

Machine Learning - House Prices Analysis

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A.Y. 2022/2023

Machine Learning Project
SpaceCapybaras

House Prices analysis



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Chapter 1

Introduction

To develop this **Machine Learning** project we are going to use the CRISP-DM methodology, which is a well-known and widely used methodology for data mining projects. It is an iterative process that is composed of six phases.

In particular, the phases are:

1. **Business Understanding:** in this phase we will try to understand the problem and the objectives of the project. We will also try to understand the data that we have at our disposal and how we can use it to solve the problem.
2. **Data Understanding:** in this phase we will try to understand the data that we have at our disposal. We will try to understand the meaning of the data and how we can use it to solve the problem.
3. **Data Preparation:** in this phase we will try to prepare the data for the next phases. We will try to clean the data and to transform it in a way that will be useful for the next phases.
4. **Modeling:** in this phase we will try to build a model that will be able to solve the problem. We will try to find the best model for our problem.
5. **Evaluation:** in this phase we will try to evaluate the model that we have built. We will try to understand if the model is good enough to solve the problem.
6. **Deployment:** in this phase we will try to deploy the model that we have built. We will try to understand how we can use the model to solve the problem.

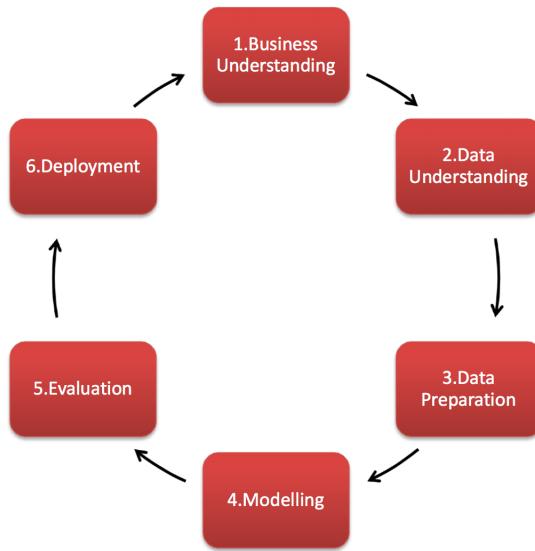


Figure 1.1: CRISP-DM methodology

Chapter 2

Business understanding

2.1 Background

Our project is based using the dataset of the Kaggle competition [House Prices: Advanced Regression Techniques](#).

The goal of the competition is to predict the final price of each home based on 79 explanatory variables describing (almost) every aspect of residential homes in Ames, Iowa. The dataset is composed by 1460 rows and 81 columns, where the last column is the target variable, the Sale Price.

A small list of the variables is the following:

- **LotArea:** Lot size in square feet
- **OverallQual:** Overall material and finish quality
- **OverallCond:** Overall condition rating
- **YearBuilt:** Original construction date
- **YearRemodAdd:** Remodel date
- **RoofStyle:** Type of roof
- **Exterior1st:** Exterior covering on house
- **Exterior2nd:** Exterior covering on house (if more than one material)
- **MasVnrType:** Masonry veneer type
- **MasVnrArea:** Masonry veneer area in square feet
- ...

2.2 Business objectives

In this part we are going to analyze the business objective of the project. Our goal is different from the one of the competition, in fact we are requested to **convert the Sale Price variable into 3 ranges**:

1. **LOW**: From 0 to 150000
2. **MEDIUM**: From 150000 to 300000
3. **HIGH**: From 300000 and beyond

So, our goal is to predict a categorical variable with 3 possible values, instead of a continuous variable. This is a very important difference, because we are not interested in the exact value of the Sale Price, but only in the range in which it falls.

2.3 Business success criteria

The success criteria of the project is to obtain a model that is able to predict the Sale Price range with a good accuracy. In particular, we want to create a model that is able to predict the Sale Price range with an accuracy of at least SOMETHING.

2.4 Assessment of the situation

There is a very important aspect that we have to consider: there are a lot of variables in the dataset that contains a values of **NA**, that could lead to thinking that the value is missing.

Actually, this is not always true. In particular, the description of the dataset contains information about the meaning of the **NA** value for each variable. For example, the **NA** value for the **PoolQC** variable means that the house doesn't have a pool, so the value is not missing, but it is a value that has a meaning.

There are more variables that have a similar meaning for the **NA** value, so we have to be careful when we are going to handle the missing values. For this project, we are going to assume that the **NA** value is not missing but is just a value that has a meaning. If we need to drop the column, will be specified in the particular section

2.5 Inventory of resources

For this project, we are going to use the following resources:

- **Python 3.10.6**: The programming language used for the project
- **Jupyter Notebook**: The IDE used for the project
- **Pandas**: The library used for the data manipulation
- **Numpy**: The library used for the data manipulation
- **Matplotlib**: The library used for the data visualization
- **Seaborn**: The library used for the data visualization
- **Scikit-learn**: The library used for the machine learning

2.6 Project Plan

The development of the project will be divided into 5 main phases, that are split like this:

- **Phase 1:** Data understanding (1 week)
- **Phase 2:** Data preparation (1 week)
- **Phase 3:** Modeling (1 week)
- **Phase 4:** Evaluation (1 week)
- **Phase 5:** Deployment (1 week)

Chapter 3

Data understanding

3.1 Data description

The dataset we are using, House Prices - Advanced Regression Techniques, is a dataset containing 79 explanatory variables describing (almost) every aspect of residential homes in Ames, Iowa. The dataset is composed of 1460 rows, each one representing a house, and 81 columns, 80 of which are features and 1 is the target variable, the SalePrice.

With the dataset is provided a *data description* with the description for each variable in the dataset.

Table 3.1: Property Features

Feature	Description
SalePrice	The property's sale price in dollars. This is the target variable that you're trying to predict.
MSSubClass	The building class
MSZoning	The general zoning classification
LotFrontage	Linear feet of street connected to property
LotArea	Lot size in square feet
Street	Type of road access
Alley	Type of alley access
LotShape	General shape of property

Continued on next page

Table 3.1 – continued from previous page

Feature	Description
LandContour	Flatness of the property
Utilities	Type of utilities available
LotConfig	Lot configuration
LandSlope	Slope of property
Neighborhood	Physical locations within Ames city limits
Condition1	Proximity to main road or railroad
Condition2	Proximity to main road or railroad (if a second is present)
BldgType	Type of dwelling
HouseStyle	Style of dwelling
OverallQual	Overall material and finish quality
OverallCond	Overall condition rating
YearBuilt	Original construction date
YearRemodAdd	Remodel date
RoofStyle	Type of roof
RoofMatl	Roof material
Exterior1st	Exterior covering on house
Exterior2nd	Exterior covering on house (if more than one material)
MasVnrType	Masonry veneer type
MasVnrArea	Masonry veneer area in square feet
ExterQual	Exterior material quality
ExterCond	Present condition of the material on the exterior

Continued on next page

Table 3.1 – continued from previous page

Feature	Description
Foundation	Type of foundation
BsmtQual	Height of the basement
BsmtCond	General condition of the basement
BsmtExposure	Walkout or garden level basement walls
BsmtFinType1	Quality of basement finished area
BsmtFinSF1	Type 1 finished square feet
BsmtFinType2	Quality of second finished area (if present)
BsmtFinSF2	Type 2 finished square feet
BsmtUnfSF	Unfinished square feet of basement area
TotalBsmtSF	Total square feet of basement area
Heating	Type of heating
HeatingQC	Heating quality and condition
CentralAir	Central air conditioning
Electrical	Electrical system
1stFlrSF	First Floor square feet
2ndFlrSF	Second floor square feet
LowQualFinSF	Low quality finished square feet (all floors)
GrLivArea	Above grade (ground) living area square feet

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Table 3.1 – continued from previous page

Feature	Description
BsmtFullBath	Basement full bathrooms
BsmtHalfBath	Basement half bathrooms
FullBath	Full bathrooms above grade
HalfBath	Half baths above grade
Bedroom	Number of bedrooms above basement level
Kitchen	Number of kitchens
KitchenQual	Kitchen quality
TotRmsAbvGrd	Total rooms above grade (does not include bathrooms)
Functional	Home functionality rating
Fireplaces	Number of fireplaces
FireplaceQu	Fireplace quality
GarageType	Garage location
GarageYrBlt	Year garage was built
GarageFinish	Interior finish of the garage
GarageCars	Size of garage in car capacity
GarageArea	Size of garage in square feet
GarageQual	Garage quality
GarageCond	Garage condition
PavedDrive	Paved driveway
WoodDeckSF	Wood deck area in square feet
OpenPorchSF	Open porch area in square feet
EnclosedPorch	Enclosed porch area in square feet

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Table 3.1 – continued from previous page

Feature	Description
3SsnPorch	Three season porch area in square feet
ScreenPorch	Screen porch area in square feet
PoolArea	Pool area in square feet
PoolQC	Pool quality
Fence	Fence quality
MiscFeature	Miscellaneous feature not covered in other categories
MiscVal	\$Value of miscellaneous feature
MoSold	Month Sold
YrSold	Year Sold
SaleType	Type of sale
SaleCondition	Condition of sale

An important thing to specify is that the dataset is given with an additional "data_description.txt" file that describes the features in detail. This file is used to understand the features and their values. From here, some variables have a specific value to point the fact the the house doesn't have that feature. For example, the feature "Alley" has the value "NA" to point the fact that the house doesn't have an alley. This is important to know. The next list contains all the features that have the value 'NA' indicating the non-existence of the feature.

1. Alley
2. BsmtQual
3. BsmtCond
4. BsmtExposure
5. BsmtFinType1
6. BsmtFinType2
7. FireplaceQu
8. GarageType
9. GarageFinish
10. GarageQual
11. GarageCond

12. PoolQC

13. Fence

14. MiscFeature

In this project, as a team we decided to consider those variables **not null**, and considering the value 'NA' always as the non-existence of the feature. This is important to know because it will be used in the data cleaning phase.

Note that this is not related to the other variables, since the variables not mentioned in the above list have the value 'NA' to indicate **null value**. For example, if in some rows the feature "MasVnrType" has the value "NA", it means that the value is null and not that the house doesn't have a masonry veneer type.

If something is missing please fill this section.

3.2 Data exploration

The dataset contains 81 features, and 1460 rows. The attributes gives information about the house, and the target variable is the SalePrice. The goal of this project is to predict the SalePrice of a house given the features. The features are a mix of categorical and numerical variables.

	Id	MSSubClass	MSZoning	LotFrontage	LotArea	Street	Alley	LotShape	LandContour	Utilities	...	PoolArea	PoolQC	Fence	MiscFeature	MiscVal	MoSold	YrSold	SaleType	SaleCondition	SalePrice
0	1	60	RL	65.0	8450	Pave	None	Reg	Lvl	AllPub	...	0	None	None	None	0	2	2008	WD	Normal	208500
1	2	20	RL	80.0	9600	Pave	None	Reg	Lvl	AllPub	...	0	None	None	None	0	5	2007	WD	Normal	181500
2	3	60	RL	68.0	11250	Pave	None	IR1	Lvl	AllPub	...	0	None	None	None	0	9	2008	WD	Normal	223500
3	4	70	RL	60.0	9550	Pave	None	IR1	Lvl	AllPub	...	0	None	None	None	0	2	2006	WD	Abnorml	140000
4	5	60	RL	84.0	14290	Pave	None	IR1	Lvl	AllPub	...	0	None	None	None	0	12	2008	WD	Normal	250000
...
1456	1456	60	RL	62.0	7917	Pave	None	Reg	Lvl	AllPub	...	0	None	None	None	0	8	2007	WD	Normal	175000
1456	1457	20	RL	85.0	13175	Pave	None	Reg	Lvl	AllPub	...	0	None	MrPrv	None	0	2	2010	WD	Normal	210000
1457	1458	70	RL	66.0	9042	Pave	None	Reg	Lvl	AllPub	...	0	None	GdPrv	Shed	2500	5	2010	WD	Normal	265500
1458	1459	20	RL	68.0	9717	Pave	None	Reg	Lvl	AllPub	...	0	None	None	None	0	4	2010	WD	Normal	142125
1459	1460	20	RL	75.0	9937	Pave	None	Reg	Lvl	AllPub	...	0	None	None	None	0	6	2008	WD	Normal	147500

Figure 3.1: Dataset print

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1460 entries, 0 to 1459
Data columns (total 81 columns):
 #   Column           Non-Null Count  Dtype  
 ____ 
 0   Id               1460 non-null    int64  
 1   MSSubClass        1460 non-null    int64  
 2   MSZoning          1460 non-null    object  
 3   LotFrontage       1201 non-null    float64 
 4   LotArea           1460 non-null    int64  
 5   Street            1460 non-null    object  
 6   Alley              91 non-null     object  
 7   LotShape           1460 non-null    object  
 8   LandContour        1460 non-null    object  
 9   Utilities          1460 non-null    object  
 10  LotConfig          1460 non-null    object
```

11	LandSlope	1460	non-null	object
12	Neighborhood	1460	non-null	object
13	Condition1	1460	non-null	object
14	Condition2	1460	non-null	object
15	BldgType	1460	non-null	object
16	HouseStyle	1460	non-null	object
17	OverallQual	1460	non-null	int64
18	OverallCond	1460	non-null	int64
19	YearBuilt	1460	non-null	int64
20	YearRemodAdd	1460	non-null	int64
21	RoofStyle	1460	non-null	object
22	RoofMatl	1460	non-null	object
23	Exterior1st	1460	non-null	object
24	Exterior2nd	1460	non-null	object
25	MasVnrType	588	non-null	object
26	MasVnrArea	1452	non-null	float64
27	ExterQual	1460	non-null	object
28	ExterCond	1460	non-null	object
29	Foundation	1460	non-null	object
30	BsmtQual	1423	non-null	object
31	BsmtCond	1423	non-null	object
32	BsmtExposure	1422	non-null	object
33	BsmtFinType1	1423	non-null	object
34	BsmtFinSF1	1460	non-null	int64
35	BsmtFinType2	1422	non-null	object
36	BsmtFinSF2	1460	non-null	int64
37	BsmtUnfSF	1460	non-null	int64
38	TotalBsmtSF	1460	non-null	int64
39	Heating	1460	non-null	object
40	HeatingQC	1460	non-null	object
41	CentralAir	1460	non-null	object
42	Electrical	1459	non-null	object
43	1stFlrSF	1460	non-null	int64
44	2ndFlrSF	1460	non-null	int64
45	LowQualFinSF	1460	non-null	int64
46	GrLivArea	1460	non-null	int64
47	BsmtFullBath	1460	non-null	int64
48	BsmtHalfBath	1460	non-null	int64
49	FullBath	1460	non-null	int64
50	HalfBath	1460	non-null	int64
51	BedroomAbvGr	1460	non-null	int64
52	KitchenAbvGr	1460	non-null	int64
53	KitchenQual	1460	non-null	object

```

54  TotRmsAbvGrd    1460 non-null   int64
55  Functional      1460 non-null   object
56  Fireplaces       1460 non-null   int64
57  FireplaceQu     770 non-null   object
58  GarageType       1379 non-null   object
59  GarageYrBlt     1379 non-null   float64
60  GarageFinish     1379 non-null   object
61  GarageCars       1460 non-null   int64
62  GarageArea        1460 non-null   int64
63  GarageQual       1379 non-null   object
64  GarageCond       1379 non-null   object
65  PavedDrive       1460 non-null   object
66  WoodDeckSF       1460 non-null   int64
67  OpenPorchSF      1460 non-null   int64
68  EnclosedPorch    1460 non-null   int64
69  3SsnPorch        1460 non-null   int64
70  ScreenPorch      1460 non-null   int64
71  PoolArea         1460 non-null   int64
72  PoolQC           7 non-null     object
73  Fence             281 non-null   object
74  MiscFeature      54 non-null    object
75  MiscVal          1460 non-null   int64
76  MoSold            1460 non-null   int64
77  YrSold            1460 non-null   int64
78  SaleType          1460 non-null   object
79  SaleCondition     1460 non-null   object
80  SalePrice         1460 non-null   int64
dtypes: float64(3), int64(35), object(43)
memory usage: 924.0+ KB

```

3.2.1 Preliminary operation on data preparation

In order to achieve **better results looking at data and graphs**, we decided to do some data transformation and cleaning before the data processing part. This choice brings an easier and more intuitive data visualization and analysis for us, in order to get a better insight of the data.

The action carried out in this part are the following:

1. Trasnforming **NA** values into **no_value** for the categorical features written in the precedent section.
2. Setting GarageYrBlt, MasVnrArea, LotFrontage null values to **0**
3. Changing all the columns with attribute **object** to **category** type
4. Changed MasVnrArea and LotFrontage to **int64** type
5. Dropped one row with Electrical null value

6. Others changes during data visualization part (Will be reported in the data processing section)

3.2.2 Data Exploration - More in depth

	count	mean	std	min	25%	50%	75%	max
Id	1460.0	730.500000	421.610009	1.0	365.75	730.5	1095.25	1460.0
MSSubClass	1460.0	56.897260	42.300571	20.0	20.00	50.0	70.00	190.0
LotFrontage	1460.0	57.623288	34.664304	0.0	42.00	63.0	79.00	313.0
LotArea	1460.0	10516.828082	9981.264932	1300.0	7553.50	9478.5	11601.50	215245.0
OverallQual	1460.0	6.099315	1.382997	1.0	5.00	6.0	7.00	10.0
OverallCond	1460.0	5.575342	1.112799	1.0	5.00	5.0	6.00	9.0
YearBuilt	1460.0	1971.267808	30.202904	1872.0	1954.00	1973.0	2000.00	2010.0
YearRemodAdd	1460.0	1984.865753	20.645407	1950.0	1967.00	1994.0	2004.00	2010.0
MasVnrArea	1460.0	103.117123	180.731373	0.0	0.00	0.0	164.25	1600.0
BsmtFinSF1	1460.0	443.639726	456.098091	0.0	0.00	383.5	712.25	5644.0
BsmtFinSF2	1460.0	46.549315	161.319273	0.0	0.00	0.0	0.00	1474.0
BsmtUnfSF	1460.0	567.240411	441.866955	0.0	223.00	477.5	808.00	2336.0
TotalBsmtSF	1460.0	1057.429452	438.705324	0.0	795.75	991.5	1298.25	6110.0
1stFlrSF	1460.0	1162.626712	386.587738	334.0	882.00	1087.0	1391.25	4692.0
2ndFlrSF	1460.0	346.992466	436.528436	0.0	0.00	0.0	728.00	2065.0
LowQualFinSF	1460.0	5.844521	48.623081	0.0	0.00	0.0	0.00	572.0
GrLivArea	1460.0	1515.463699	525.480383	334.0	1129.50	1464.0	1776.75	5642.0
BsmtFullBath	1460.0	0.425342	0.518911	0.0	0.00	0.0	1.00	3.0
BsmtHalfBath	1460.0	0.057534	0.238753	0.0	0.00	0.0	0.00	2.0
FullBath	1460.0	1.565068	0.550916	0.0	1.00	2.0	2.00	3.0
HalfBath	1460.0	0.382877	0.502885	0.0	0.00	0.0	1.00	2.0
BedroomAbvGr	1460.0	2.866438	0.815778	0.0	2.00	3.0	3.00	8.0
KitchenAbvGr	1460.0	1.046575	0.220338	0.0	1.00	1.0	1.00	3.0

Figure 3.2: Numerical info 1

TotRmsAbvGrd	1460.0	6.517808	1.625393	2.0	5.00	6.0	7.00	14.0
Fireplaces	1460.0	0.613014	0.644666	0.0	0.00	1.0	1.00	3.0
GarageYrBlt	1460.0	1868.739726	453.697295	0.0	1958.00	1977.0	2001.00	2010.0
GarageCars	1460.0	1.767123	0.747315	0.0	1.00	2.0	2.00	4.0
GarageArea	1460.0	472.980137	213.804841	0.0	334.50	480.0	576.00	1418.0
WoodDeckSF	1460.0	94.244521	125.338794	0.0	0.00	0.0	168.00	857.0
OpenPorchSF	1460.0	46.660274	66.256028	0.0	0.00	25.0	68.00	547.0
EnclosedPorch	1460.0	21.954110	61.119149	0.0	0.00	0.0	0.00	552.0
3SsnPorch	1460.0	3.409589	29.317331	0.0	0.00	0.0	0.00	508.0
ScreenPorch	1460.0	15.060959	55.757415	0.0	0.00	0.0	0.00	480.0
PoolArea	1460.0	2.758904	40.177307	0.0	0.00	0.0	0.00	738.0
MiscVal	1460.0	43.489041	496.123024	0.0	0.00	0.0	0.00	15500.0
MoSold	1460.0	6.321918	2.703626	1.0	5.00	6.0	8.00	12.0
YrSold	1460.0	2007.815753	1.328095	2006.0	2007.00	2008.0	2009.00	2010.0
SalePrice	1460.0	180921.195890	79442.502883	34900.0	129975.00	163000.0	214000.00	755000.0

Figure 3.3: Numerical info 2

	count	unique	top	freq
MSZoning	1460	5	RL	1151
Street	1460	2	Pave	1454
Alley	1460	3	no_value	1369
LotShape	1460	4	Reg	925
LandContour	1460	4	Lvl	1311
Utilities	1460	2	AllPub	1459
LotConfig	1460	5	Inside	1052
LandSlope	1460	3	Gtl	1382
Neighborhood	1460	25	NAmes	225
Condition1	1460	9	Norm	1260
Condition2	1460	8	Norm	1445
BldgType	1460	5	1Fam	1220
HouseStyle	1460	8	1Story	726
RoofStyle	1460	6	Gable	1141
RoofMatl	1460	8	CompShg	1434
Exterior1st	1460	15	VinylSd	515
Exterior2nd	1460	16	VinylSd	504
MasVnrType	1460	4	no_value	872
ExterQual	1460	4	TA	906
ExterCond	1460	17	TA	1282
Foundation	1460	6	PConc	647

BsmtCond	1460	5	TA	1311
BsmtExposure	1460	5	No	953
BsmtFinType1	1460	7	Unf	430
BsmtFinType2	1460	7	Unf	1256
Heating	1460	6	GasA	1428
HeatingQC	1460	5	Ex	741
CentralAir	1460	2	Y	1365
Electrical	1459	5	SBrkr	1334
KitchenQual	1460	4	TA	735
Functional	1460	7	Typ	1360
FireplaceQu	1460	6	no_value	690
GarageType	1460	7	Attchd	870
GarageFinish	1460	4	Unf	605
GarageQual	1460	6	TA	1311
GarageCond	1460	6	TA	1326
PavedDrive	1460	3	Y	1340
PoolQC	1460	4	no_value	1453
Fence	1460	5	no_value	1179
MiscFeature	1460	5	no_value	1406
SaleType	1460	9	WD	1267
SaleCondition	1460	¹⁸ 6	Normal	1198

Figure 3.5: Categorical info 2