AI for Efficient Routing of Customer Inquiries at Mercari

Prashant Anand

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- Working in the Customer Support domain
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Takeaways

01 Translate business problem to ML one

02 Solving the ML problem using NLP and Python

03 Insights into the routing of customer inquiries

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Table of Contents

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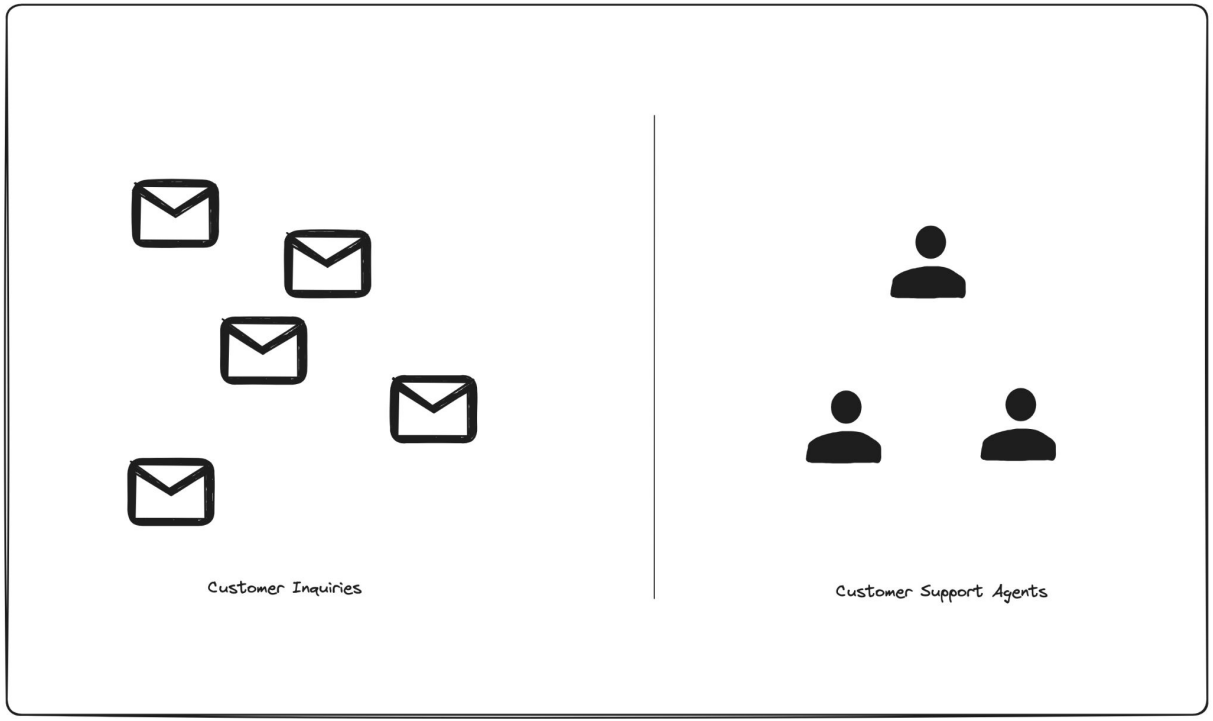
01

Understanding the business problem

Routing Customer Inquiries



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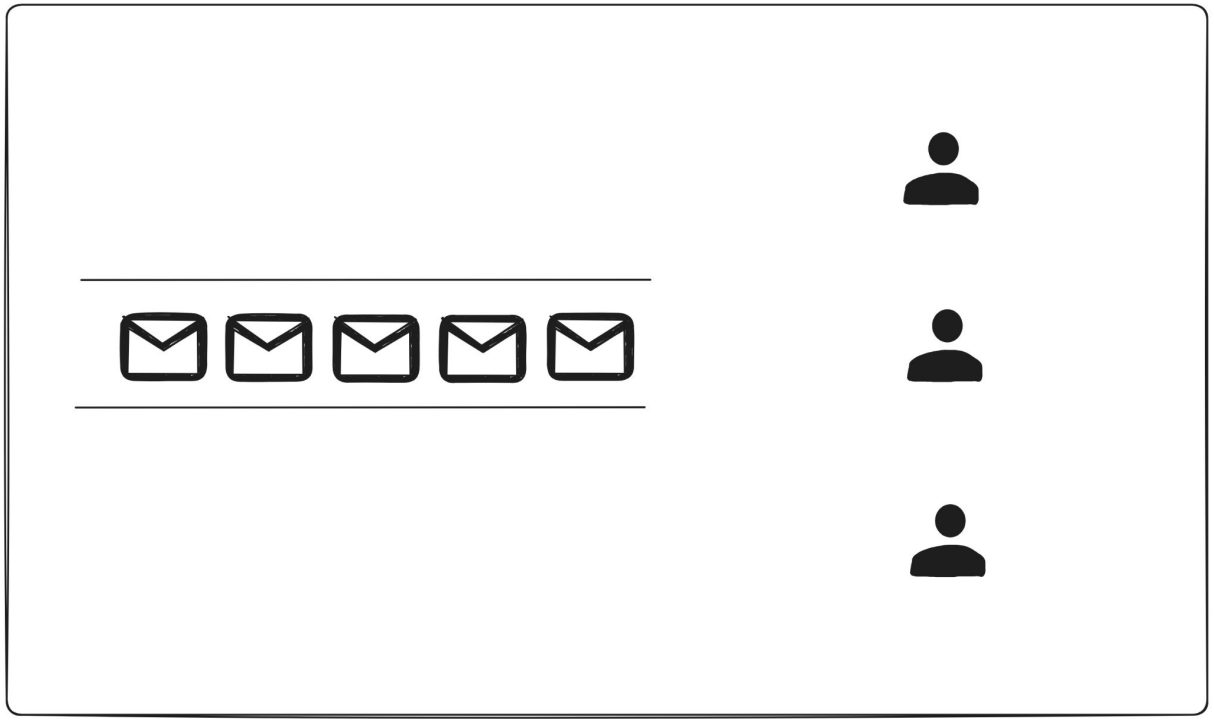

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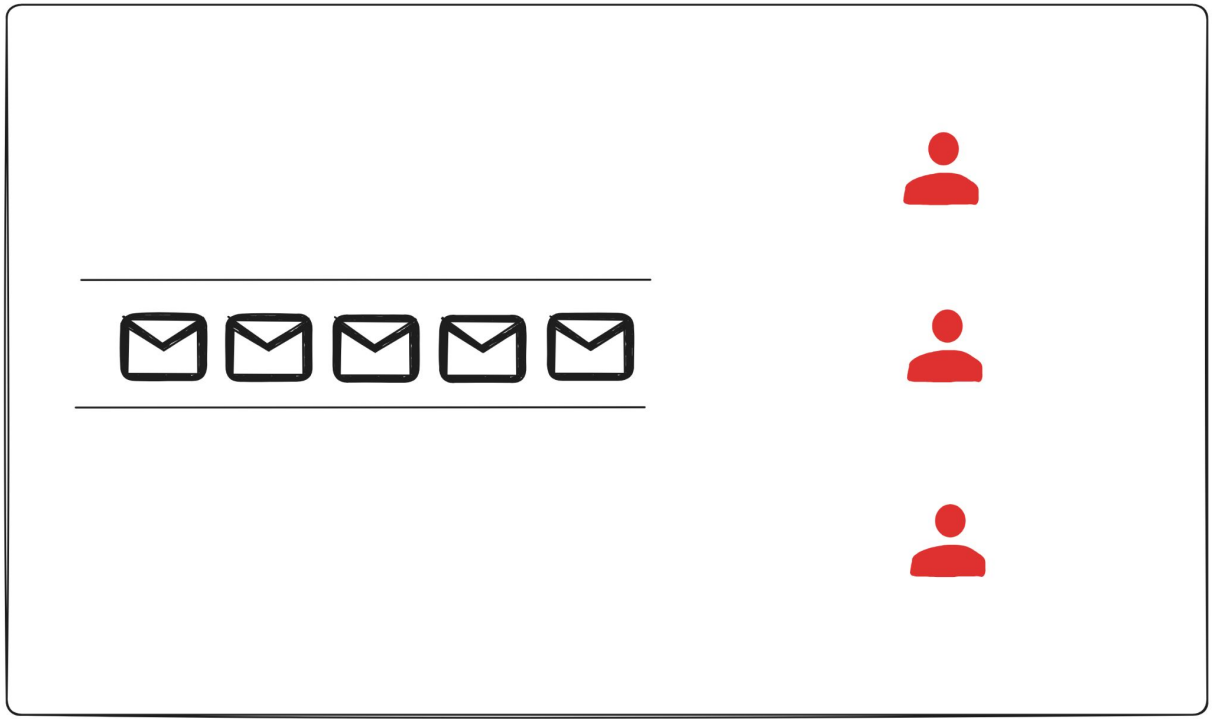

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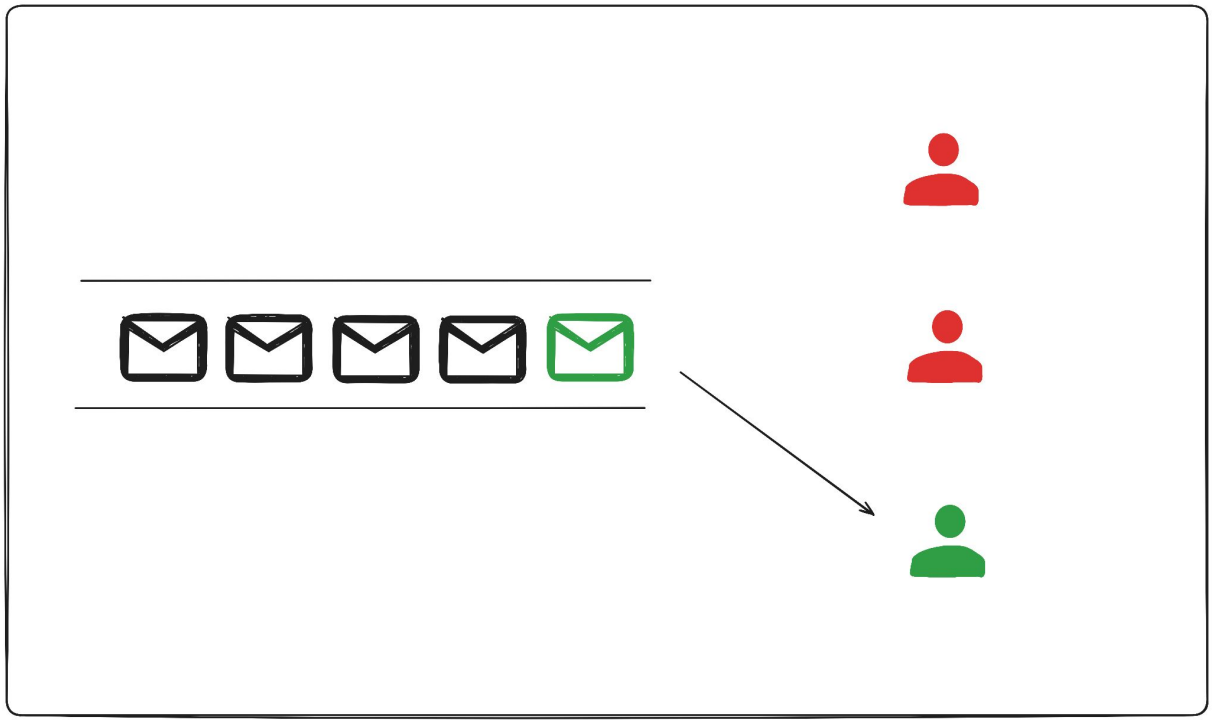

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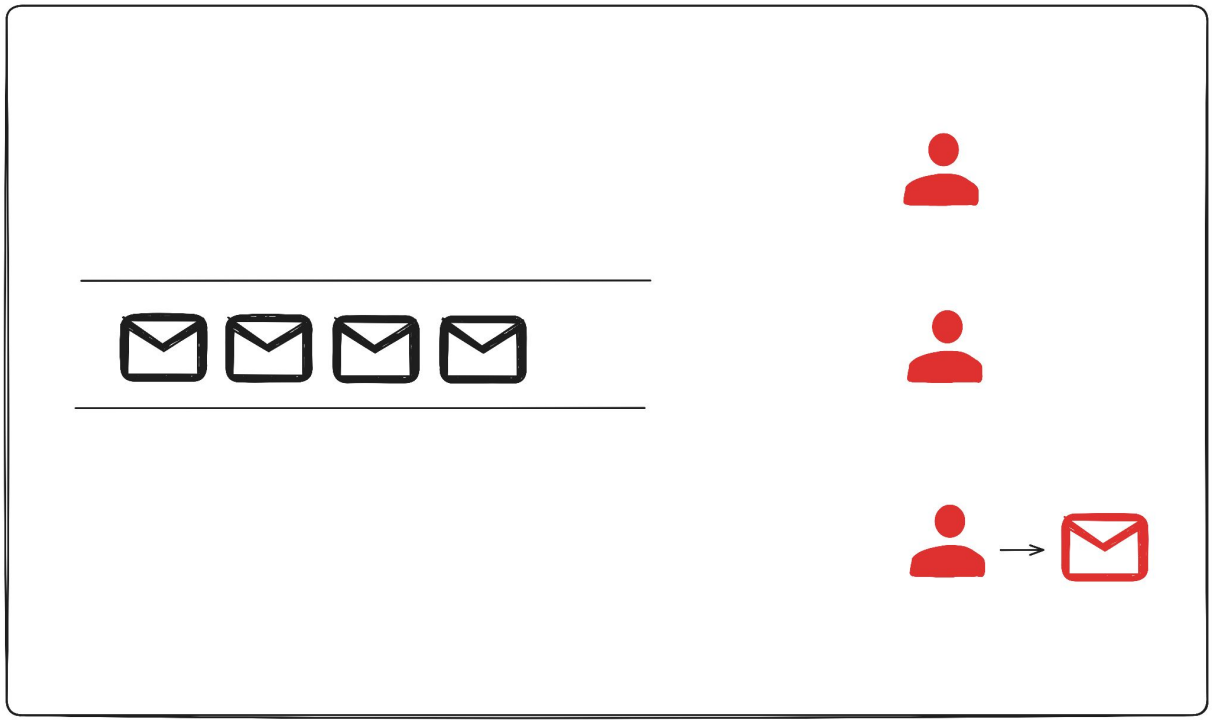

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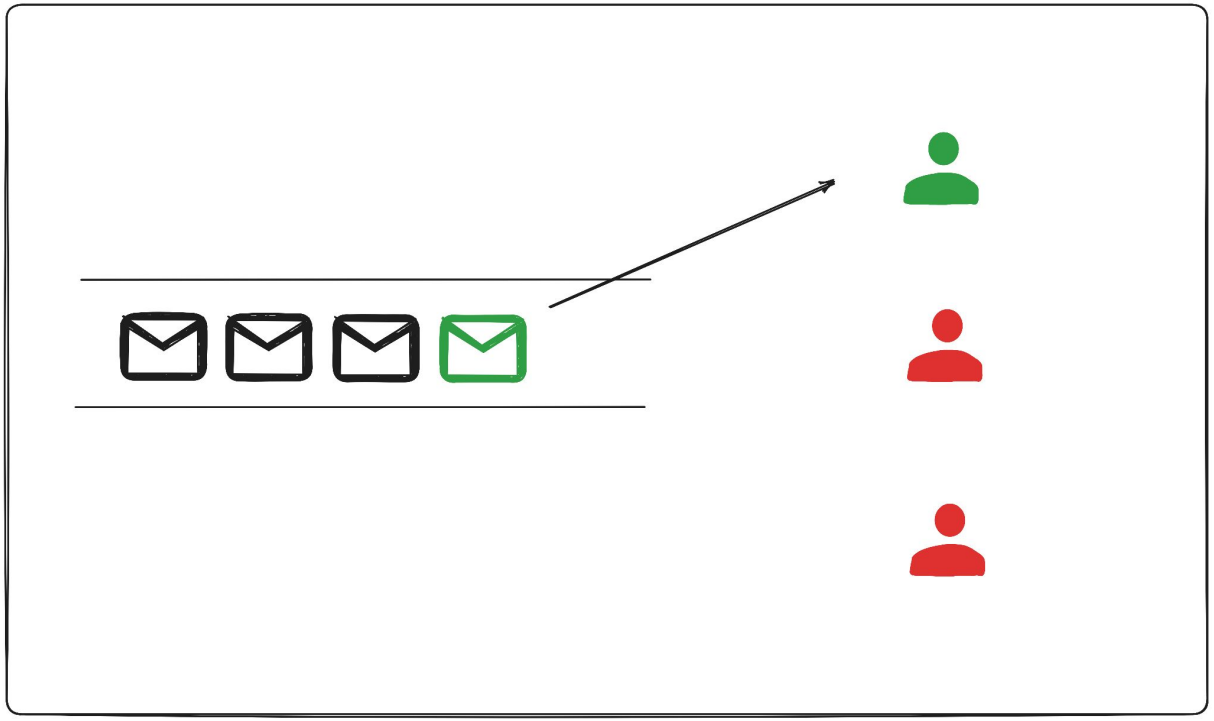
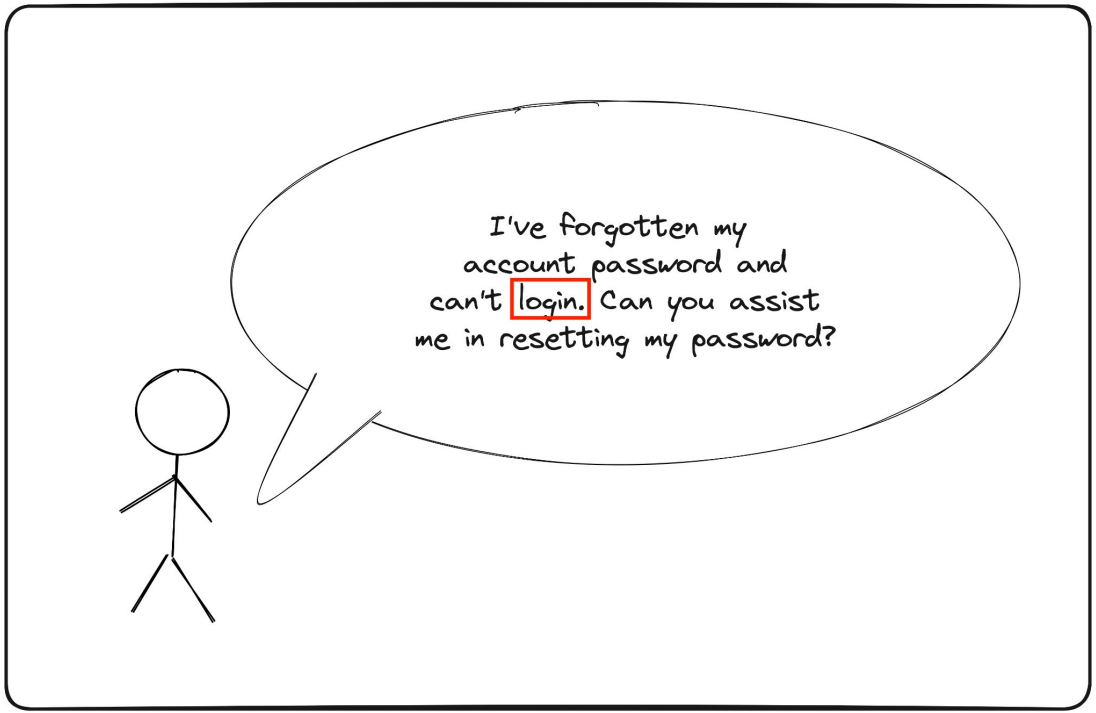


Sample Inquiries



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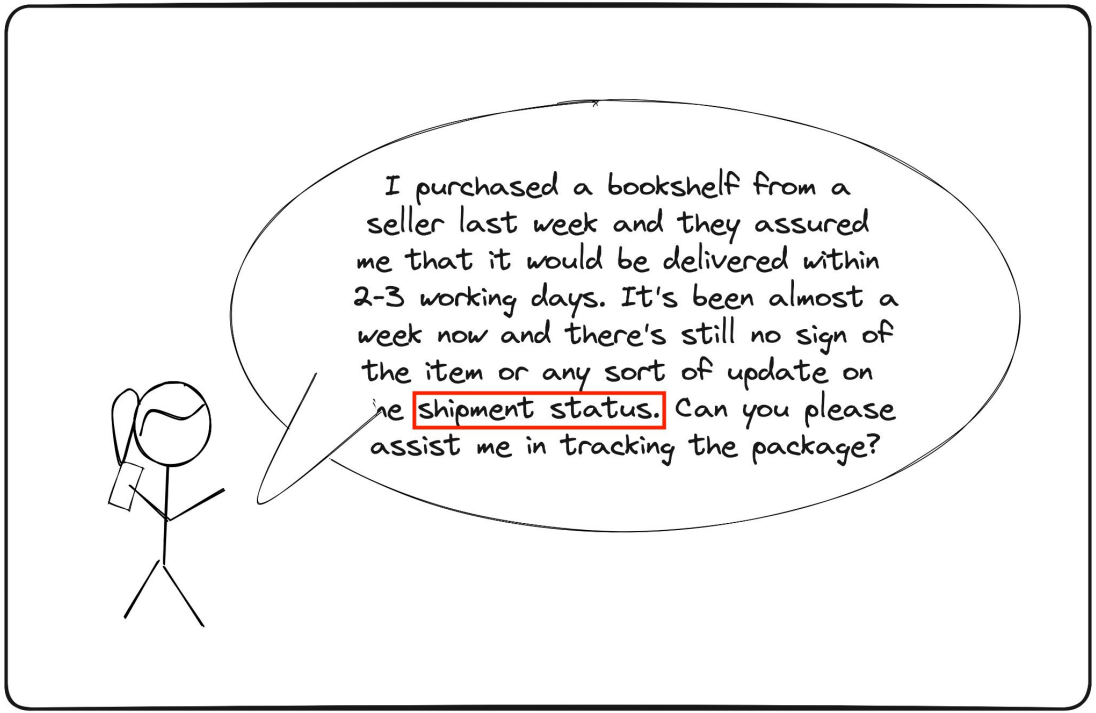

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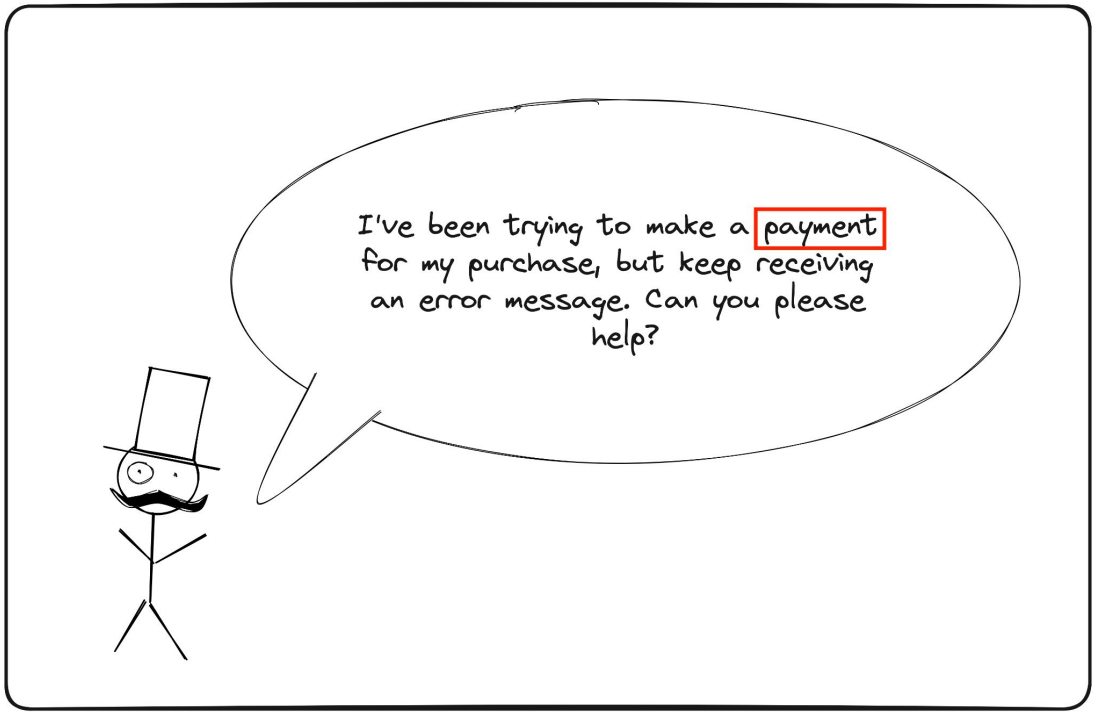

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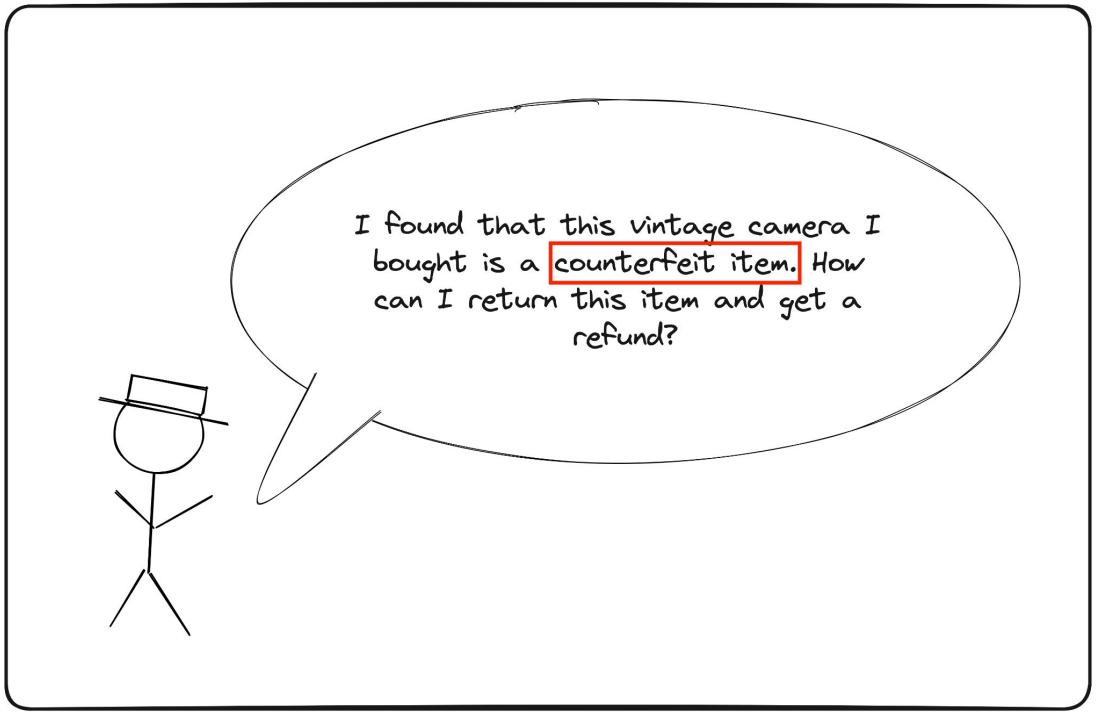

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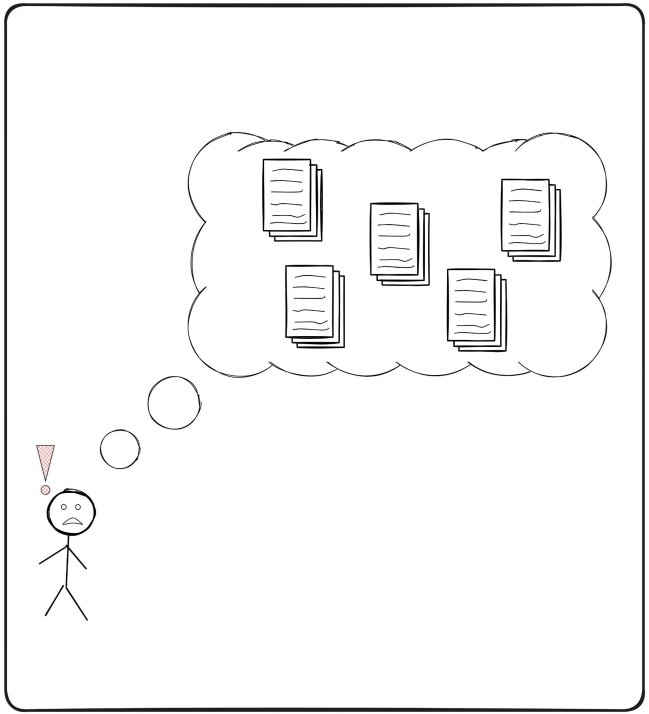
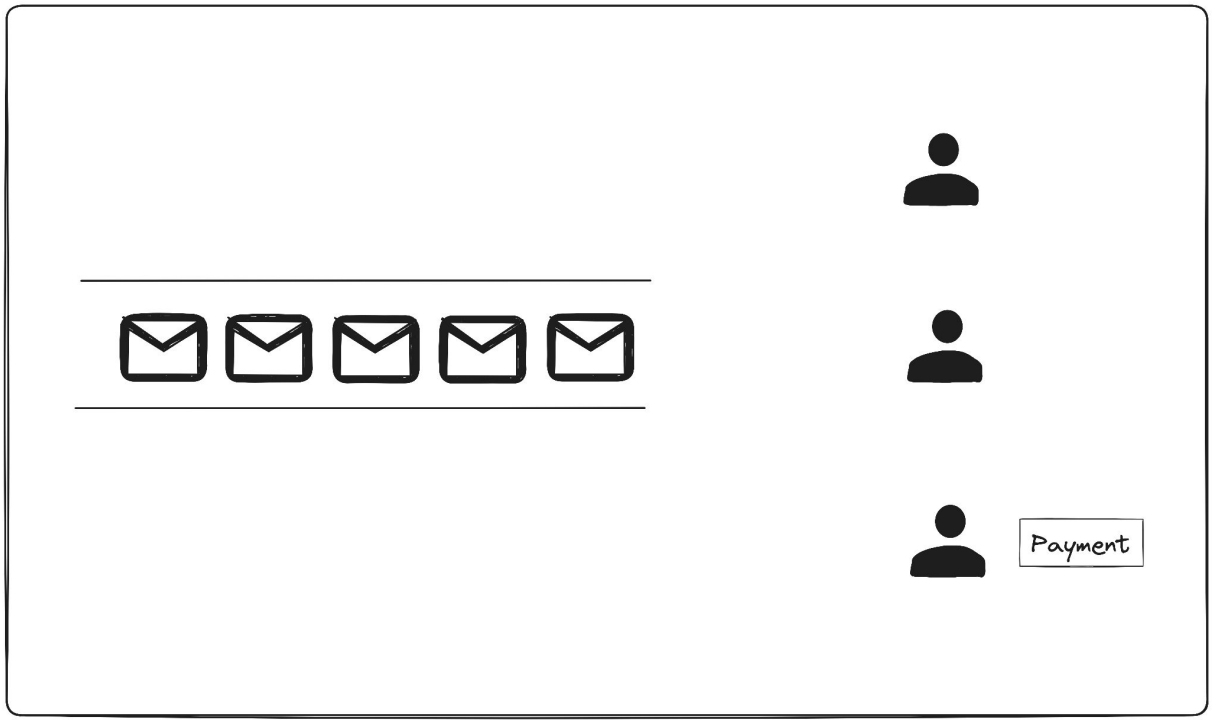
Random Allocation Problems

- Knowledge of handling all types of inquiries
- High onboarding cost for new agents
- Difficulty in changing guidelines for any type of inquiry



Skill Based Routing



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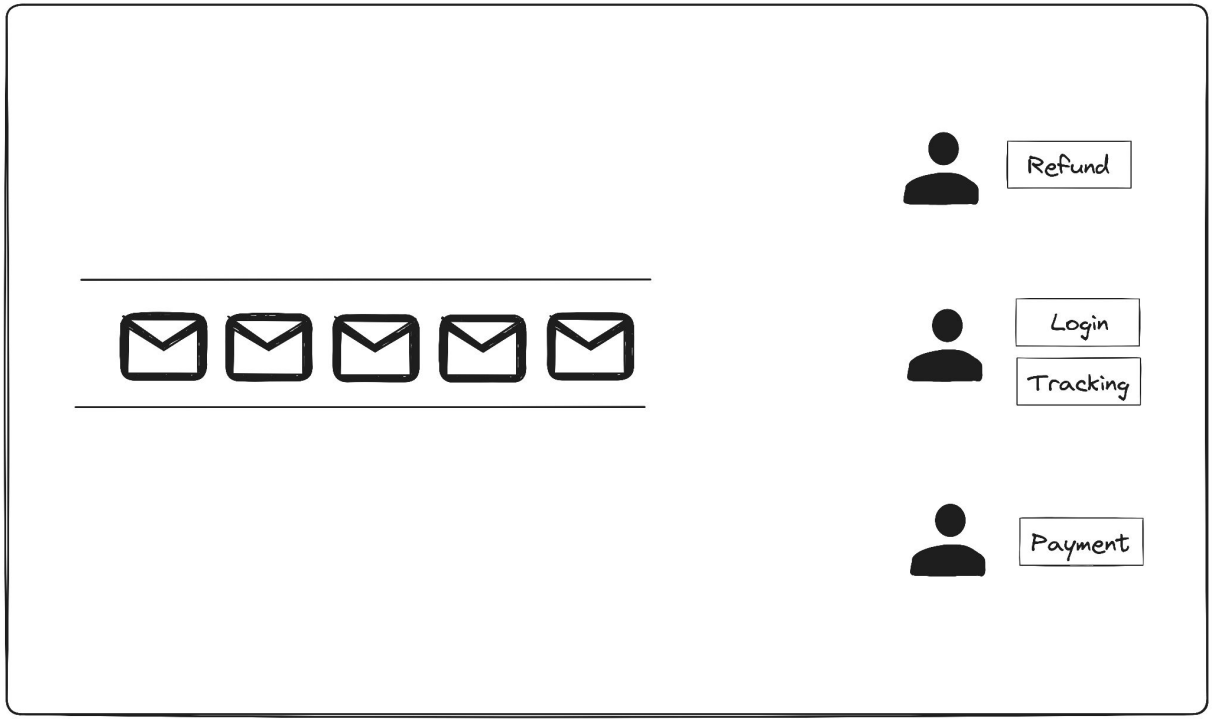

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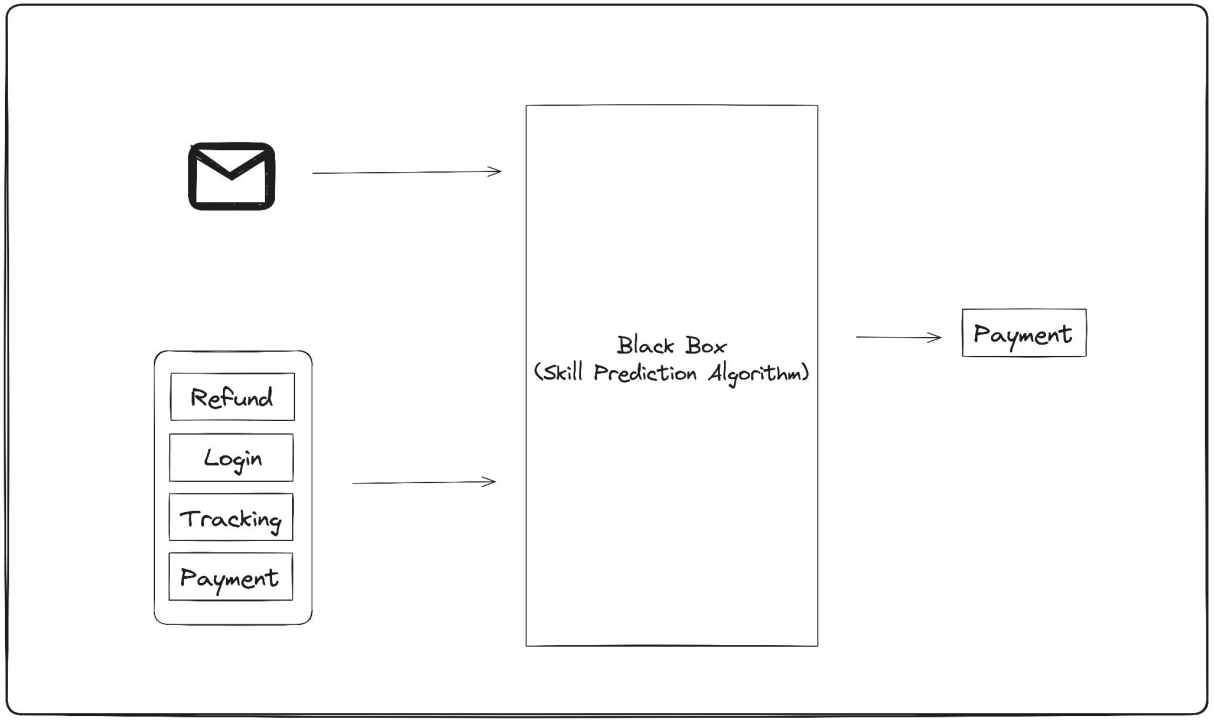

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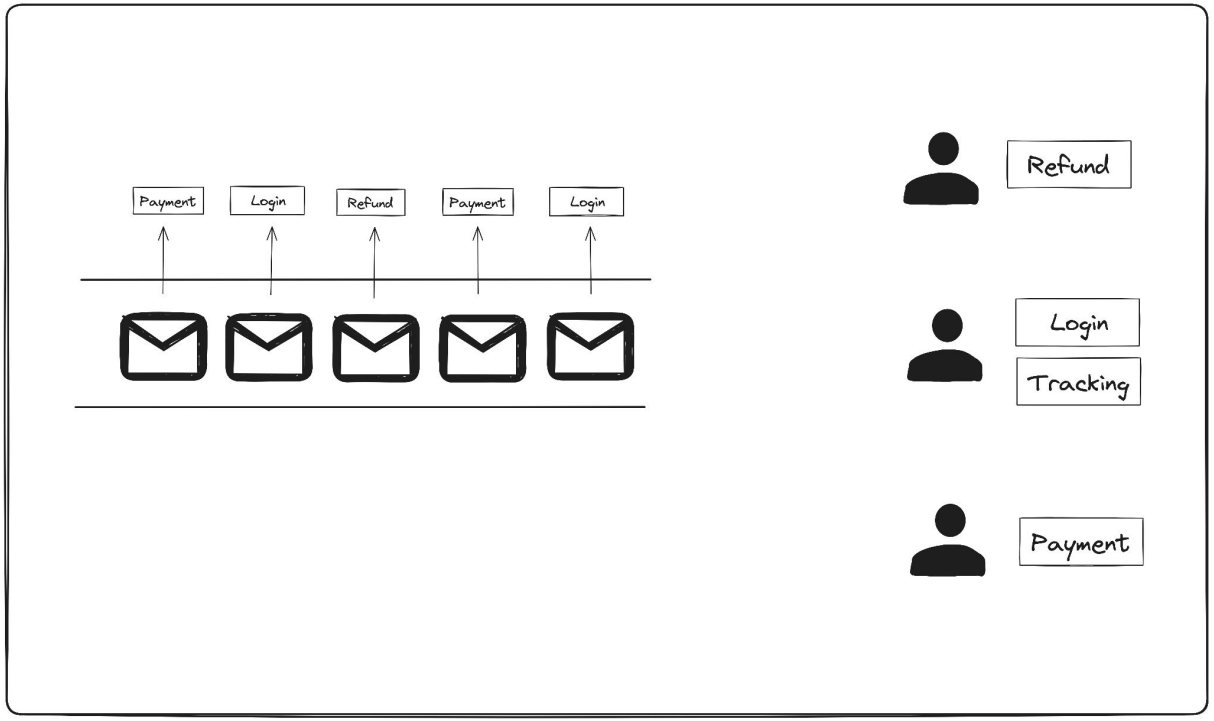

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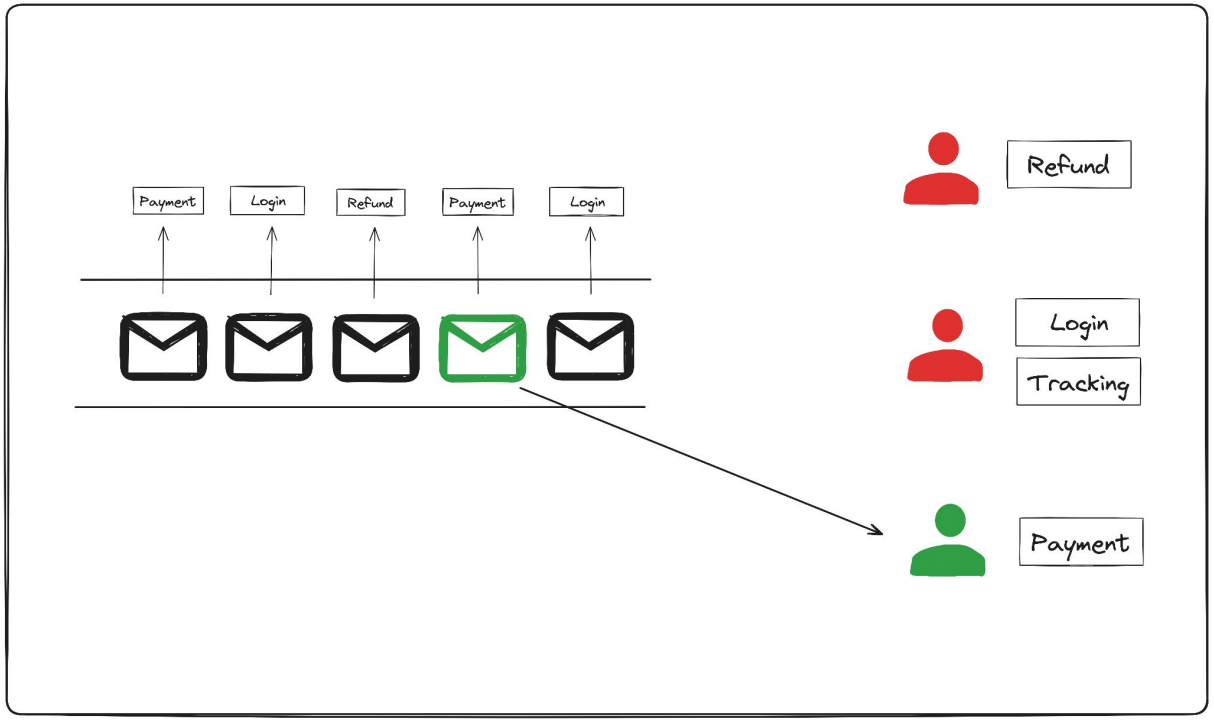

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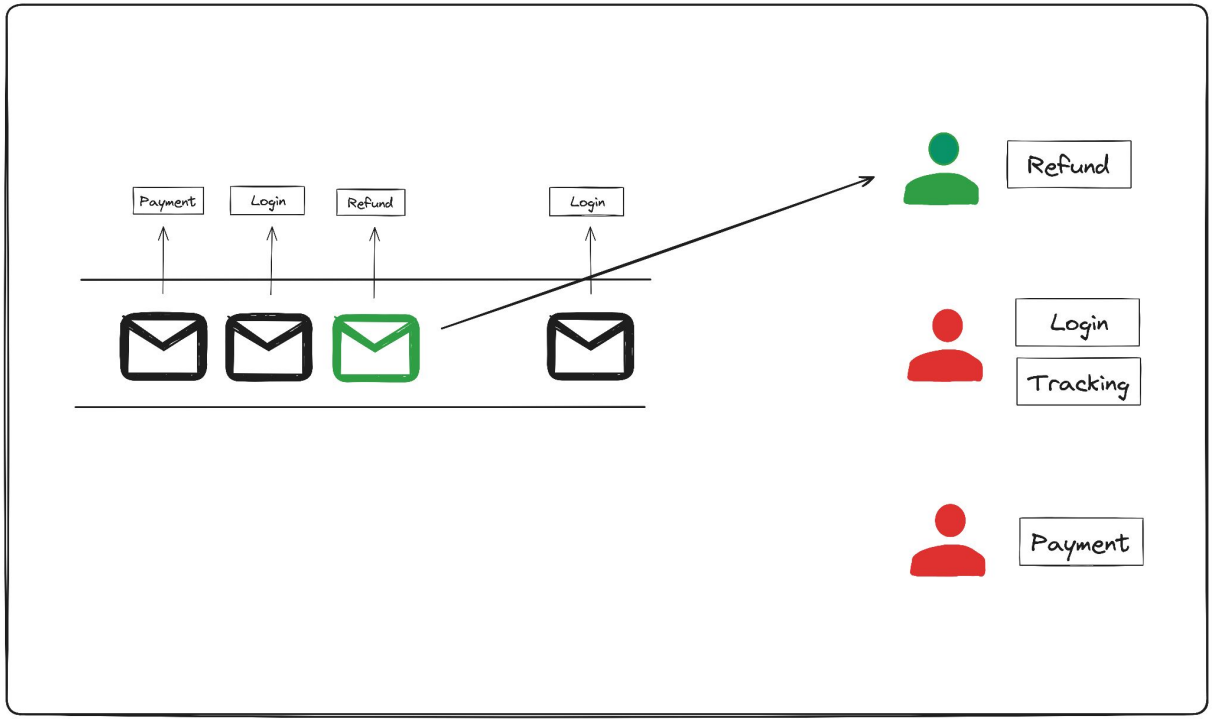
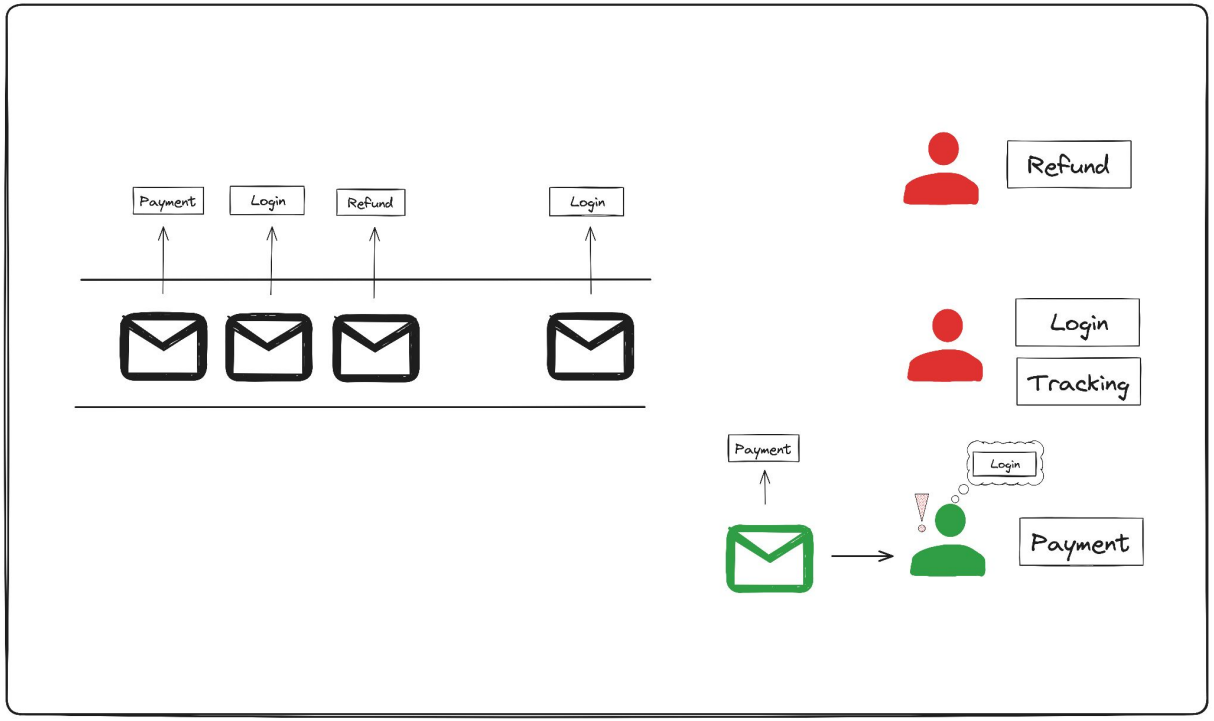


Skill Based Routing

- Agents have one or more skills
- Assign one skill to each inquiry
- Routing algorithm
  - An agent becomes available
  - Find the first inquiry whose assigned skill is one of the skills of the agent
  - Route that inquiry to be handled by that available agent

Transfers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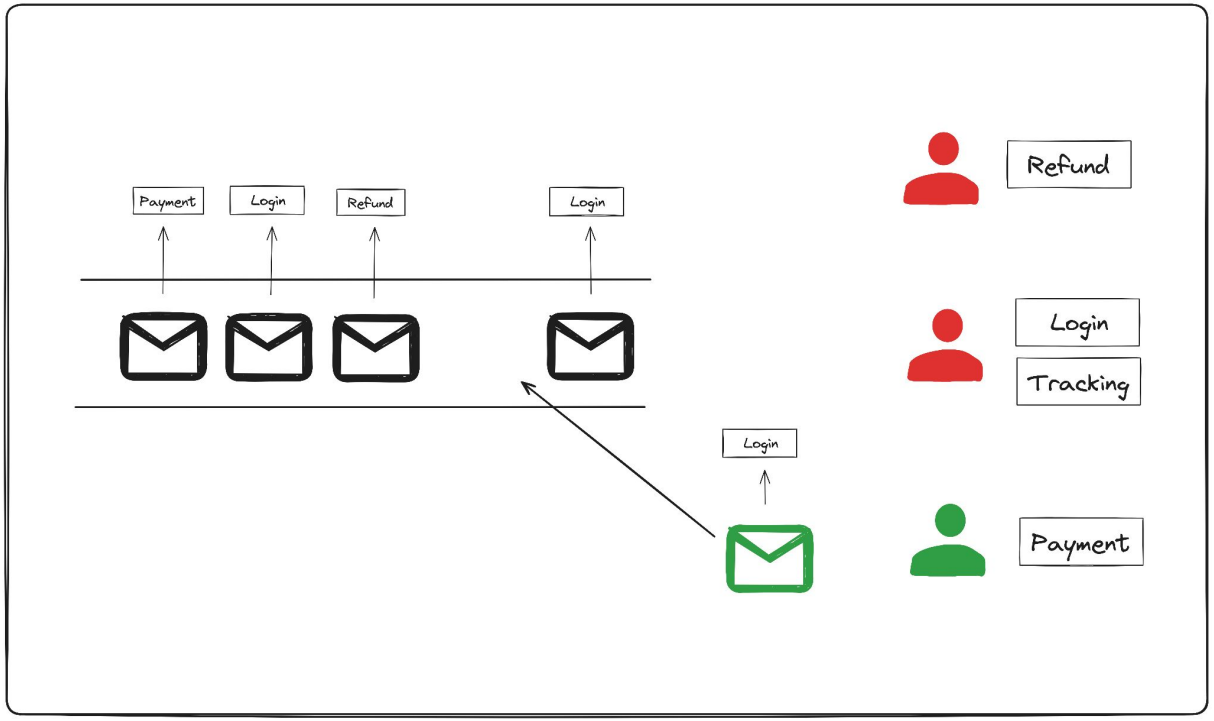
Login
Refund
Login
Refund
Login
Tracking
Payment
Login
Payment

Transfers


Payment
Login
Refund
Login
Refund
Login
Tracking
Login
Payment

Business Problem

- Transfer: Manual change of skill assigned to a case by a CS agent
- Problem: High number of transfers
- Transfer Rate: Ratio of number of transfers and number of times inquiries sent to agents
- **Business problem: Reducing the Transfer Rate**

Why reducing Transfer Rate is important?

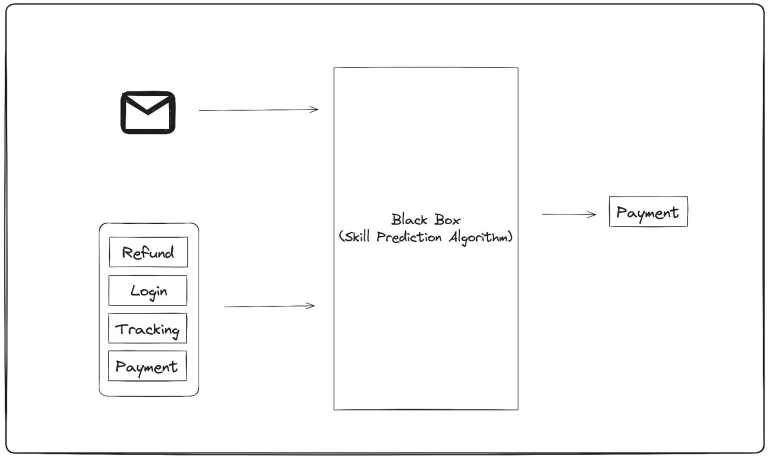
- Faster response
- Improved efficiency

02

Baseline solution

How to reduce Transfer Rate?

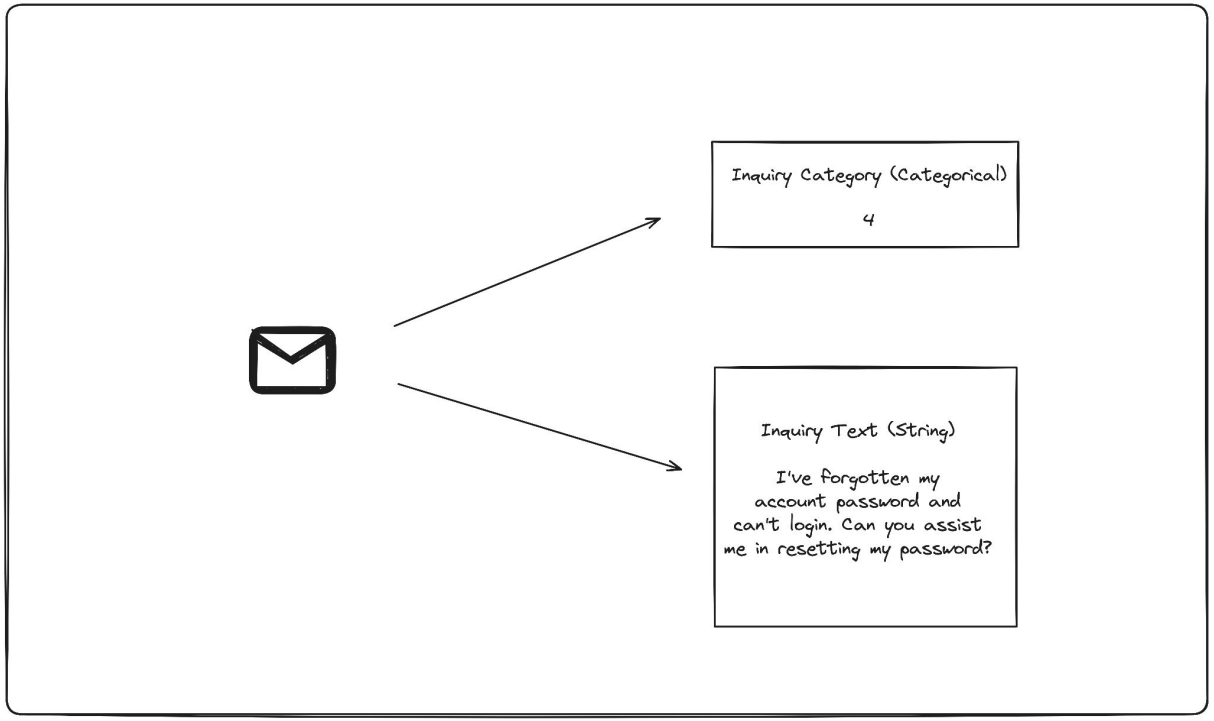
- If assigned skill to an inquiry is correct, no need for any transfer.
- Improvement in the accuracy of Skill Prediction Algorithm should lead to lesser number of transfers which will reduce transfer rate.



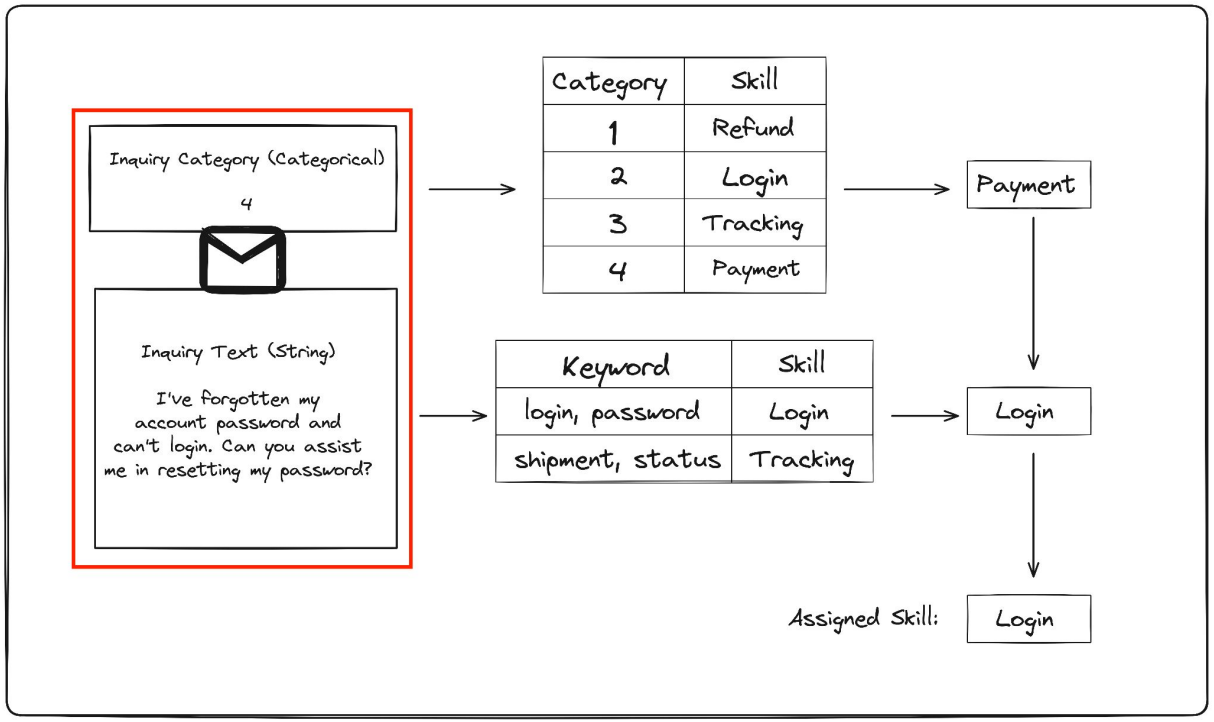
Improving Skill Prediction Algorithm

- Target metric: Accuracy
- Baseline skill prediction algorithm
- Using NLP and ML for improvement

Baseline Skill Prediction Algorithm



Baseline Skill Prediction Algorithm Example 1



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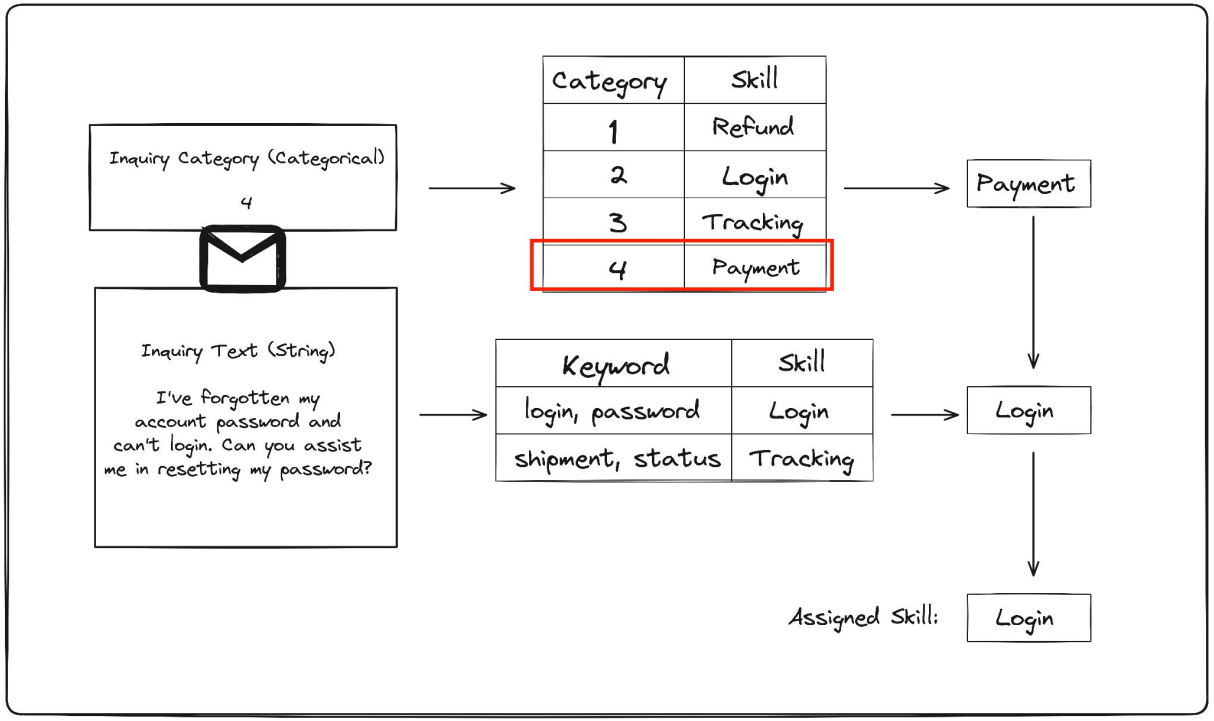

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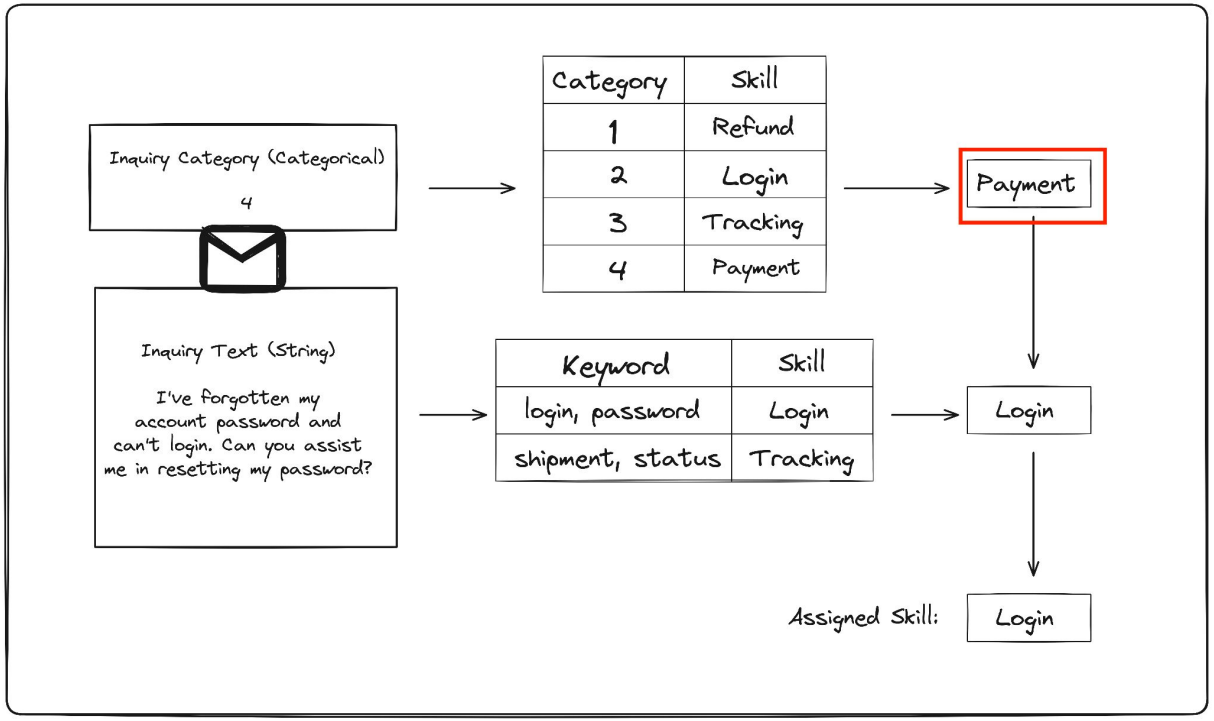

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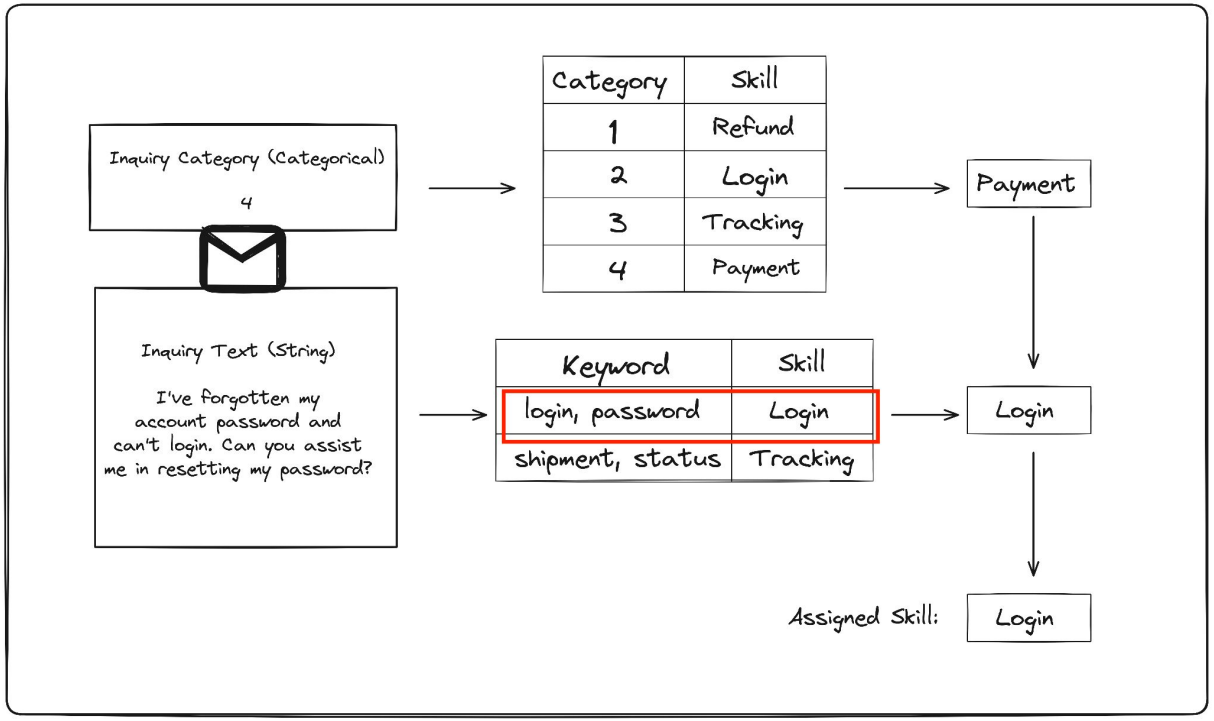

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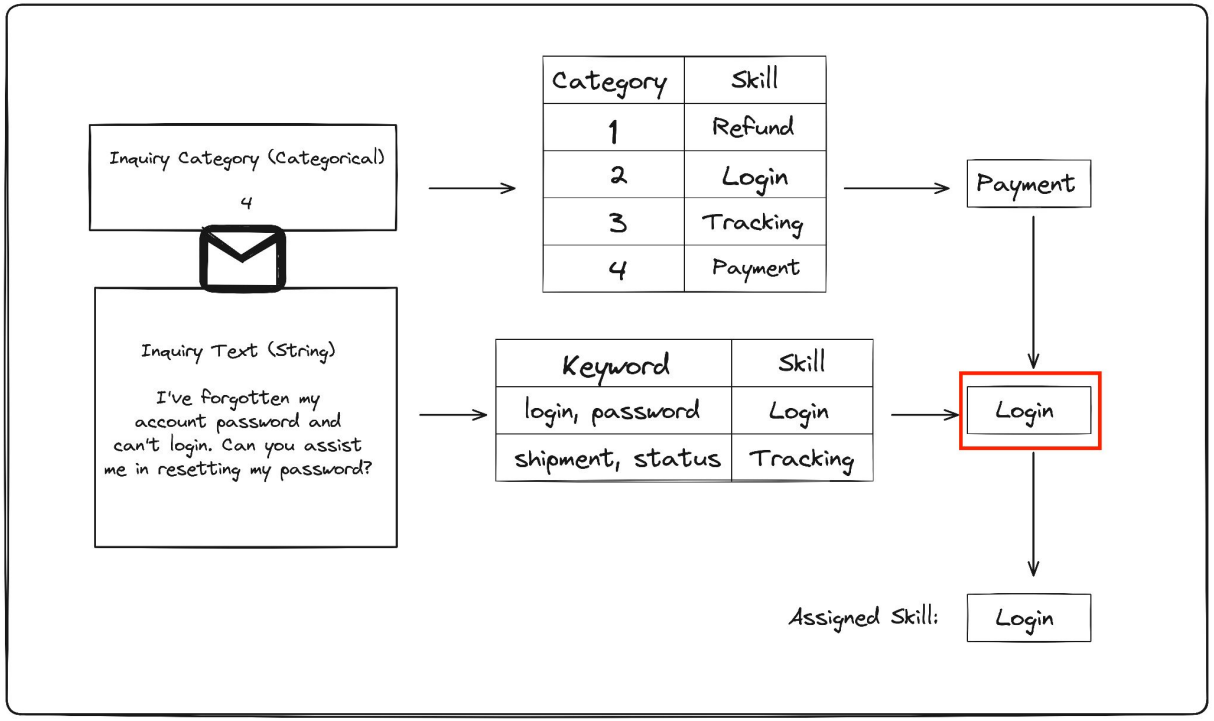

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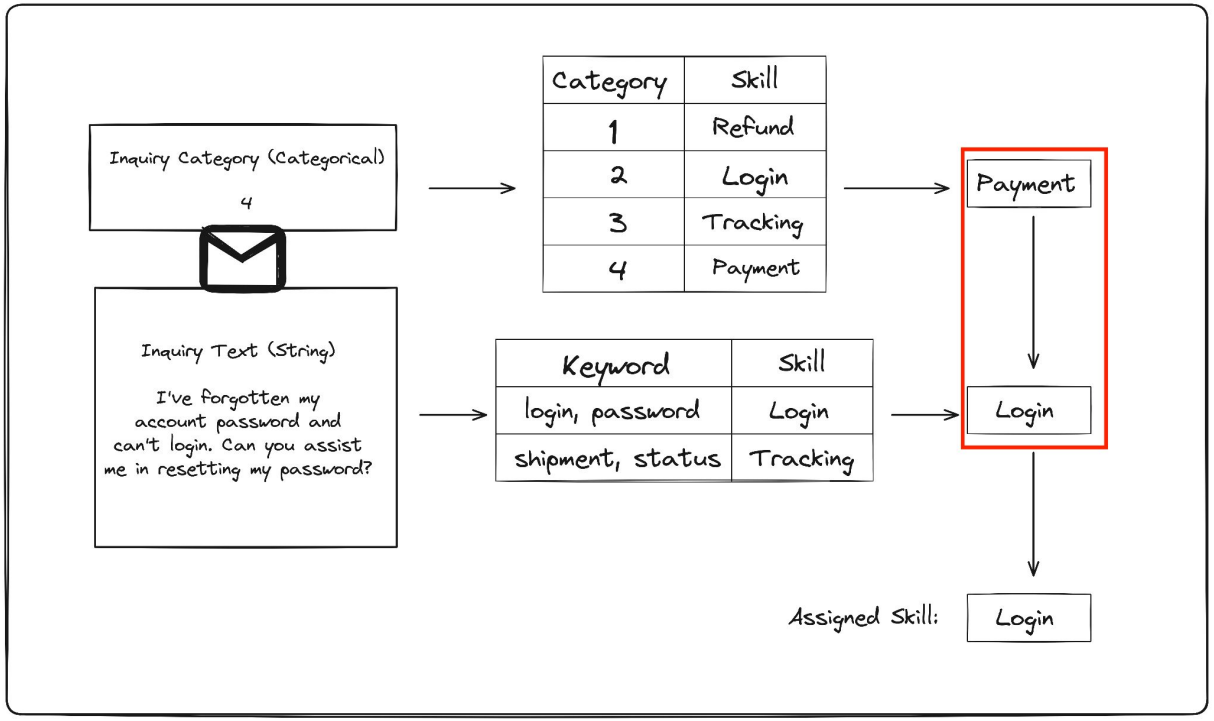

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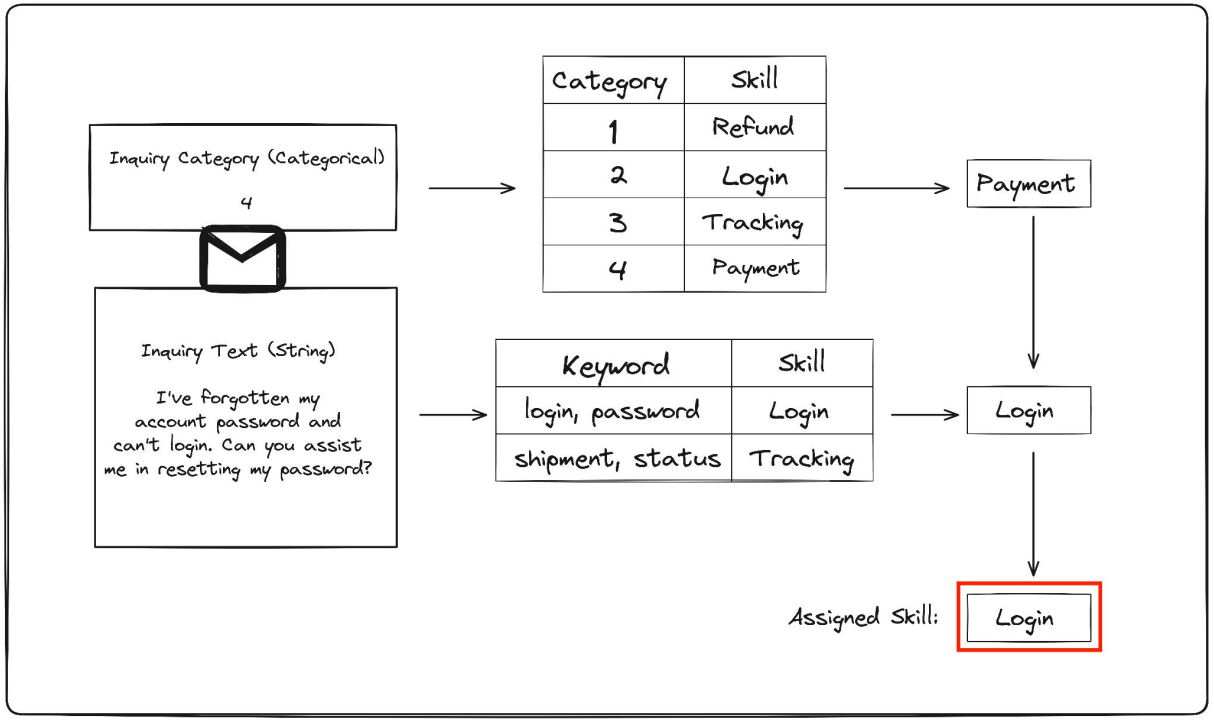
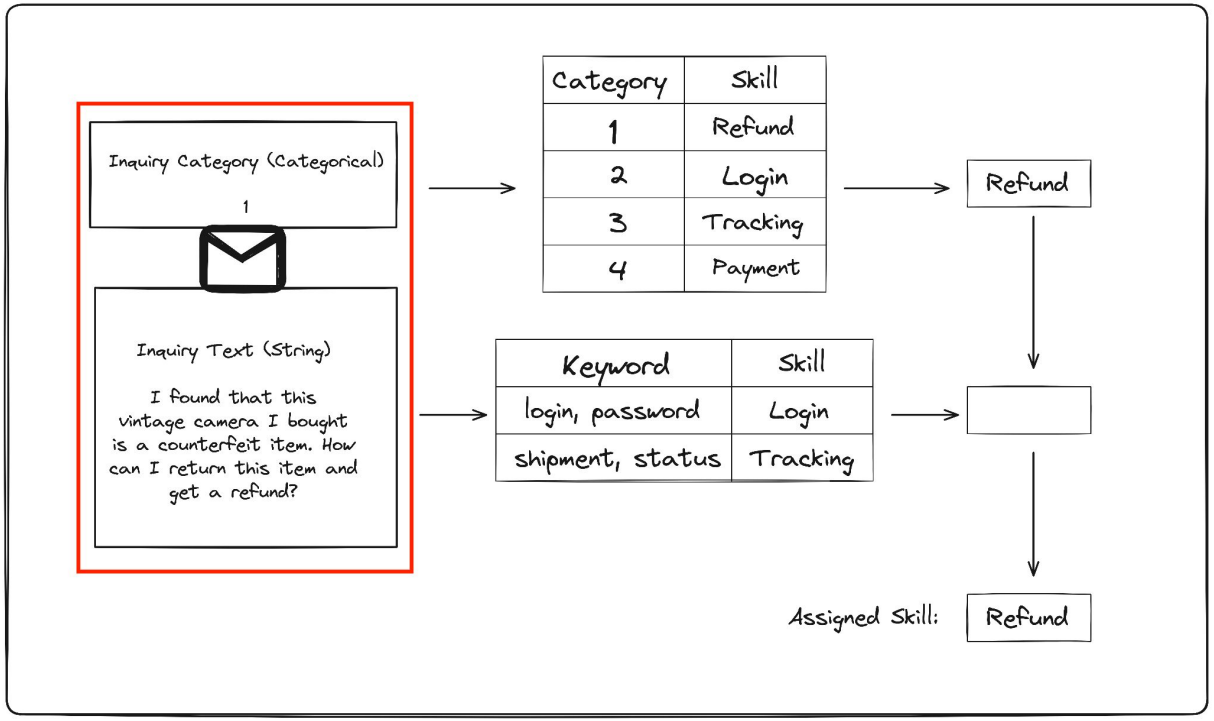


Baseline Skill Prediction Algorithm Example 2



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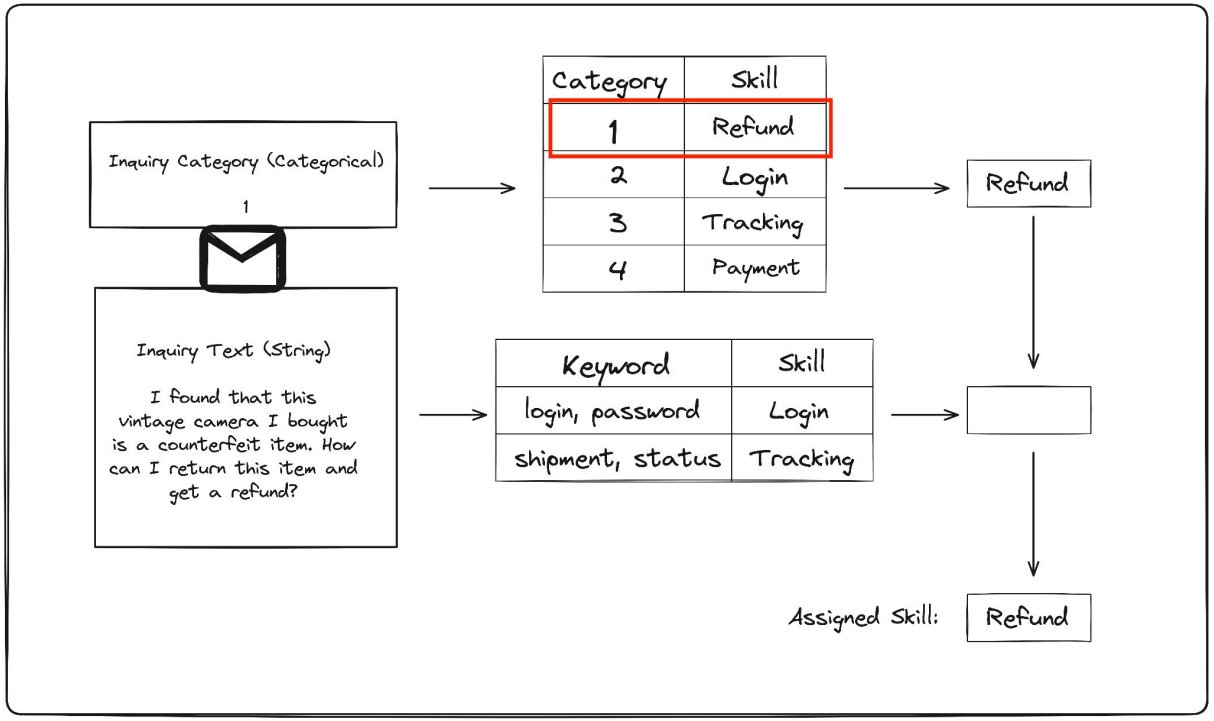

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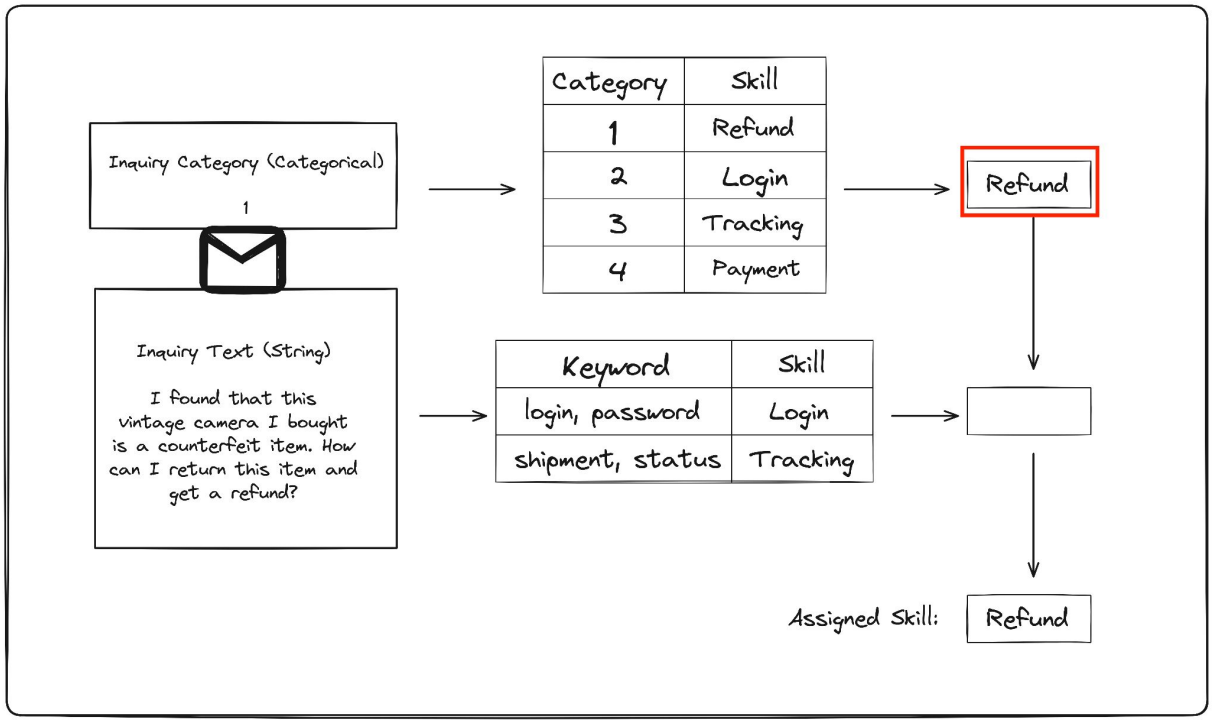

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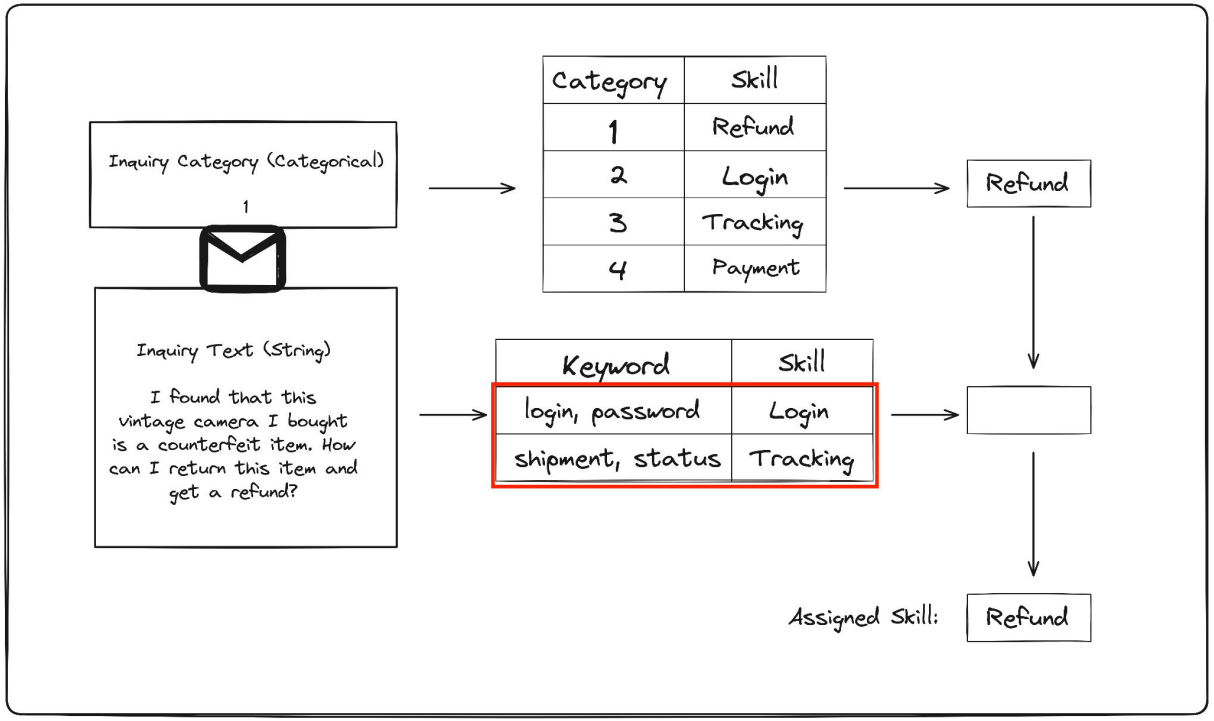

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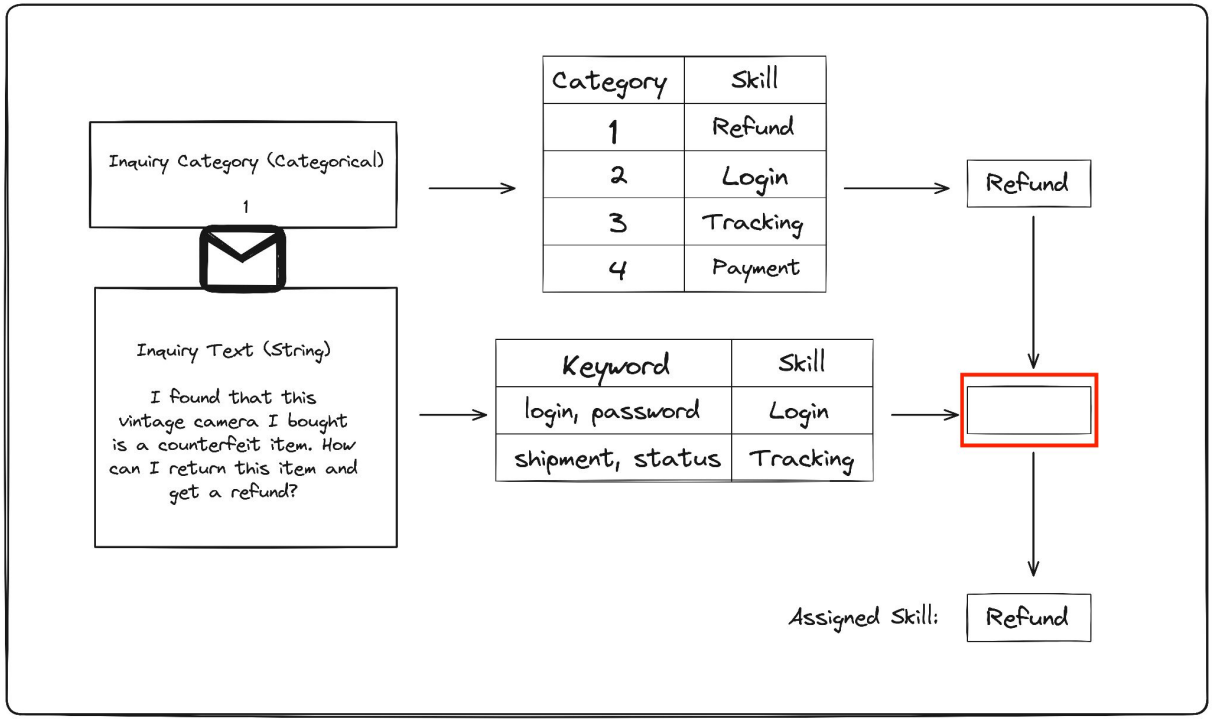

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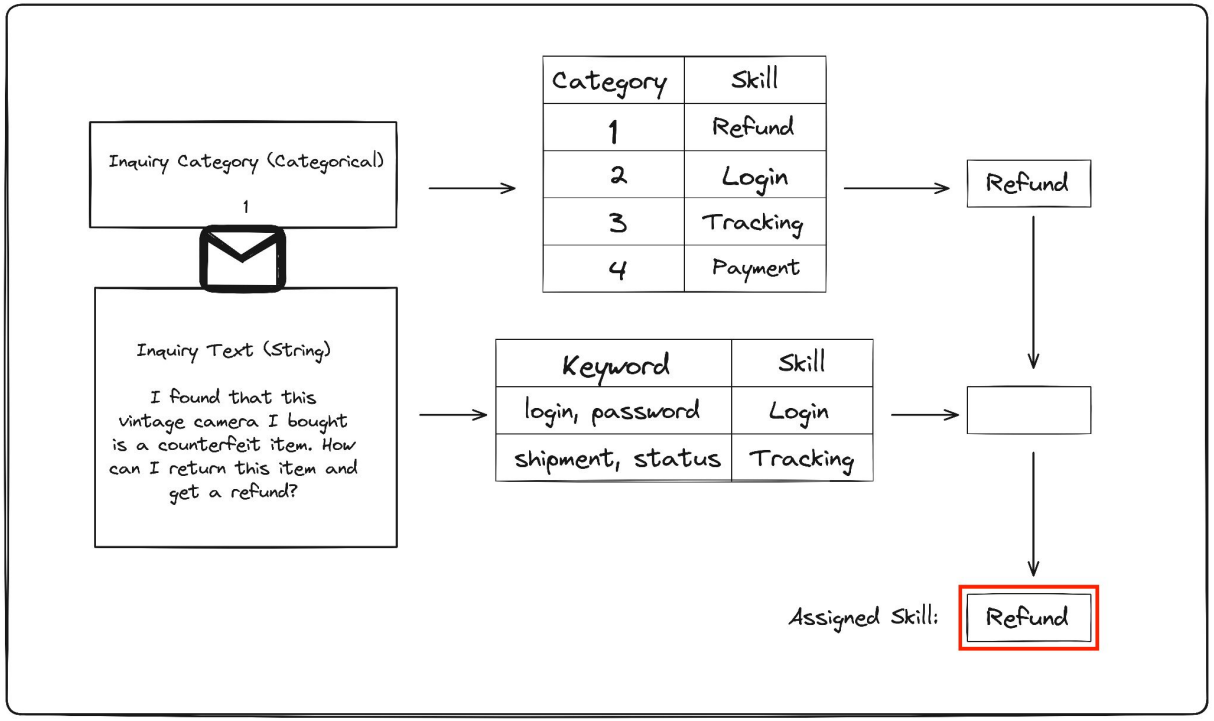


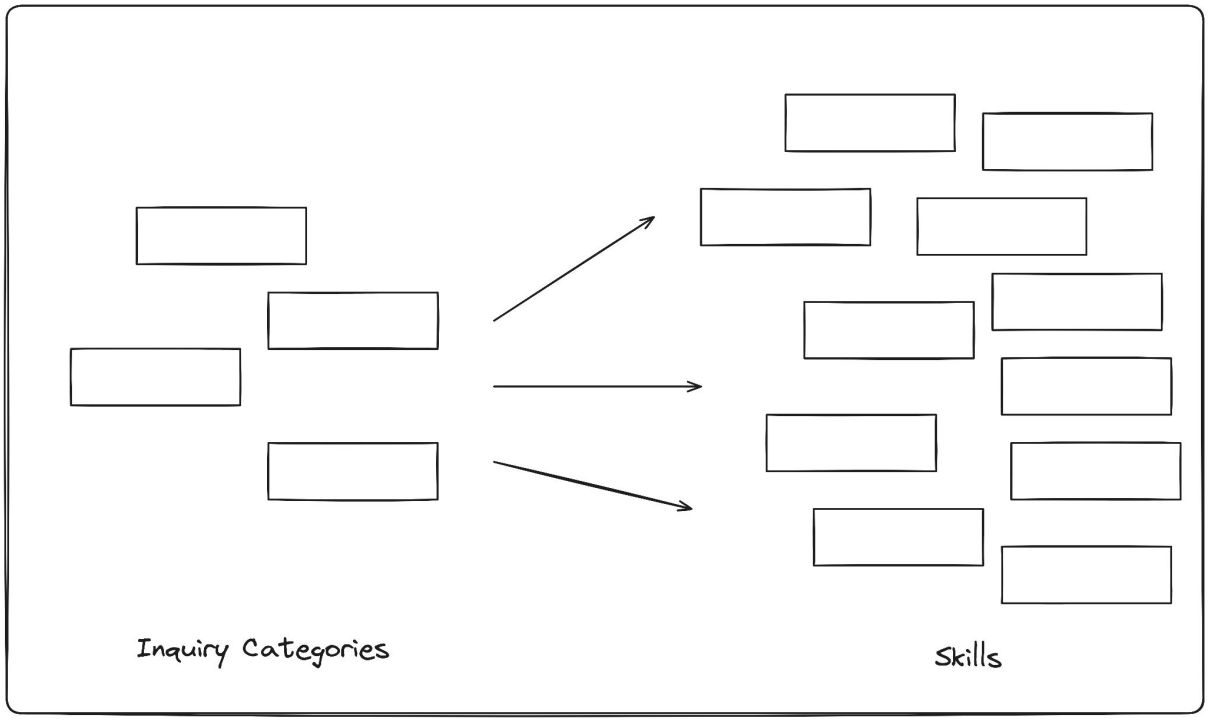
Baseline Skill Prediction Algorithm

- All inquiry categories have associated skill
- Assign skill to the inquiry based on the inquiry category
- Any of the keyword rules match with the inquiry text?
- Update the skill of the inquiry based on the keyword rule

Problems with the Baseline Algorithm

Few inquiry categories

Lots of skills



Problems with the Baseline Algorithm

Handling synonyms

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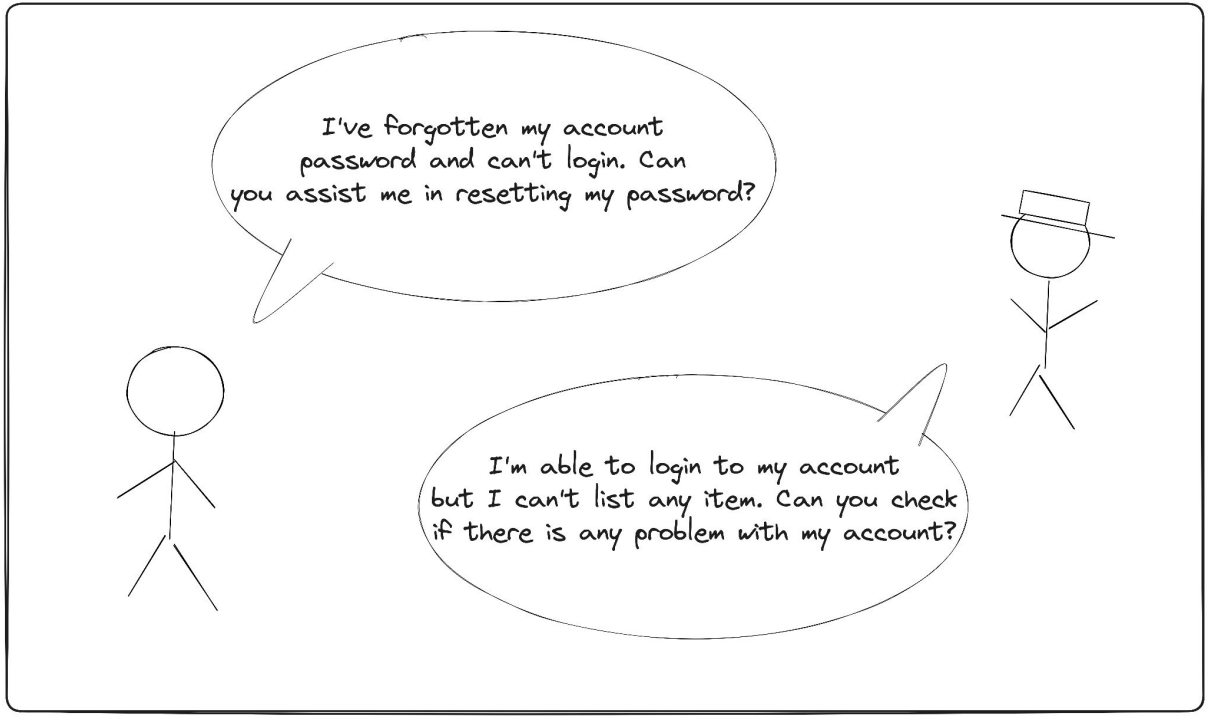
Problems with the Baseline Algorithm

Understanding context

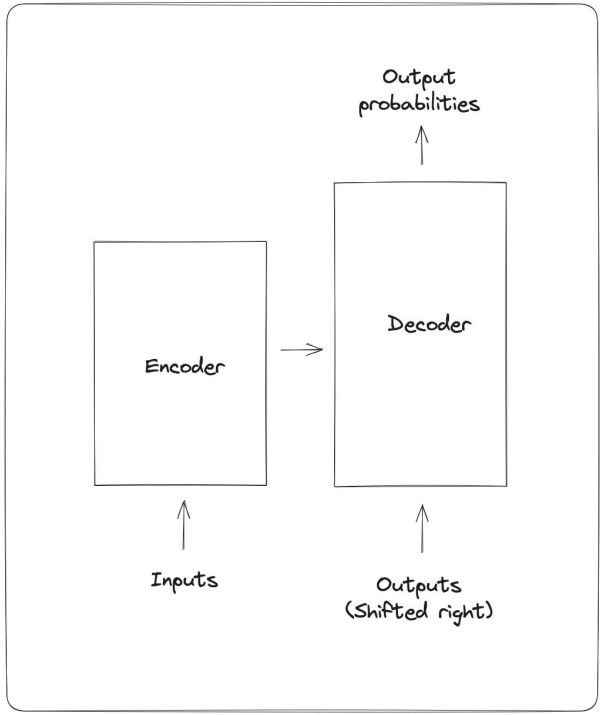


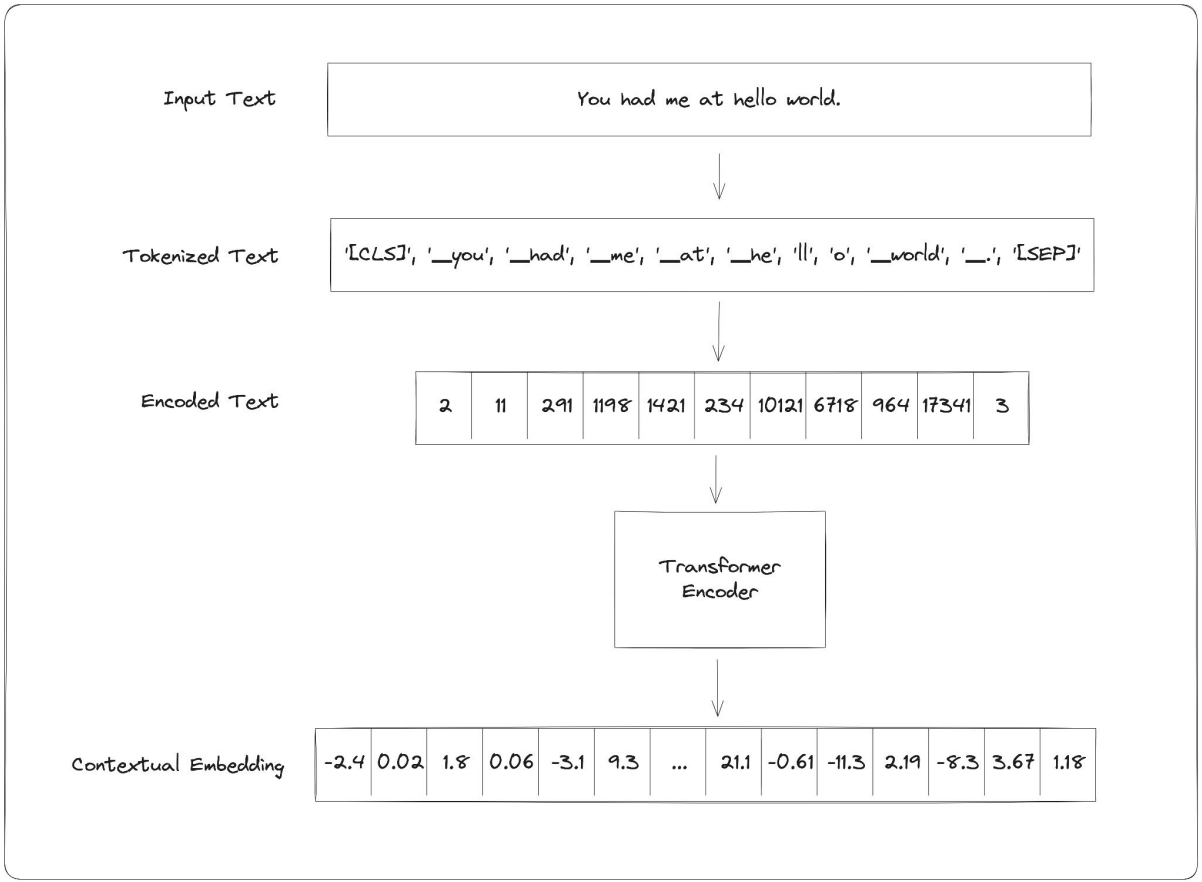
03

Developing the ML solution

Transformers Overview

- Introduced in 2017
- State-of-the-art architecture for NLP tasks
- Pre-trained on massive amount of data
- Contextual understanding




Input Text
You had me at hello world.
Tokenized Text
'[CLS]', '▁you', '▁had', '▁me', '▁at', '▁he', 'll', 'o', '▁world', '▁.', '[SEP]'
Encoded Text
2
11
291
1198
1421
234
10121
6718
964
17341
3
Transformer Encoder
Contextual Embedding
-2.4
0.02
1.8
0.06
-3.1
9.3
...
21.1
-0.61
-11.3
2.19
-8.3
3.67
1.18

Pre-trained Models

Model Name	Release Year	Link
Tohoku BERT base Japanese V3	2023	https://huggingface.co/cl-tohoku/bert-base-japanese-v3
LINE DistilBERT Japanese	2023	https://github.com/line/LINE-DistilBERT-Japanese
Rinna Japanese RoBERTa Base	2021	https://huggingface.co/rinna/japanese-roberta-base
Bandai Namco DistilBERT-base-jp	2020	https://github.com/BandaiNamcoResearchInc/DistilBERT-base-jp

```python
from transformers import AutoTokenizer, AutoModel

sentence = "パスワードを忘れてしまいました。リセットの手立てを教えてください。"

tokenizer = AutoTokenizer.from_pretrained(
    "line-corporation/line-distilbert-base-japanese"
)
tokenizer_output = tokenizer(sentence, return_tensors="pt")

model = AutoModel.from_pretrained(
    "line-corporation/line-distilbert-base-japanese"
)
last_hidden_state = model(
    input_ids=tokenizer_output["input_ids"],
    attention_mask=tokenizer_output["attention_mask"],
)[0]
contextual_embedding = last_hidden_state[:, 0]

print(contextual_embedding.shape)
# torch.Size([1, 768])
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```

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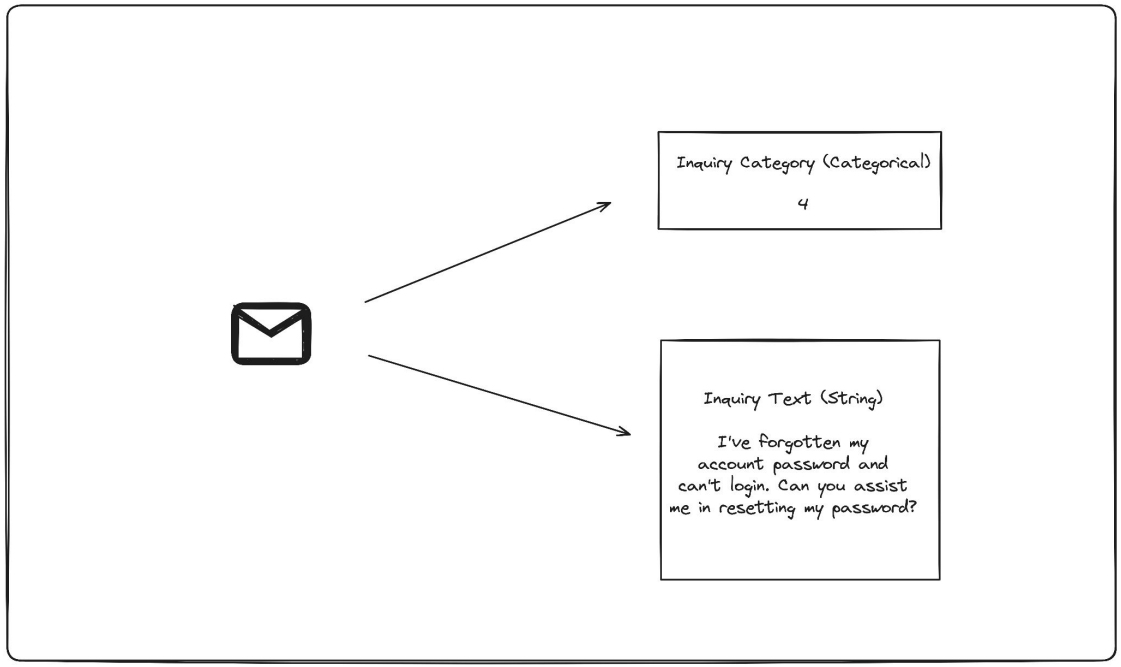
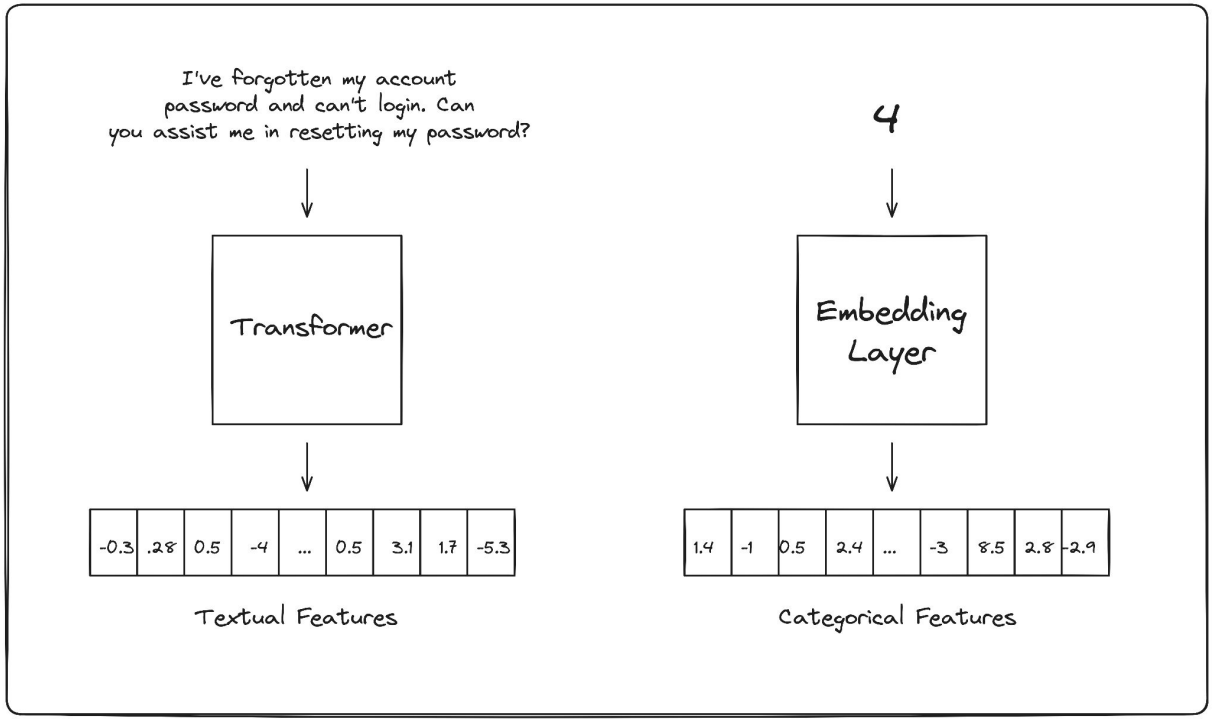
ML Model for Skill Prediction

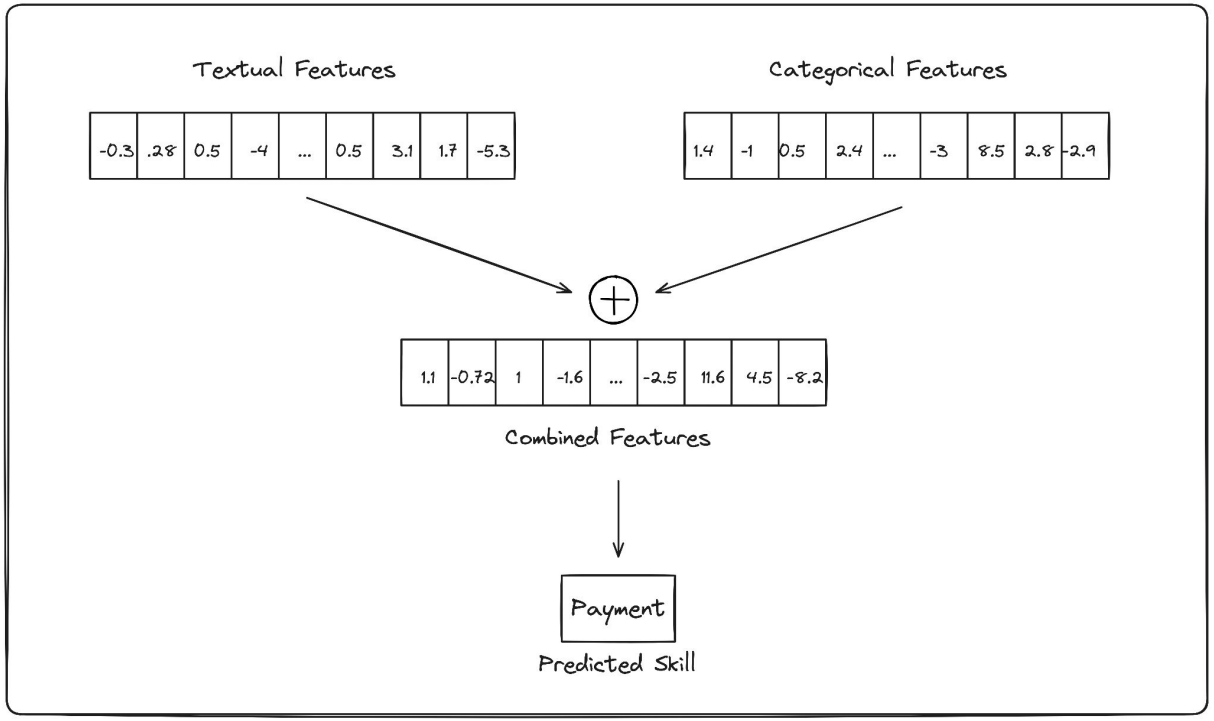
- Inputs:
  - Inquiry category
  - Inquiry text
- Outputs:
  - Skill for the inquiry



ML Model for Skill Prediction



ML Model for Skill Prediction



```python
import torch
from transformers import DistilBertModel


class DistilBertWithCategorial(torch.nn.Module):
    def __init__(
        self,
        categorical_input_distinct_values: int,
        distilbert_pretrained_model_name: str,
        pre_classifier_units: int,
        num_labels: int,
    ):
        super(DistilBertWithCategorial, self).__init__()
        self.distilbert = DistilBertModel.from_pretrained(
            distilbert_pretrained_model_name
        )

        self.text_feat_linear = torch.nn.Linear(
            self.distilbert.config.dim, self.distilbert.config.dim
        )
```

mercari

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mercari

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        self.text_feat_linear = torch.nn.Linear(
            self.distilbert.config.dim, self.distilbert.config.dim
        )
        self.text_feat_bn = torch.nn.BatchNorm1d(self.distilbert.config.dim)

        self.cat_embedding = torch.nn.Embedding(
            categorical_input_distinct_values, self.distilbert.config.dim
        )
        self.cat_bn = torch.nn.BatchNorm1d(self.distilbert.config.dim)

        self.pre_classifier_linear = torch.nn.Linear(
            self.distilbert.config.dim, pre_classifier_units
        )
        self.pre_classifier_bn = torch.nn.BatchNorm1d(pre_classifier_units)

        self.classifier = torch.nn.Linear(pre_classifier_units, num_labels)

    def forward(
```

mercari

```python
def forward(
    self,
    input_ids: torch.Tensor,
    attention_mask: torch.Tensor,
    categorical_input: int,
):
    distilbert_output = self.distilbert(
        input_ids=input_ids, attention_mask=attention_mask
    )
    last_hidden_state = distilbert_output[0]
    text_features = last_hidden_state[:, 0]

    text_features = self.text_feat_linear(text_features)
    text_features = self.text_feat_bn(text_features)
    text_features = torch.nn.ReLU()(text_features)

    categorical_features = self.cat_embedding(categorical_input)
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    combined_features = torch.add(text_features, categorical_features)

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    logits = self.classifier(combined_features)
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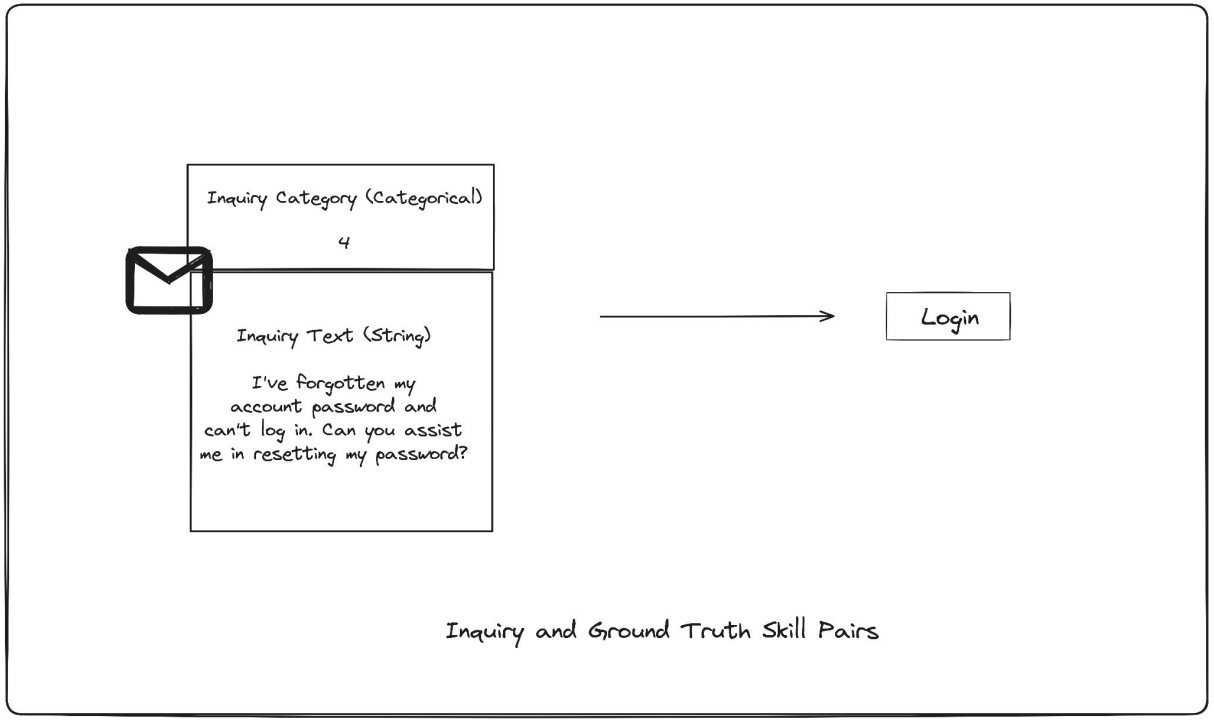
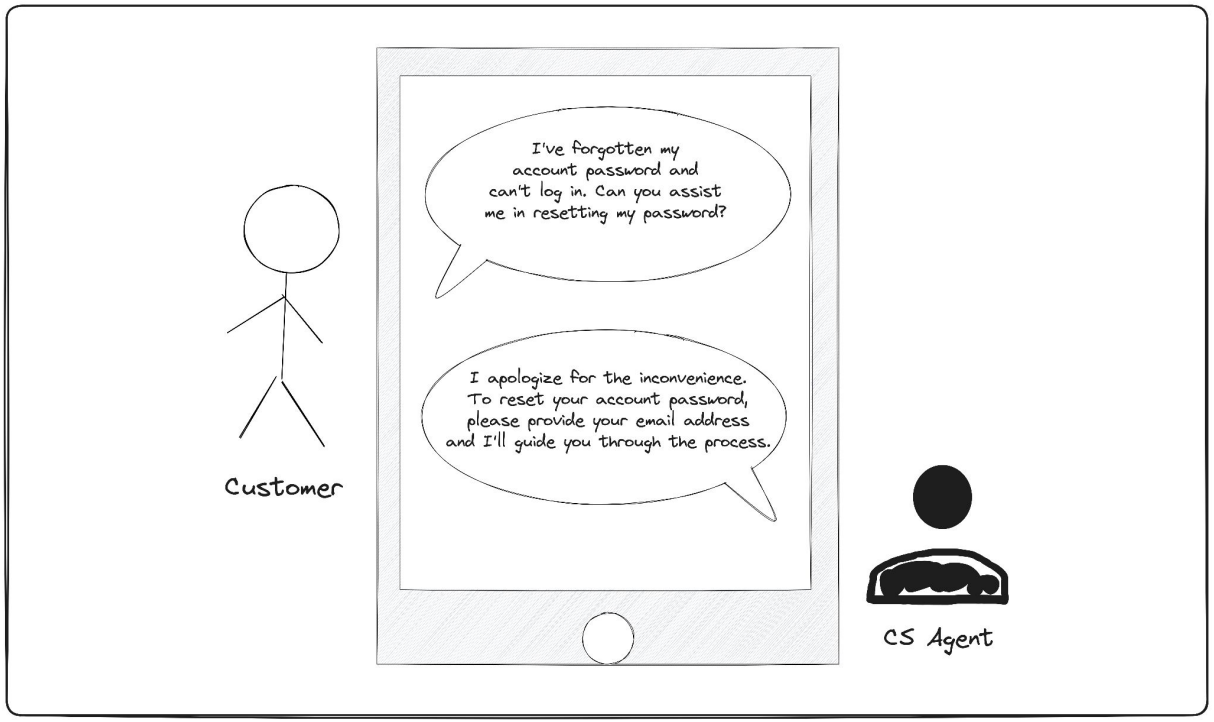
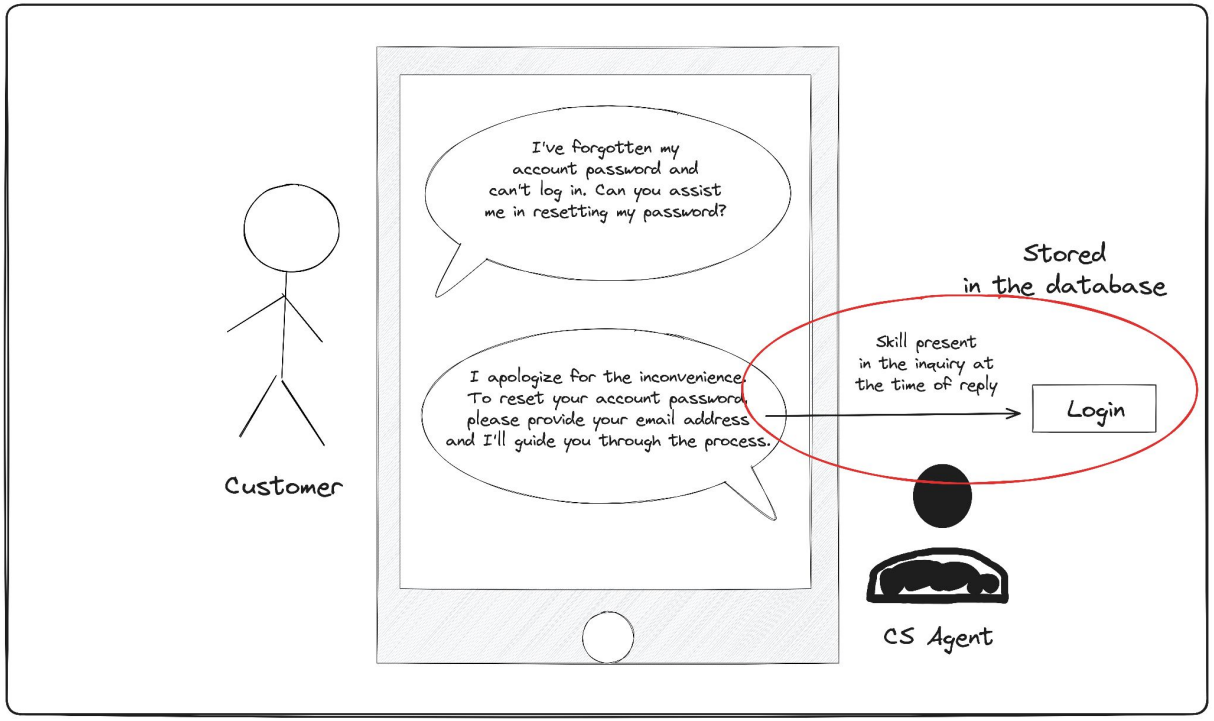
Gathering Annotated Data



Gathering Annotated Data



Gathering Annotated Data



Fine-Tuning Strategy

- Goal: Improve the accuracy of skill prediction
- Model:
  - DistilBert model to extract text features
  - Embedding layer to convert inquiry category to categorical features
  - Combine text and categorical features to predict the skill of the inquiry
- Data: Gather annotated data from last 1 year
  - 8 months of data for training
  - 1 month of data for validation
  - 3 months of data for testing

04

Business impact

A/B Test

- Control: Use baseline algorithm to predict skill for inquiries
- Treatment: Use ML model to predict skill for inquiries
- Time period: 1 week

A/B Test Metrics

- Goal:
  - Accuracy of assigning skills
  - Transfer Rate
- Guardrail:
  - Average number of transfers per reply

A/B Test Results

Metric	Change in Treatment compared to Control
Accuracy (of assigning skill)	+8.2%
Transfer Rate	-4.7%
Average number of transfers per reply	-26.4%

What We Learnt!

- Routing algorithm for routing customer inquiries to CS agents using skill of the inquiry
- Using NLP to build an ML model to predict the skill of the inquiry
- Impact from using the ML model

Appendix

- Multimodal-Toolkit
  - For combining textual features with numerical and categorical ones in different ways
-