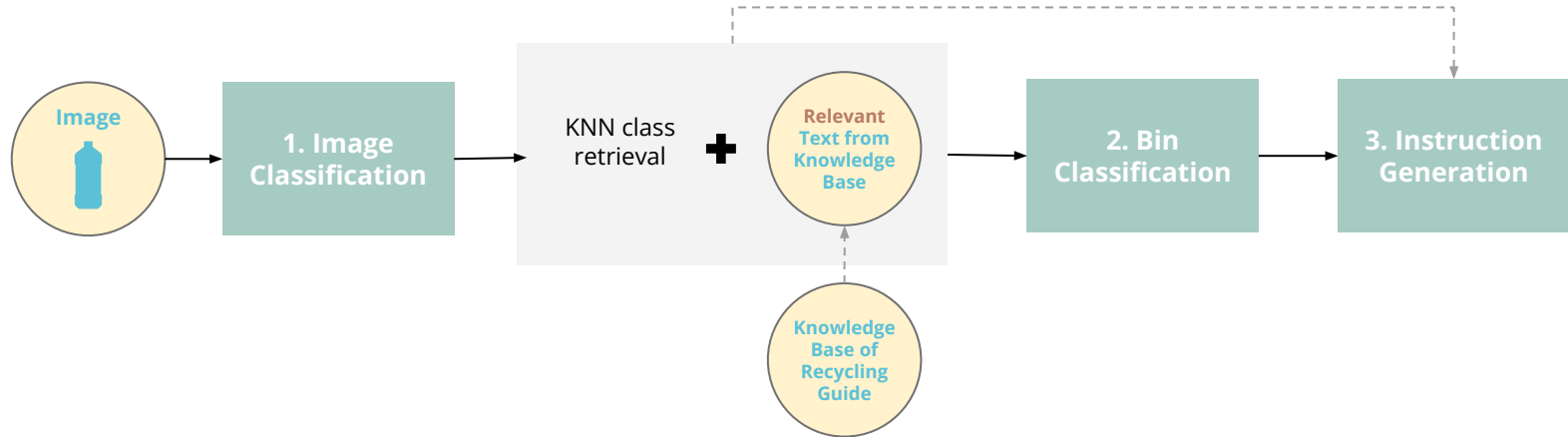
- ✓ Improves accuracy & output format on 6 classes, able to distinguish glass vs plastic bottle
- ✗ Does not generalise well on unseen classes / with open-ended prompt

Decision: Not to use fine-tuned LLaVA model for Stage 1 in MVP

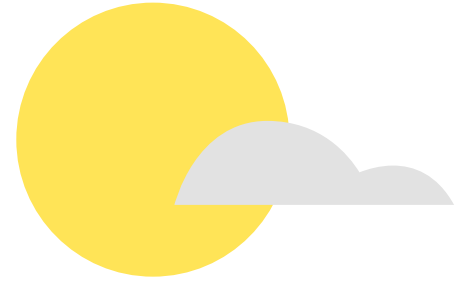


Experimentation: RAG

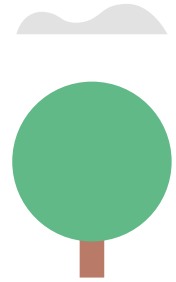
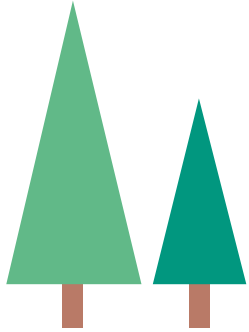
- Knowledge base of recycling instructions for different locations and materials
- Embedding-based retrieval of the most relevant recycling instructions from knowledge base
- Input relevant text to stage 2 & 3 to improve quality of output



04



Summary



Key Technical Takeaways

1. **End-to-End Challenge:** No single model can tackle whole pipeline
 - Multi-stage model approach
2. **Bin Classification Challenge:** Model is retrieving incorrect information from pre-training and running out of context window space for longer guides
 - Used embedding-based retrieval to shorten the size of the context window on large recycling guides and improve accuracy of recycling instructions
3. **Text Generation Challenge:** Models cannot handle negative case
 - Implemented threshold value in embedding retrieval

Roadmap Items



1. Implement RAG with traditional vector store approach using LangChain
2. Extend infrastructure to accommodate use of the best performing model for different stages
3. To fine-tune models for stage 2 & 3, since it worked well in adjusting the tone and format of output

**Together we can
save time,
reduce waste
and protect the
environment!**

RecycleRight



Appendix

Recycling Pain Point

Berkeley, CA

No:

- Food-soiled paper or cardboard (e.g., pizza boxes, greasy paper bags), plastic-lined paper (e.g. milk cartons, paper cups, aseptic soy milk cartons), plastic, glass, metal, food, liquids

Example: Some places say you can recycle coated paper cartons and in others you can't

Oregon

Coffee cups and restaurant take-out boxes

Why it doesn't belong

To-go coffee cups and other to-go food containers are not accepted in recycling programs, because they are coated with plastic or wax that makes it difficult to separate from paper in the recycling process. These items should be put in the garbage.

Palm Desert, CA

What Items Can Be Recycled

Paper

- White and colored paper
- Phone books
- Magazines
- Junk Mail
- Envelopes
- File folders
- Cardboard (flattened)
- Cartons (milk, juice, & broth)
- Books (remove hard covers or binding)
- Cardboard boxes, e.g. cereal, etc.

Plastic

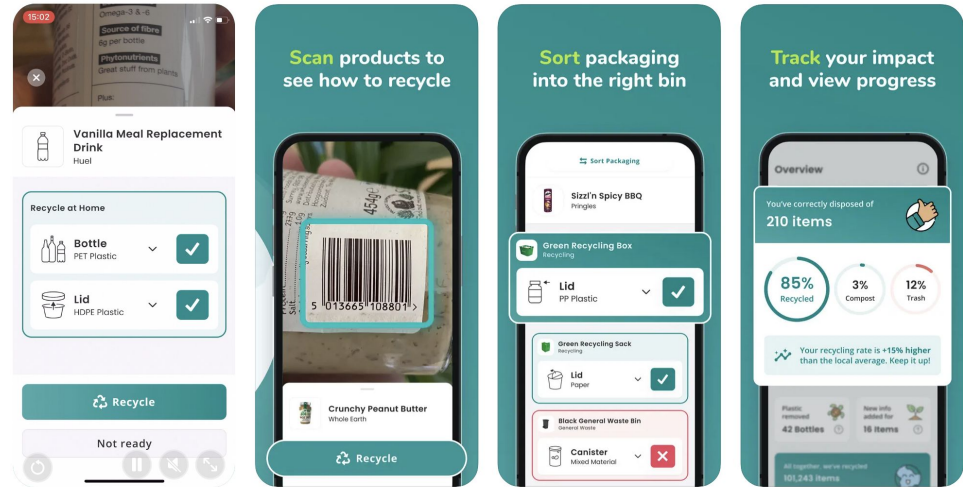
- Styrofoam packing blocks
- Plastic medicine bottles (empty)
- Plastic bottles numbered 1-7 (remove plastic film or wrap)

Metal & Glass

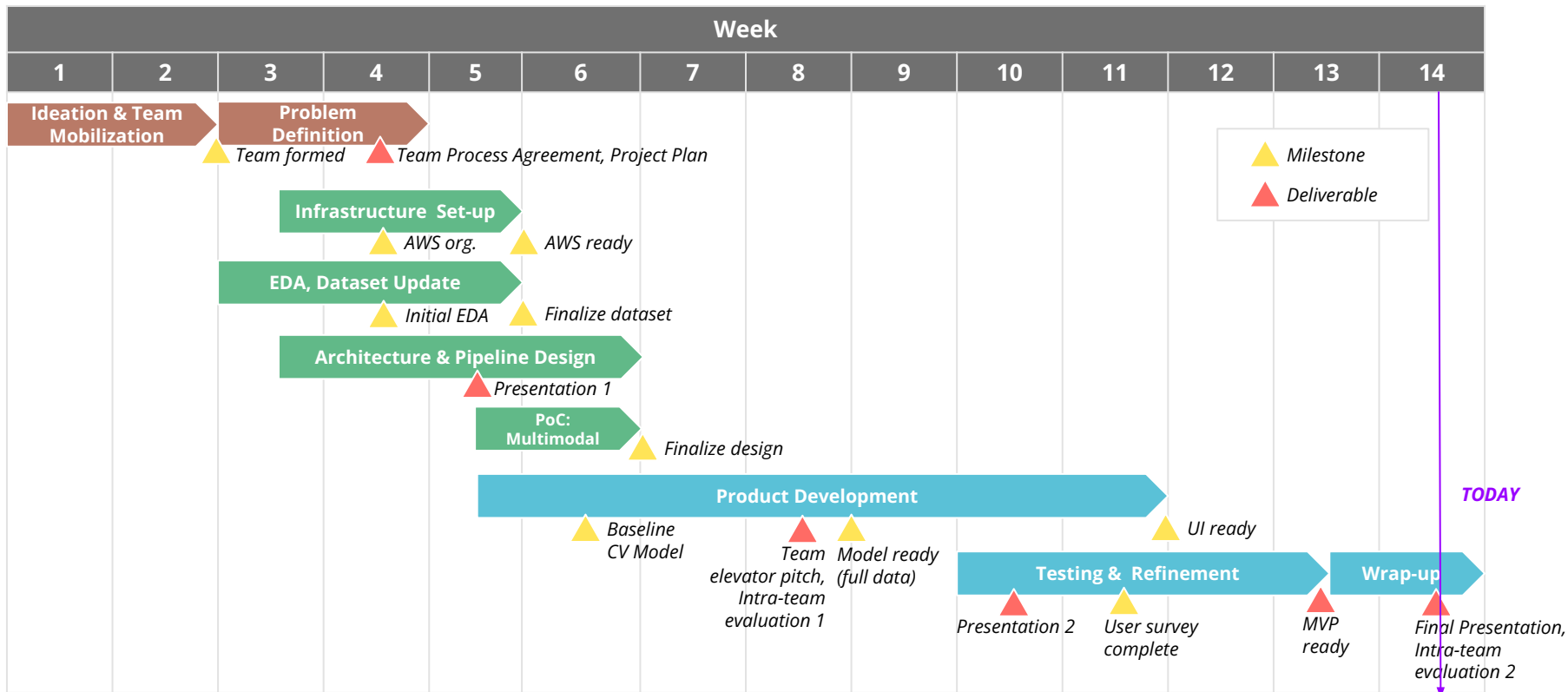
- Aluminum, steel, and tin cans
- Clean aluminum foil
- Glass bottles and jars (remove lids)

Market Analysis: Competitor

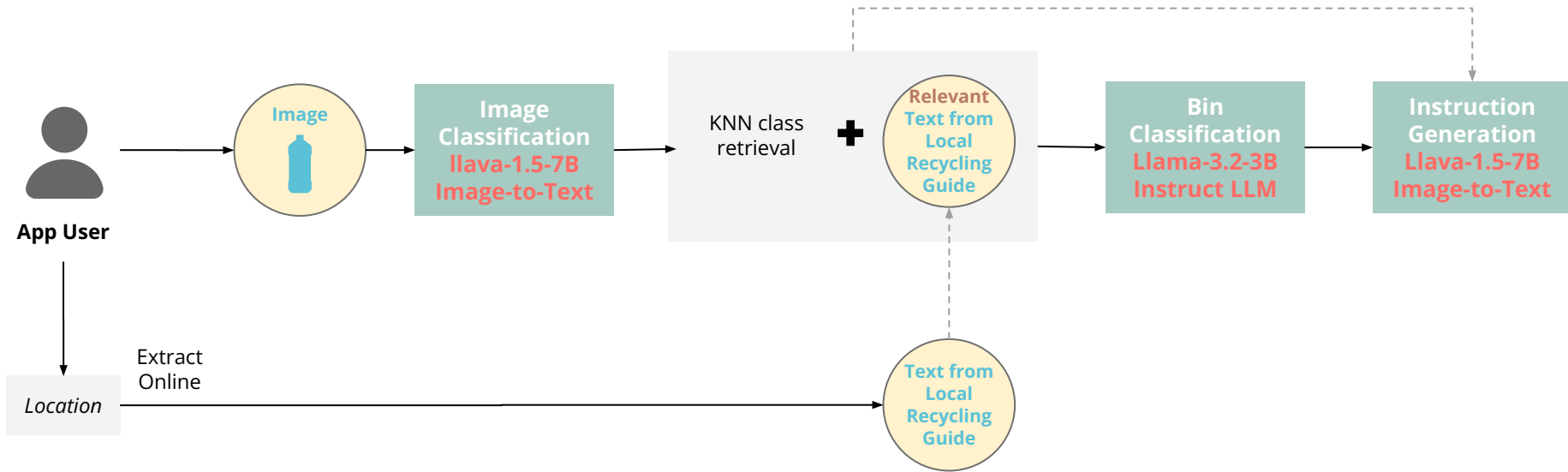
- Most are text-based apps that do not allow you to upload own photos of trash
- Biggest competitor (Scrapp) has photo-based and region-based solution
 - 6 states
 - No alternative for missing / faded barcode



Project Management Plan

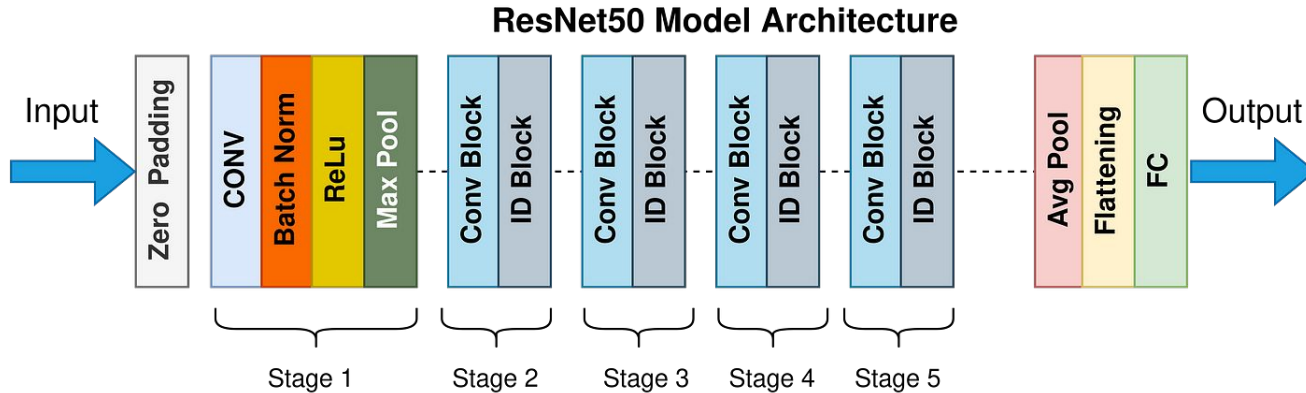


MVP: Solution & Data Flow



Model Result: Baseline

- ResNet50
- Utilize image classification to directly map to the bin classification and sentence output



Model Result: LLaVA

1. Stage 1: Item classification

LLaVA - Stage 1	
Accuracy	0.88
Precision	0.80
Recall	0.59
F-1	0.60

Model Result: LLaVA

2. Stage 2: Bin classification

LLaVA - Stage 2	
Accuracy	0.77

3. Sentence Generation

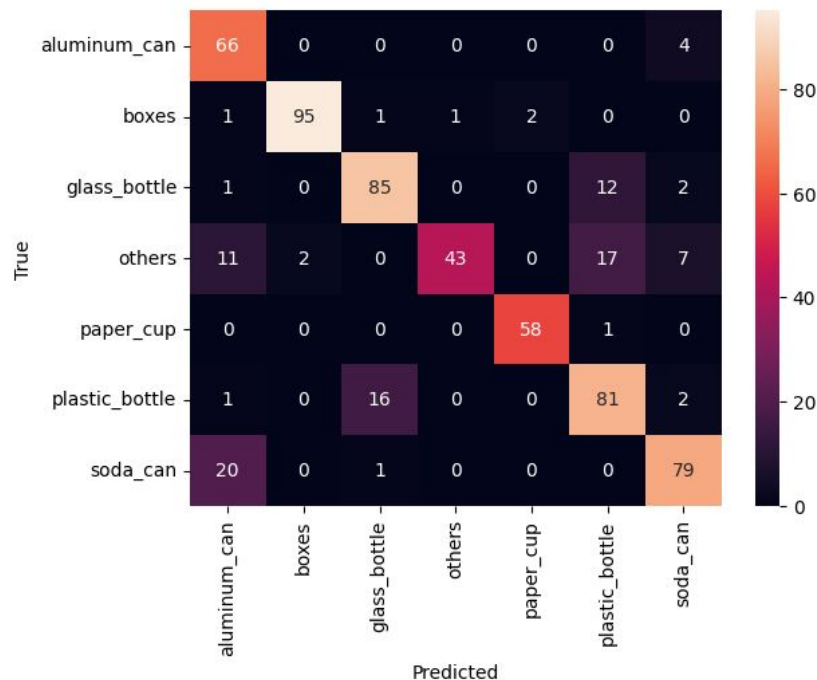
Sample Output: The image shows a box of cereal, which is made of cardboard. Cardboard is a type of paperboard and can be recycled. To recycle the cardboard box, it should be placed in the recycling bin along with other paperboard materials. After collection, the cardboard is processed and transformed into new products, such as cardboard boxes for cereal or other packaging materials.

LLaVA - Stage 3	
Cosine Similarity	0.52
BLEU	0.22

Model Result: LLaMA 3.2

1. Item Classification

LLaMA - Stage 1	
Accuracy	0.83
Precision	0.85
Recall	0.84
F-1	0.83



Model Result: LLaMa 3.2

2. Bin Classification

LLaMA - Stage 2	
Accuracy	0.64

3. Sequence Generation

- Sample Output: For glass_bottle, rinse and dry thoroughly before recycling. Do not bag or wrap items; keep them loose in the bin for easy sorting.

LLaMA - Stage 3	
Cosine Similarity	0.83
BLEU	0.24

Ethics & Data Privacy

User Privacy

- Stored info: Location
- Sensitive/private information in background of photos

Consequences of Misclassification

Negative environmental impact of Type I and Type II errors

