MULTIMODALITY AND STACKING ENSEMBLE MODELS IN DEMAND PREDICTION

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PROJECT OVERVIEW

Problem Statement

Challenge:

- to predict deal probability for listings on Avito.com, Russia's largest classified advertisement platform

Goal:

- to equip sellers with insights to optimize listings and help the platform to improve user experience

Data Summary

Scope

- 1.5M listings in March 2017
- Tabular, text, image data

Target Variable

- *deal_probability*

Challenge

- Tabular mostly categorical
- Russian text
- Large size (50GB+ images)

Methodology

Multi-modality

- Text embeddings with TF-IDF, SpaCy, FastText and images embeddings with ResNet 50
- SVD dimensionality reduction

Stacking Ensemble

- Combine outputs from base models across data modalities

(TABULAR) FEATURE ENGINEERING

Original Features	Price Statistical Features	Text-Related Features	Combination Features
region	category_price_mean	title_length	region_city
city	category_price_std	description_length	all_category
parent_category_name	category_price_skew	title_word_count	category_param_1
category_name	city_price_mean	description_word_count	region_category_user
param_1	city_price_max	title_has_keyword	city_category_user
param_2	city_price_skew	description_has_keyword	
param_3	price_to_category_mean	title_digit_count	
price	price_to_category_max	description_digit_count	
user_type	price_log	description_newline_count	
	price_bin	description_missing	
TOTAL: 9	TOTAL: 10	TOTAL: 10	TOTAL: 5
TOTAL: 34			

Table 1: Tabular Feature Engineering

- **9** Original Features
- **10** Price Statistical Features
- **10** Text-related Features (length, word count...)
- **5** Combination Features

34

Total Tabular Features into future models

TEXT FEATURE EXTRACTION

- Extract Embeddings with three different methods
- Use Singular Value Decomposition (SVD) to reduce dimension

TF-IDF

- TF-IDF, 500 Embeddings
- TF-IDF, Embeddings SVD to 5d

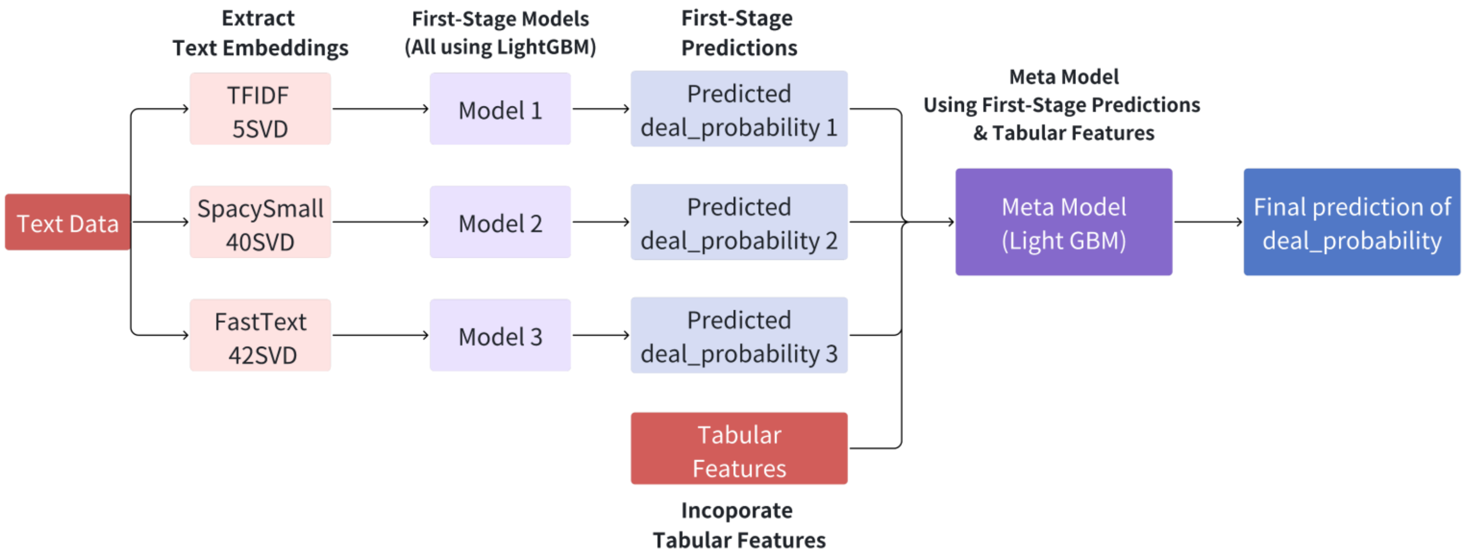
SpaCy

- SpaCy Small Russian, 98 Embeddings / Medium Russian, 300 Embeddings
- SpaCy Small Russian, SVD to 40d / Medium Russian, SVD to 100d

FastText

- FastText trained on our data, Embeddings 100
- FastText trained on our data, SVD to 42d
- Pretrained FastText, Embeddings 300
- Pretrained FastText, SVD to 50d

STACKING MODELS



Stacking Model 1:

- **3 First-Stage Models:**
  - TFI-DF, Spacy, FastText Embeddings→ Predict deal_probability separately
- **Meta Model:**
  - Combines first-stage predictions and tabular features

Stacking Model 2:

- **2 First-Stage Models:**
  - FastText → Predict price
  - Spacy → Predict deal_probability
- **Meta Model:**
  - Combines first-stage predictions, tabular features, and TFI-DF embeddings

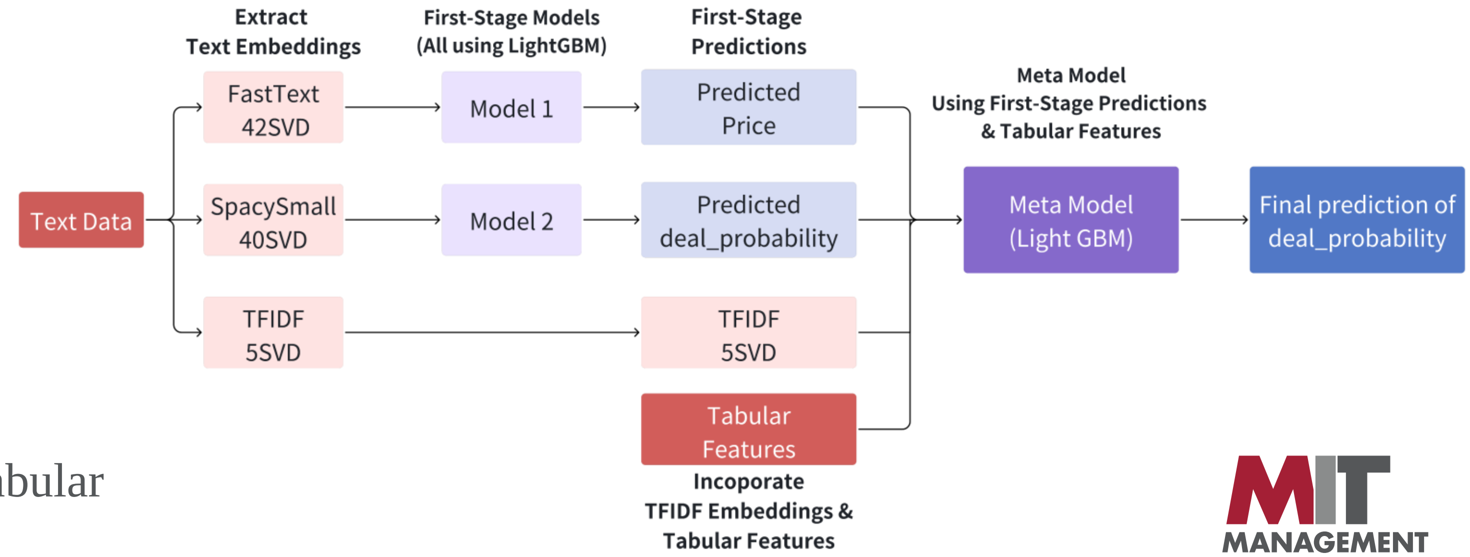


Table 4.1: Summary of Text and Tabular Models Performance in Complete Dataset

Tabular Baseline	.227894

RMSEs when Directly Using Embedding as Features for LightGBM

	SVD Dimension	RMSE - Embedding Only	RMSE - **With Tabular**
TF-IDF	5	.252066	.227283
SpaCy Small	40	.248780	.227110
SpaCy Medium	100	.246289	.227009
FastText	42	.235021	**.226067**
FastText Pretrained	50	.235337	.227278

RMSEs when Stacking Embedding LightGBM

First-stage Models	Second-stage Model	RMSE
deal_probability ~ SpaCy deal_probability ~ TF-IDF deal_probability ~ FastText	First-stage Preds + Tabular	**.226904**
price ~ FastText deal_probability ~ SpaCy	First-stage Preds + Tabular + TD-IDF	.227119

0.227894

RMSE of Tabular Baseline

6.7%

Average RMSE improvement By combining Tabular and Embeddings Features

0.226067

RMSE of Best Model

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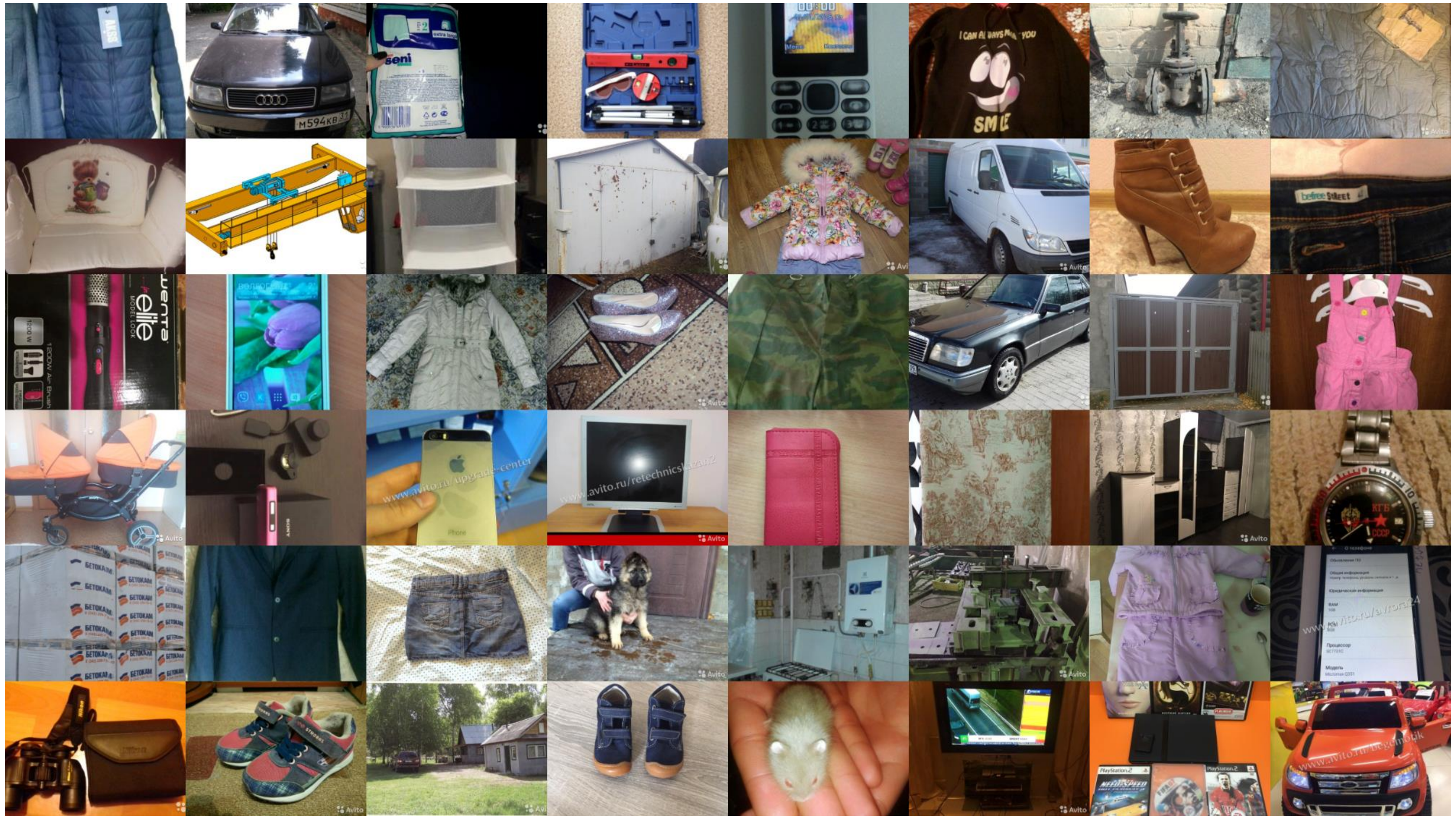
IMAGE FEATURE EXTRACTION



- Visual features matter
  - Important product characteristics, product quality, and buyer interest
  - Majority (93%) of listings has associated image for the listed product
- Images are expensive
  - 50+ GB of image data, not realistic for our computing resources
  - 20% subset of data with images to evaluate image and other features

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MODEL PERFORMANCE IN IMAGE SUBSET

Tabular Baseline			.232013

RMSEs for Training and Testing Models in Subset for Image Data

	SVD Dimension	RMSE - Embedding Only	RMSE - **With Tabular**
Text Embedding	42	.241487	.230863
Image Embedding	500	.242552	.230489
Text + Image			**.229803**

.232013
RMSE of Tabular Baseline

.230489
RMSE of Best Bi-Modality

.229803
RMSE of Tri-Modality

CONCLUSION

- Our experiments demonstrate that
  - **Power of multimodality**: Inclusion of unstructured data is crucial for improving predicting *deal probability* of online listings
  - **Comparing text models**: Neural-network-based text embedding (FastText) outperforms frequency-based embedding (TF-IDF) in this task
  - **Complementary power**: Inclusion of image features on top of text and tabular models significantly boosted predictive accuracy
- Stacking ensemble
  - **Stacking boosted accuracy:** Effective in leveraging information from diverse sources

- Some constraints still require future work
  - **Feature Engineering**: Explore additional engineered features from tabular, text, and image data to enhance predictive performance
  - **Advanced Stacking**: Incorporate image embeddings alongside text embeddings in first-stage models, explore multi-stage stacking, or test new intermediate response variables
  - **Scaling Image Analysis**: Extend image feature analysis to the full dataset to fully capture the role of visual features in deal probability
  - **Model Extensions**: Experiment with more advanced architectures for image and text embeddings, such as transformers

THANK YOU

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