hotel-bookings

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1 Hotel Bookings

Programmazione di Applicazioni Data Intensive
Laurea in Ingegneria e Scienze Informatiche
DISI - Università di Bologna, Cesena

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[166]:
```
# Setup librerie
%matplotlib inline
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import sklearn
```

1.1 Caso di studio

- Data una prenotazione di un cliente presso un hotel, si vuole valutare se questa verrà cancellata
- Da ciascuna prenotazione possono essere estratte delle caratteristiche
  - numero di adulti, giorno di arrivo, numero di posti auto richiesti, …
- Vogliamo addestrare un modello a classificare ciascuna prenotazione sulla base di queste caratteristiche
- Utilizziamo Hotel booking demand, in cui ogni osservazione contiene le caratteristiche estratte da una prenotazione
- Con `read_csv` possiamo importare il dataset direttamente in un frame pandas dato il suo URL

[167]:
```
HBD_URL = "https://bitbucket.org/alessandrolombardini/hotel-bookings/raw/
↪d5130f7e47e3e943886c1ab5266197202e6fe9af/hotel_bookings.csv"
hbd_complete = pd.read_csv(HBD_URL)
```

[168]:
```
hbd_complete.head(3)
```

[168]:
```
          hotel  is_canceled  lead_time  arrival_date_year arrival_date_month  \
0  Resort Hotel            0        342               2015               July
1  Resort Hotel            0        737               2015               July
2  Resort Hotel            0          7               2015               July
```

```
   arrival_date_week_number  arrival_date_day_of_month  \
0                        27                          1
1                        27                          1
2                        27                          1

   stays_in_weekend_nights  stays_in_week_nights  adults  children  babies  \
0                        0                     0       2       0.0       0
1                        0                     0       2       0.0       0
2                        0                     1       1       0.0       0

  meal country market_segment distribution_channel  is_repeated_guest  \
0   BB     PRT         Direct               Direct                  0
1   BB     PRT         Direct               Direct                  0
2   BB     GBR         Direct               Direct                  0

   previous_cancellations  previous_bookings_not_canceled reserved_room_type  \
0                       0                               0                  C
1                       0                               0                  C
2                       0                               0                  A

  assigned_room_type  booking_changes deposit_type  agent  company  \
0                  C                3   No Deposit    NaN      NaN
1                  C                4   No Deposit    NaN      NaN
2                  C                0   No Deposit    NaN      NaN

   days_in_waiting_list customer_type   adr  required_car_parking_spaces  \
0                     0     Transient   0.0                            0
1                     0     Transient   0.0                            0
2                     0     Transient  75.0                            0

   total_of_special_requests reservation_status reservation_status_date
0                          0          Check-Out              2015-07-01
1                          0          Check-Out              2015-07-01
2                          0          Check-Out              2015-07-02
```

- `Hotel booking demand` prevede al suo interno due dataset, uno per *Resort Hotel* e uno per *City Hotel*
  - Entrambi i dataset condividono la stessa struttura
  - Entrambi comprendono prenotazioni effettuate dal 1 Luglio 2015 al 31 Agosto 2017
- Poichè questi sono dati reali, tutti i dati personali dei clienti sono stati eliminati oppore sostiuiti con identificativi anonimi
- Il dataset presenta le seguenti dimensioni…

[169]:
```
print(hbd_complete.shape[0], "istanze")
print(hbd_complete.shape[1], "variabili\n")
```

```
print(hbd_complete[hbd_complete["hotel"]=="City Hotel"].shape[0], "istanze di␣
↪City Hotel")
print(hbd_complete[hbd_complete["hotel"]=="Resort Hotel"].shape[0], "istanze di␣
↪Resort Hotel")
```

```
119390 istanze
32 variabili

79330 istanze di City Hotel
40060 istanze di Resort Hotel
```

- Il nostro obiettivo è realizzare un modello di classificazione per la struttura *City Hotel*
- Si tratta di classificazione binaria, ovvero con due possibili classi
  - La colonna `is_canceled` indica la classificazione delle prenotazioni
    * 0 = non cancellata
    * 1 = cancellata
  - Le altre 31 colonne corrispondono alle altre variabili estratte dalla prenotazione

1.1.1 Lista delle variabili

- `hotel`: hotel prenotato dal cliente (H1 = Resort Hotel o H2 = City Hotel)
- `lead_time`: numero di giorni che intercorrono dal giorno di prenotazione al giorno di arrivo in hotel del cliente
- `arrival_date_year`: anno di arrivo del cliente in hotel
- `arrival_date_month`: mese di arrivo del cliente in hotel
- `arrival_date_week_number`: numero della settimana dell'anno di arrivo del cliente in hotel
- `arrival_date_day_of_month`: numero del giorno del mese di arrivo del cliente in hotel
- `stays_in_weekend_nights`: numero di notti di finesettimana (Sabato e Domenica) prenotate del cliente
- `stays_in_week_nights`: numero di notti non di finesettimana (da Lunedi a Venerdi) prenotate del cliente
- `adults`: numero di adulti
- `children`: numero di bambini
- `babies`: numero di neonati
- `meal`: pacchetto pasti richiesto dal cliente
  - Undefined/SC – nessuno pacchetto
  - BB – Bed & Breakfast
  - HB – Mezza pensione (colazione ed un altro pasto – solitamente cena);
  - FB – Pensione completa (colazione, pranzo e cena)
- `country`: stato di provenienza
- `market_segment`: segmento di mercato associato alla prenotazione (utile per raggruppare le prenotazioni in gruppi, al fine di adottare stategie di marketing adeguate)
- `distribution_channel`: canale per tramite del quale il cliente ha effettuato la prenotazione (TA/TO: il cliente si è appoggiato ad un agente di viaggio, Direct: la prenotazione è stata fatta dal cliente direttamente, ed altri)
- `is_repeated_guest`: indica se la prenotazione è fatta da un cliente che aveva già prenotato in passato

    - 1: Si, aveva già prenotato
    - 0: No, non aveva mai prenotato
- `previous_cancellations`: numero di prenotazioni cancellate in passato dal cliente
- `previous_bookings_not_canceled`: numero di prenotazioni effettuate in passato dal cliente e non cancellate
- `reserved_room_type`: codice del tipo di stanza richiesta dal cliente
- `assigned_room_type`: codice del tipo di stanza assegnata alla prenotazione. A volte vengono assegnate stanze diverse da quelle riservate per motivi legati all'Hotel (es. overbooking) o per richiesta del cliente.
- `booking_changes`: numero di cambiamenti apportati alla prenotazione fino al momento del Check-In o della cancellazione
- `deposit_type`: indica se il cliente ha effettuato un deposito per garantirsi la prenotazione
    - No Deposit: nessun deposito è stato fatto
    - Non Refund: è stato pagato l'intero importo del soggiorno
    - Refundable: è stata pagata solo una parte dell'importo dell'intero soggiorno
- `agent`: ID dell'agente di viaggio che ha effettuato la prenotazione
- `company`: ID della compagnia che ha effettuato la prenotazione o che ha pagato la prenotazione.
- `days_in_waiting_list`: numero di giorni in cui la prenotazione è rimasta in lista di attesa prima di essere confermata al cliente
- `customer_type`: tipologia di prenotazione
    - Contract: la prenotazione è associata ad un contratto
    - Group: la prenotazione è associata ad un gruppo
    - Transient: la prenotazione non è parte ne di un gruppo ne di un contratto, e non è associata ad altre prenotazione Transient
    - Transient-party: la prenotazione è Transient ed è associata ad altre prenotazioni Transient (Transient è un termine utilizzato per indicare quelle prenotazioni effettuate da soggetti prevalentemente in movimento che effettuano brevi soggiorni in hotel, spesso last minute)
- `adr`: Avarage Daily Rate, definito come il costo del soggiorno diviso il numero di notti
- `required_car_parking_spaces`: numero di spazi macchina richiesti dal cliente
- `total_of_special_requests`: numero di richieste speciali effettuate dal cliente
- `reservation_status`: ultimo stato registrato della prenotazione
    - Canceled: la prenotazione è stata cancellata dal cliente
    - Check-Out: il client ha effettuato il Check-In e la sua permanenza è terminata
    - No-Show: il cliente non ha effettuato il Check-In e ha informato l'hotel del motivo
- `reservation_status_date`: data dell'ultima modifica alla variabile `reservation_status`
- `is_canceled`: indica se la prenotazione è stata cancellata o no
    - 0: Non cancellata
    - 1: Cancellata
- La variabile **is_canceled** indica la classificazione della prenotazione, vogliamo stabilire il valore di questa variabile in funzione delle altre

- Aumentiamo il limite di colonne che pandas di default ci consente di visualizzare

[170]:
```
pd.options.display.max_columns = 32
```

[171]:
```
hbd_complete.head(3)
```

[171]:
```
          hotel  is_canceled  lead_time  arrival_date_year arrival_date_month  \
0  Resort Hotel            0        342               2015               July
1  Resort Hotel            0        737               2015               July
2  Resort Hotel            0          7               2015               July

   arrival_date_week_number  arrival_date_day_of_month  \
0                        27                          1
1                        27                          1
2                        27                          1

   stays_in_weekend_nights  stays_in_week_nights  adults  children  babies  \
0                        0                     0       2       0.0       0
1                        0                     0       2       0.0       0
2                        0                     1       1       0.0       0

  meal country market_segment distribution_channel  is_repeated_guest  \
0   BB     PRT         Direct               Direct                  0
1   BB     PRT         Direct               Direct                  0
2   BB     GBR         Direct               Direct                  0

   previous_cancellations  previous_bookings_not_canceled reserved_room_type  \
0                       0                               0                  C
1                       0                               0                  C
2                       0                               0                  A

  assigned_room_type  booking_changes deposit_type  agent  company  \
0                  C                3   No Deposit    NaN      NaN
1                  C                4   No Deposit    NaN      NaN
2                  C                0   No Deposit    NaN      NaN

   days_in_waiting_list customer_type   adr  required_car_parking_spaces  \
0                     0     Transient   0.0                            0
1                     0     Transient   0.0                            0
2                     0     Transient  75.0                            0

   total_of_special_requests reservation_status reservation_status_date
0                          0          Check-Out              2015-07-01
1                          0          Check-Out              2015-07-01
2                          0          Check-Out              2015-07-02
```

1.2 Preparazione dei dati

- Riportiamo lo spazio occupato in memoria dal dataset

[172]:
```python
hbd_complete.info(verbose=False, memory_usage="deep");
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 119390 entries, 0 to 119389
```

```
Columns: 32 entries, hotel to reservation_status_date
dtypes: float64(4), int64(16), object(12)
memory usage: 105.7 MB
```

- Osserviamo che sono presenti molte variabili di tipo *object*
  - Il dataset così caricato occupa molto spazio, è quindi opportuno specificare che parte delle variabili *object* devono essere gestite come categoriche
    - Tutte eccetto `reservation_status_date` in quanto presenta come valori delle date

[173]:
```
object_variable = hbd_complete.dtypes[hbd_complete.dtypes == np.object].
↪drop(["reservation_status_date"]).index
hbd_complete[object_variable] = hbd_complete[object_variable].astype("category")
```

- Verifichiamo la dimensione in memoria attuale

[174]:
```
hbd_complete.info(verbose=False, memory_usage="deep")
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 119390 entries, 0 to 119389
Columns: 32 entries, hotel to reservation_status_date
dtypes: category(11), float64(4), int64(16), object(1)
memory usage: 27.2 MB
```

- Lo spazio occupato in memoria si è circa dimezzato due volte
- Come accennato il nostro obiettivo è realizzare un modello di classificazione per una specificia struttura ospitante, la struttura *City Hotel*
  - Il dataset prevede istanze di due strutture: *Resort Hotel* e *City Hotel*

[175]:
```
hbd_complete["hotel"].unique()
```

[175]:
```
[Resort Hotel, City Hotel]
Categories (2, object): [Resort Hotel, City Hotel]
```

- La preparazione dei dati viene effettuata sul dataset completo per poi rimuovere le istanze di *Resort Hotel* al termine
  - Il dataset completo ci sarà utile in seguito
- Visualizziamo il numero di valori distinti per ciascuna feature

[176]:
```
hbd_complete.nunique()
```

[176]:
```
hotel                               2
is_canceled                         2
lead_time                         479
arrival_date_year                   3
arrival_date_month                 12
arrival_date_week_number           53
arrival_date_day_of_month          31
stays_in_weekend_nights            17
stays_in_week_nights               35
```

```
adults                              14
children                             5
babies                               5
meal                                 5
country                            177
market_segment                       8
distribution_channel                 5
is_repeated_guest                    2
previous_cancellations              15
previous_bookings_not_canceled      73
reserved_room_type                  10
assigned_room_type                  12
booking_changes                     21
deposit_type                         3
agent                              333
company                            352
days_in_waiting_list               128
customer_type                        4
adr                               8879
required_car_parking_spaces          5
total_of_special_requests            6
reservation_status                   3
reservation_status_date            926
dtype: int64
```

- Tutte le feature presentano una variabilità adatta alla loro semantica
- La variabili temporali associate all' arrivo del cliente in hotel attualmente presenti possono essere sostituite con altre variabili che presentano maggiore correlazione con ciò che stiamo cercando di prevedere
- Le variabili attualmente in nostro possesso sono:
  - `arrival_date_year`
  - `arrival_date_month`
  - `arrival_date_week_number`
  - `arrival_date_day_of_month`
- Per prima cosa vogliamo aggiungere il giorno della settimana (Lunedi, Martedi, …)
  - In questo contesto è infatti più rilevante il giorno della settimana piuttosto che il giorno del mese
    * Per farlo è necessario avere a nostra disposizione un dizionario che ci consenta di ottenere, dato il nome del mese, il suo indice (1. Gennaio, 2. Febbrario, …)

[177]:
```
import calendar
dict_month_convertion = dict((v,k) for k,v in enumerate(calendar.month_name))
```

- Mostriamo un esempio

[178]:
```
hbd_complete["arrival_date_month"].head(1)
```

[178]:
```
0    July
Name: arrival_date_month, dtype: category
Categories (12, object): [April, August, December, February, …, May, November,
October, September]
```

[179]:
```
hbd_complete["arrival_date_month"].head(1).map(dict_month_convertion)
```

[179]:
```
0    7
Name: arrival_date_month, dtype: category
Categories (12, int64): [4, 8, 12, 2, …, 5, 11, 10, 9]
```

- Utilizziamo questo dizionario per ottenere una serie che mappa, con il metodo appena mostrato, la variabile `arrival_date_month`

[180]:
```
arrival_date_month_number = hbd_complete["arrival_date_month"].
↪map(dict_month_convertion)
```

- Definiamo una funzione che presa in input una data, una stringa nel formato *giorno mese anno* , ci restituisca il nome del giorno

[181]:
```
import datetime

def findDay(date):
    day = datetime.datetime.strptime(date, '%d %m %Y').weekday()
    return (calendar.day_name[day])
```

- Realizziamo la nuova variabile `arrival_date_day`
  - Anche essa categorica

[182]:
```
arrival_date_day = []
for index, row in hbd_complete.iterrows():
    arrival_date_day.append(findDay("{0} {1} {2}".
↪format(row["arrival_date_day_of_month"], arrival_date_month_number[index],␣
↪row["arrival_date_year"])))

hbd_complete.insert(2, "arrival_date_day", arrival_date_day)
hbd_complete["arrival_date_day"] = hbd_complete["arrival_date_day"].
↪astype("category")
```

- Eliminiamo la variabile `arrival_date_day_of_month`, ovvero il giorno del mese di arrivo in hotel
- Eliminiamo anche la variabile `arrival_date_year`, in quanto non particolarmente utile

[183]:
```
hbd_complete.drop(inplace=True, axis=1, labels=['arrival_date_year',␣
↪'arrival_date_day_of_month'])
```

- La variabile `assigned_room_type` non è disponibile al momento della prenotazione, ma solo al momento del Check-In. Rappresenta la camera che viene assegnata al cliente al momento del suo arrivo in hotel, e non la camera prenotata.
  - E' dunque rimossa

[184]:
```
hbd_complete.drop(inplace=True, axis=1, labels=['assigned_room_type'])
```

- Osservando la descrizione delle variabili è possibile notare come vi sia una grossa affinità tra le variabili `is_canceled` e `reservation_status`
- I possibili valori di `reservation_status` sono…

[185]:
```
hbd_complete["reservation_status"].unique()
```

[185]:
```
[Check-Out, Canceled, No-Show]
Categories (3, object): [Check-Out, Canceled, No-Show]
```

- Il valore *Check-Out* potrebbe corrispondere alla mancata cancellazione, mentre il valore *Canceled* alla effettiva cancellazione. Anche il campo *No-Show* potrebbe essere considerato come prenotazione cancellata.
  - Definiziamo un dizionario in cui mappiamo i valori di `reservation_status`
    * Check-Out come non cancellata (0)
    * No-Show come cancellata (1)
    * Canceled come cancellata (1)

[186]:
```
mapping_reservation_status = {}
mapping_reservation_status['Check-Out'] = 0
mapping_reservation_status['No-Show'] = 1
mapping_reservation_status['Canceled'] = 1
```

- Mappiamo la variabile `reservation_status` con il dizionario creato

[187]:
```
reservation_status_mapped = hbd_complete["reservation_status"].
 ↪map(mapping_reservation_status)
```

- Verifichiamo se la serie ottenuta coincice con la variabile `is_canceled`.

[188]:
```
all(hbd_complete["is_canceled"] == reservation_status_mapped)
```

[188]:
```
True
```

- La considerazione era corretta, le variabili `is_canceled` e `reservation_status` coincidono.
  - Il valore *Check-Out* viene utilizzato quando la prenotazione non è stata cancellata
  - I valori *Canceled* e *No-Shown* vengono invece utilizzati quando la prenotazione è stata cancellata.
- Questa variabile va dunque rimossa in quanto coincide con la variabile da predire
  - Rimuoviamo anche `reservation_status_date`, in quanto inutile senza `reservation_status`

[189]:
```
hbd_complete.drop(inplace=True, axis=1, labels=['reservation_status',␣
↪'reservation_status_date'])
```

- Verifichiamo la presenza del valore `nan` nelle istanze

[190]:
```
hbd_complete.isnull().sum()
```

[190]:
```
hotel                                0
is_canceled                          0
arrival_date_day                     0
lead_time                            0
arrival_date_month                   0
arrival_date_week_number             0
stays_in_weekend_nights              0
stays_in_week_nights                 0
adults                               0
children                             4
babies                               0
meal                                 0
country                            488
market_segment                       0
distribution_channel                 0
is_repeated_guest                    0
previous_cancellations               0
previous_bookings_not_canceled       0
reserved_room_type                   0
booking_changes                      0
deposit_type                         0
agent                            16340
company                         112593
days_in_waiting_list                 0
customer_type                        0
adr                                  0
required_car_parking_spaces          0
total_of_special_requests            0
dtype: int64
```

- Il valore `nan` è presente nelle variabili:
  - `children`
  - `country`
  - `agent`
  - `company`
- Per le variabili `children` e `country` tale valore non è accettabile, per cui rimuovo quelle istanze

[191]:
```
hbd_complete.dropna(subset=["country", "children"], inplace=True)
```

- La variabile `company` è nulla in quasi tutte le istanze, mentre `agent` per una buona parte di esse.

- Il valore nullo in questo caso è di nostro interesse in quanto implica che per quella prenotazione non è presente, rispettivamente, una company e/o un agent
  - Sostituiamo i valori di queste due variabili con 0 e 1
    * 0 se il valore è `nan`
    * 1 altrimenti
  - In questo modo manteniamo l'informazione relativa alla presenta (o assenza) di un agent e/o di una company in una prenotazione
    * Non è di particolare interesse sapere esattamente chi sia il soggetto interessato

[192]:
```
hbd_complete.loc[hbd_complete["agent"].isnull(), "agent"] = 0
hbd_complete.loc[hbd_complete["agent"] != 0, "agent"] = 1
hbd_complete.loc[hbd_complete["company"].isnull(), "company"] = 0
hbd_complete.loc[hbd_complete["company"] != 0, "company"] = 1
```

- Un' alternativa era quella di selezionare solo parte dei possibili valori di `agent` e `company` (i più frequenti) e considerare questa variabile come categorica. Ai valori più frequenti ottenuti ne andrebbero aggiunti due: *Nessuno* per sostituire tutti i valori `nan` e *Altro* , per sostituire tutti i valori diversi da `nan` non presenti fra i valori più frequenti.
  - Si è optato di non seguire questa strada
- Non sono più presenti valori `nan`

[193]:
```
hbd_complete.isnull().sum()
```

[193]:
```
hotel                             0
is_canceled                       0
arrival_date_day                  0
lead_time                         0
arrival_date_month                0
arrival_date_week_number          0
stays_in_weekend_nights           0
stays_in_week_nights              0
adults                            0
children                          0
babies                            0
meal                              0
country                           0
market_segment                    0
distribution_channel              0
is_repeated_guest                 0
previous_cancellations            0
previous_bookings_not_canceled    0
reserved_room_type                0
booking_changes                   0
deposit_type                      0
agent                             0
```

```
company                           0
days_in_waiting_list              0
customer_type                     0
adr                               0
required_car_parking_spaces       0
total_of_special_requests         0
dtype: int64
```

- Verifichiamo la tipologia delle variabili in nostro possesso

[194]:
```
hbd_complete.dtypes
```

[194]:
```
hotel                             category
is_canceled                          int64
arrival_date_day                  category
lead_time                            int64
arrival_date_month                category
arrival_date_week_number             int64
stays_in_weekend_nights              int64
stays_in_week_nights                 int64
adults                               int64
children                           float64
babies                               int64
meal                              category
country                           category
market_segment                    category
distribution_channel              category
is_repeated_guest                    int64
previous_cancellations               int64
previous_bookings_not_canceled       int64
reserved_room_type                category
booking_changes                      int64
deposit_type                      category
agent                              float64
company                            float64
days_in_waiting_list                 int64
customer_type                     category
adr                                float64
required_car_parking_spaces          int64
total_of_special_requests            int64
dtype: object
```

- Converto ad intero le variabili
  - children
  - agent
  - company

[195]:
```
hbd_complete["agent"] = hbd_complete["agent"].astype("int64")
hbd_complete["company"] = hbd_complete["company"].astype("int64")
hbd_complete["children"] = hbd_complete["children"].astype("int64")
```

[196]:
```
print("children: ", hbd_complete["children"].dtype)
print("agent: ", hbd_complete["children"].dtype)
print("company: ", hbd_complete["children"].dtype)
```

```
children:  int64
agent:  int64
company:  int64
```

- Abbiamo terminato la preparazione dei dati
  - Viene ora creato un nuovo dataframe senza le istanze di *Resort Hotel*

[197]:
```
hbd = hbd_complete[hbd_complete["hotel"] == "City Hotel"].copy()
hbd["hotel"].unique()
```

[197]:
```
[City Hotel]
Categories (1, object): [City Hotel]
```

- Il dataset ora presenta...

[198]:
```
print(hbd.shape[0], "istanze")
```

```
79302 istanze
```

- La variabile `hotel` è diventata inutile, è quindi rimossa

[199]:
```
hbd.drop(inplace=True, axis=1, labels=['hotel'])
```

1.3 Analisi esplorativa

- Visualizziamo le statistiche principali (media, dev, standard, ...) delle variabili

[200]:
```
hbd.describe().T
```

[200]:
```
                                 count        mean         std  min   25%  \
is_canceled                    79302.0    0.417089    0.493081  0.0   0.0
lead_time                      79302.0  109.740183  110.953223  0.0  23.0
arrival_date_week_number       79302.0   27.173564   13.397803  1.0  17.0
stays_in_weekend_nights        79302.0    0.795339    0.884985  0.0   0.0
stays_in_week_nights           79302.0    2.182896    1.456096  0.0   1.0
adults                         79302.0    1.851126    0.509013  0.0   2.0
children                       79302.0    0.091397    0.372230  0.0   0.0
babies                         79302.0    0.004943    0.084338  0.0   0.0
is_repeated_guest              79302.0    0.025624    0.158010  0.0   0.0
previous_cancellations         79302.0    0.079771    0.415543  0.0   0.0
previous_bookings_not_canceled 79302.0    0.132418    1.693708  0.0   0.0
```

```
booking_changes                79302.0    0.187435    0.608718  0.0   0.0
agent                          79302.0    0.897594    0.303183  0.0   1.0
company                        79302.0    0.046417    0.210389  0.0   0.0
days_in_waiting_list           79302.0    3.227914   20.874486  0.0   0.0
adr                            79302.0  105.326470   43.590608  0.0  79.2
required_car_parking_spaces    79302.0    0.024375    0.154946  0.0   0.0
total_of_special_requests      79302.0    0.547035    0.780835  0.0   0.0

                                50%    75%     max
is_canceled                     0.0    1.0     1.0
lead_time                      74.0  163.0   629.0
arrival_date_week_number       27.0   38.0    53.0
stays_in_weekend_nights         1.0    2.0    16.0
stays_in_week_nights            2.0    3.0    41.0
adults                          2.0    2.0     4.0
children                        0.0    0.0     3.0
babies                          0.0    0.0    10.0
is_repeated_guest               0.0    0.0     1.0
previous_cancellations          0.0    0.0    21.0
previous_bookings_not_canceled  0.0    0.0    72.0
booking_changes                 0.0    0.0    21.0
agent                           1.0    1.0     1.0
company                         0.0    0.0     1.0
days_in_waiting_list            0.0    0.0   391.0
adr                            99.9  126.0  5400.0
required_car_parking_spaces     0.0    0.0     3.0
total_of_special_requests       0.0    1.0     5.0
```

- Tutte le variabili presentano come minimo il valore (~) 0
- I valori non presentano la stessa scala, la standardizzazione potrà quindi essere certamente utile
- Alcune variabili mostrano un valore di massimo che in relazione alla loro semantica pare poco sensato
    - Visualizziamo il box plot di queste variabili

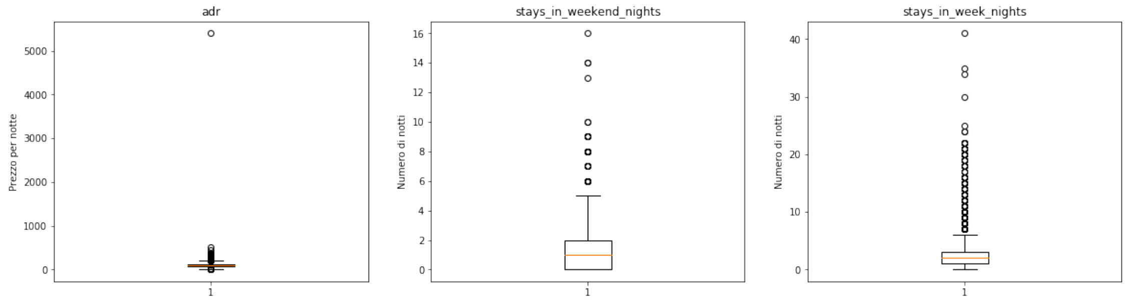
[201]:
```
plt.figure(figsize=(20, 5))

plt.subplot(1, 3, 1)
plt.title('adr')
plt.boxplot(hbd['adr'])
plt.ylabel('Prezzo per notte')

plt.subplot(1, 3, 2)
plt.title('stays_in_weekend_nights')
plt.boxplot(hbd['stays_in_weekend_nights'])
plt.ylabel('Numero di notti')
```

```
plt.subplot(1, 3, 3)
plt.title('stays_in_week_nights')
plt.boxplot(hbd['stays_in_week_nights'])
plt.ylabel('Numero di notti')

plt.show()
```



- Possiamo notare alcuni outliers in tutte e tre le variabili
  - Il valore di massimo della variabile **adr** è estremamente lontanto dalla media
    - Viene rimosso in quanto potrebbe potenzialmente compromette i grafici dell'analisi esplorativa e alterare il modello

[202]:
```
hbd = hbd[hbd["adr"] != hbd["adr"].max()]
```

- In un problema di classificazione è utile visualizzare quanto le variabili predittive siano correlate con la classe da predire
- Per iniziare calcoliamo la correlazione Pearson tra tutte le coppie di features

[203]:
```
hbd.corr().style.background_gradient(cmap='Spectral').set_precision(2)
```

[203]:
```
<pandas.io.formats.style.Styler at 0x1d68ea975c8>
```

- A noi interessa particolamente la prima colonna, ovvero la relazione che intercorre tra la variabile dipendendente e tutte le altre
  - Prendiamo questi valori in valore assoluto e in ordine decrescente

[204]:
```
cancel_corr = hbd.corr()["is_canceled"]
cancel_corr.abs().sort_values(ascending=False)[1:]
```

[204]:
```
lead_time                         0.309369
total_of_special_requests         0.293807
previous_cancellations            0.166758
booking_changes                   0.149448
required_car_parking_spaces       0.133070
company                           0.092296
```

```
agent                              0.066481
is_repeated_guest                  0.065795
days_in_waiting_list               0.061039
adults                             0.053412
previous_bookings_not_canceled     0.053117
stays_in_week_nights               0.048691
babies                             0.030171
children                           0.027002
adr                                0.014641
stays_in_weekend_nights            0.007085
arrival_date_week_number           0.001331
Name: is_canceled, dtype: float64
```

- Apprendiamo che le variabili numeriche più correlate con la variabile dipendente sono:
  - lead_time
  - total_of_special_requests
  - required_car_parking_spaces
  - previous_cancellations
  - booking_changes
- Visualizziamo anche i valori più alti fra tutti quelli ottenuti (sempre in valore assoluto e sempre in ordine decrescente)
  - Sono indice di collinearità, è quindi opportuno tenerne conto
  - La matrice con i valori di correlazione è simmetrica, estraiamo dunque solo metà di essa

[205]:
```
(hbd.corr().abs().where(np.triu(np.ones(cancel_corr.abs().shape), k=1).
 ↪astype(np.bool))
                  .stack()
                  .sort_values(ascending=False)
                  .head(10))
```

[205]:
```
agent                           company                           0.643897
is_repeated_guest               previous_bookings_not_canceled    0.451963
                                company                           0.395515
previous_cancellations          previous_bookings_not_canceled    0.392139
children                        adr                               0.346216
is_canceled                     lead_time                         0.309369
previous_bookings_not_canceled  company                           0.304077
is_canceled                     total_of_special_requests         0.293807
is_repeated_guest               agent                             0.291368
adults                          adr                               0.290379
dtype: float64
```

- Possiamo per esempio notare che…

[206]:
```
hbd.groupby(['is_repeated_guest','previous_bookings_not_canceled']).size().
 ↪unstack().fillna(0)[[0, 1, 2, 3, 4, 5]]
```

[206]:
```
previous_bookings_not_canceled        0      1      2      3     4     5
is_repeated_guest
0                                77096.0  136.0    5.0    2.0   6.0   0.0
1                                  617.0  433.0  187.0  127.0  96.0  90.0
```

- La forte correlazione tra le variabili `is_repeated_guest` e `previous_bookings_not_canceled` è dovuta al fatto che quando un cliente è nuovo (la gran parte dei casi) ovviamente non ha a suo nome nessuna prenotazione cancellata
- Oppure che…

[207]:
```
hbd.groupby(['previous_cancellations', 'previous_bookings_not_canceled']).
↪size().unstack().fillna(0)[[0,1,2]].head(3)
```

[207]:
```
previous_bookings_not_canceled        0      1      2
previous_cancellations
0                                72759.0  526.0  173.0
1                                 4936.0   25.0   16.0
2                                    4.0    5.0    2.0
```

- L'osservazione enunciata sopra può essere applicata anche alle variabili `previous_cancellations` e `previous_bookings_not_canceled`
  - quando un cliente è nuovo non ha a suo nome nessuna prenotazione, sia essa cancellata o non cancellata
- Visualizziamo i grafici a dispersione delle variabili che tenuto conto del dominio analizzato possono essere ritenute le più interessanti

[208]:
```
import seaborn as sns
hbd_temp = hbd.copy()
hbd_temp["is_canceled"] = hbd_temp["is_canceled"].map(lambda value: "N" if␣
↪value is 0 else "Y")
sns.pairplot(hbd_temp[['previous_cancellations',␣
↪'previous_bookings_not_canceled', 'total_of_special_requests',␣
↪'required_car_parking_spaces', 'booking_changes', 'is_canceled']],␣
↪hue="is_canceled", palette="husl")
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\statsmodels\nonparametric\kde.py:487: RuntimeWarning: invalid value
encountered in true_divide
  binned = fast_linbin(X, a, b, gridsize) / (delta * nobs)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\statsmodels\nonparametric\kdetools.py:34: RuntimeWarning: invalid value
encountered in double_scalars
  FAC1 = 2*(np.pi*bw/RANGE)**2
```

[208]:
```
<seaborn.axisgrid.PairGrid at 0x1d6ef89f9c8>
```

- Osserviamo che…
  - Quando la variabile `required_car_parking_spaces` assume valore maggiore o uguale a 1 nessuna prenotazione risulta essere cancellata
  - Quando vengono effettuate molte modifiche alla prenotazione è molto probabile che il cliente non abbia mai effettuato ne cancellazioni ne altro.
    - Possiamo supporre che quando vengono effettuate molte modifiche alla prenotazione questa provenga da un nuovo cliente
  - Le prenotazioni che prevedono molte modifiche in genere non vengono cancellate
  - All'aumentare del numero di prenotazioni non cancellate si dimostrano meno presenti prenotazioni cancellate
- Analiziamo ora alcune variabili più nel dettaglio, iniziando dalla variabile dipendente

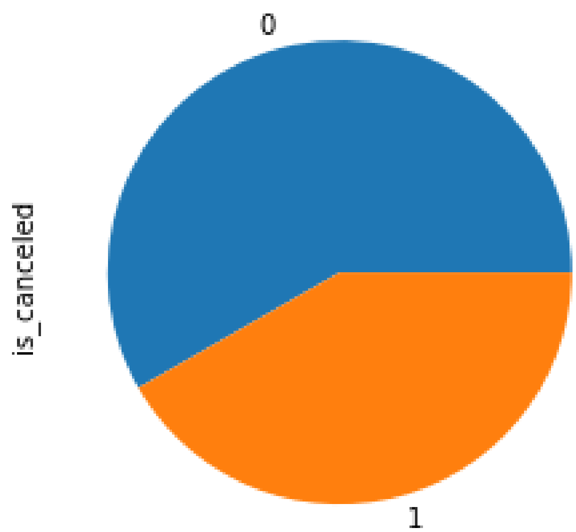
Variabile `is_canceled`

- Stampiamo il numero di valori `0` e `1` della variabile `is_canceled`, e rappresentiamo la distribuzione di tali valori in un diagramma a torta

[209]:
```
hbd["is_canceled"].value_counts()
```

[209]:
```
0    46226
1    33075
Name: is_canceled, dtype: int64
```

[210]:
```
hbd["is_canceled"].value_counts().plot.pie();
```



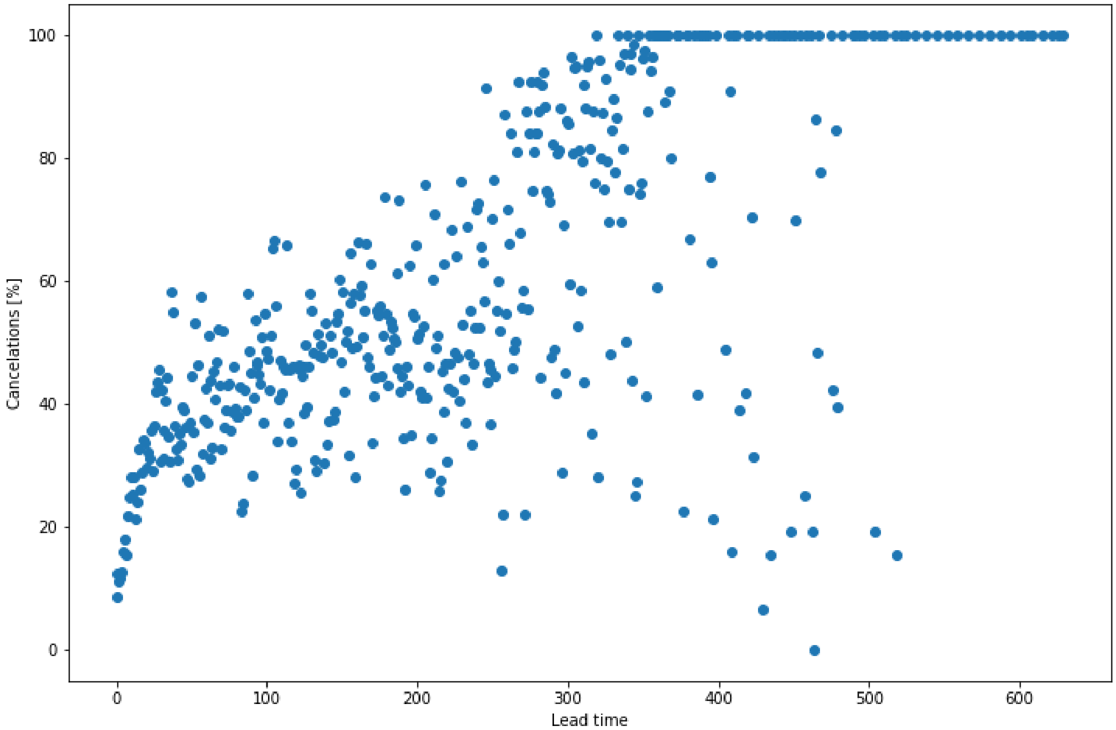
- La suddivisione delle istanze nelle classi è abbastanza bilanciata, non siamo dunque soggetti ai problemi che un forte sblinciamento comporterebbe.
- Analizziamo ora le variabili che hanno ottenuto il maggiore valore di correlazione con la variabile dipendende, ovvero:
  - `lead_time`
  - `total_of_special_requests`
  - `required_car_parking_spaces`
  - `previous_cancellations`
  - `booking_changes`

Variabile `lead_time`

- Visualizziamo la percentuale di cancellazione per i valori di `lead_time`

[211]:
```
plt.figure(figsize=(12, 8))
lead_time_describe = hbd.groupby("lead_time")["is_canceled"].describe()
plt.scatter(lead_time_describe.index, lead_time_describe["mean"] * 100)
plt.xlabel("Lead time")
plt.ylabel("Cancelations [%]")
```

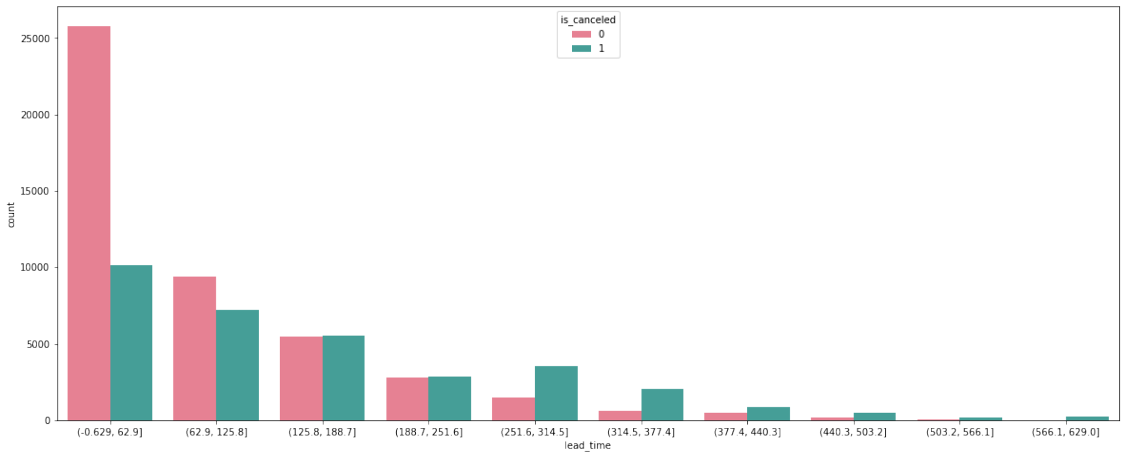
[211]: Text(0, 0.5, 'Cancelations [%]')



- Le prenotazione fatte qualche giorno prima dell'arrivo in struttura sono raramente cancellate, a differenza di prenotazioni fatte a distanza di mesi (se non di anni)
- Visualizziamo un l'istogramma in cui andiamo a quantificare la frequenza delle classi nei valori che la variabile assume

[212]:
```
from matplotlib import rcParams
rcParams['figure.figsize'] = 20, 8
sns.countplot(x=pd.cut(hbd["lead_time"], 10), hue='is_canceled', data = hbd,␣
↪palette="husl")
```

[212]: <matplotlib.axes._subplots.AxesSubplot at 0x1d694092148>



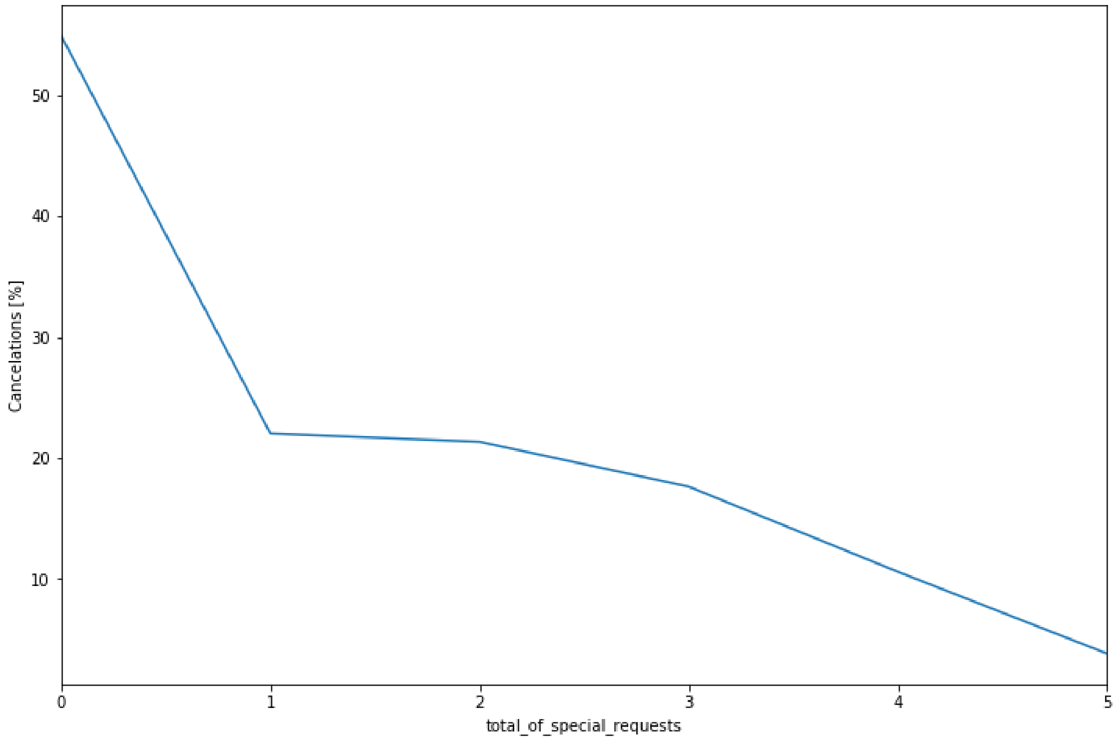
- Le prenotazioni più frequenti sono quelle a breve termine, ovvero senza lunghi periodi fra il momento della prenotazione e l'arrivo in hotel
- Medesima cosa vale per le cancellazioni, anche esse maggiori nelle prenotazioni a breve termine

Variabile `total_of_special_requests`

- Visualizziamo la percentuale di cancellazione per i valori di `total_of_special_requests`

[213]:
```
plt.figure(figsize=(12, 8))
plt.xlabel("Total of special request")
plt.ylabel("Cancelations [%]")
(100 * (hbd.groupby("total_of_special_requests").sum()["is_canceled"] /␣
 ↪hbd["total_of_special_requests"].value_counts())).plot()
```

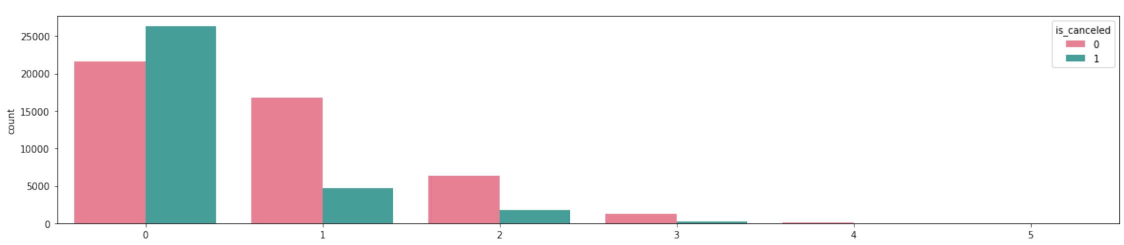
[213]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1d68fb31808>
```



- Visualizziamo un l'istogramma in cui andiamo a quantificare la frequenza delle classi nei valori che la variabile assume

[214]:
```
from matplotlib import rcParams
rcParams['figure.figsize'] = 20, 4
sns.countplot(x="total_of_special_requests", hue='is_canceled', data = hbd,␣
 ↪palette="husl")
```

[214]: <matplotlib.axes._subplots.AxesSubplot at 0x1d6911154c8>



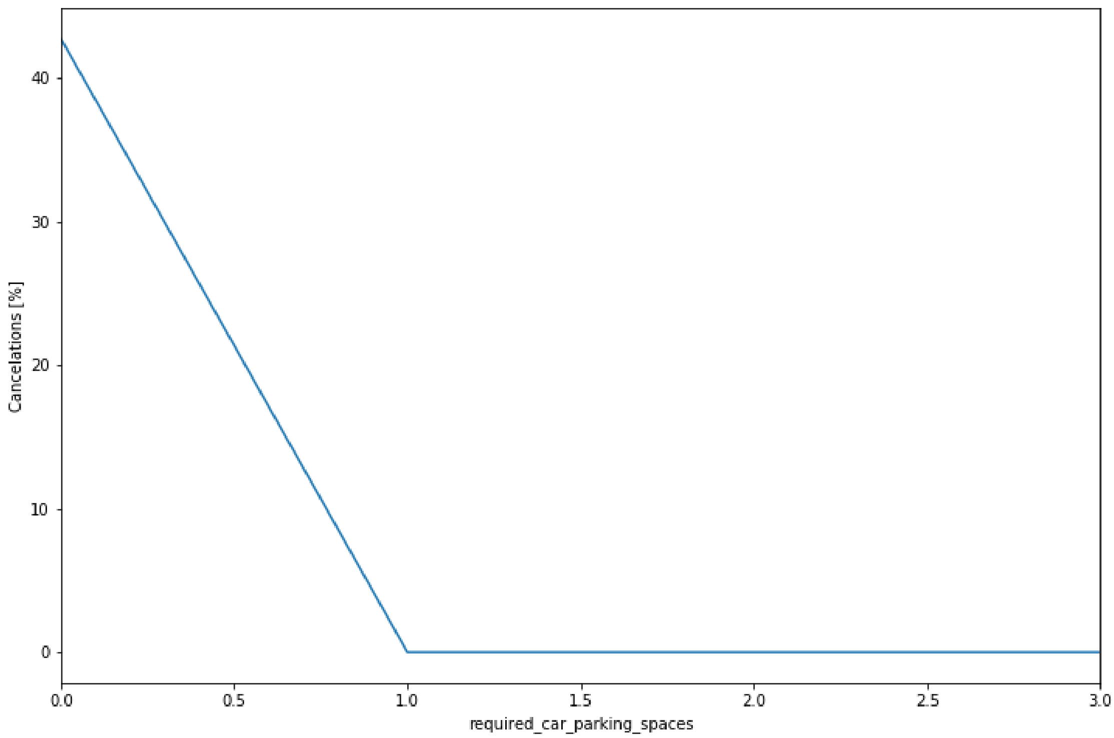
- All'aumentare del numero di richieste speciali la percentuale di cancellazioni diminuisce
  - Tanto più un cliente effettua richieste speciali tanto più è improbabile che cancelli la sua prenotazione

Variabile `required_car_parking_spaces`

- Visualizziamo la percentuale di cancellazione per i valori di `required_car_parking_spaces`

[215]:
```
plt.figure(figsize=(12, 8))
plt.xlabel("Required car parking spaces")
plt.ylabel("Cancelations [%]")
(100 * (hbd.groupby("required_car_parking_spaces").sum()["is_canceled"] /␣
 ↪hbd["required_car_parking_spaces"].value_counts())).plot()
```

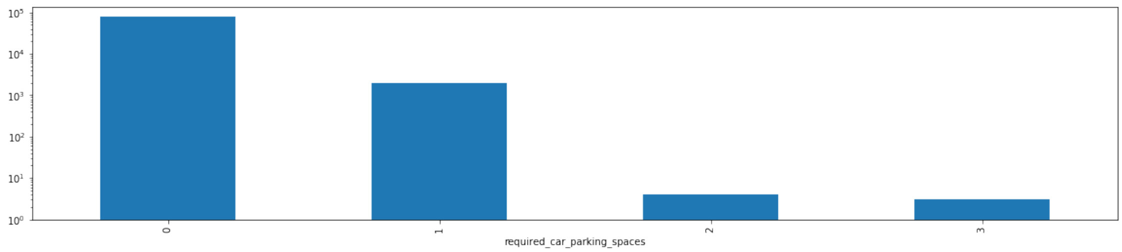
[215]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1d691146a88>
```



- Visualizziammo anche il numero di prenotazioni effettuate per ciacun valore di `required_car_parking_spaces`

[216]:
```
hbd.groupby("required_car_parking_spaces").size().plot.bar(log=True)
```

[216]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1d693aea448>
```



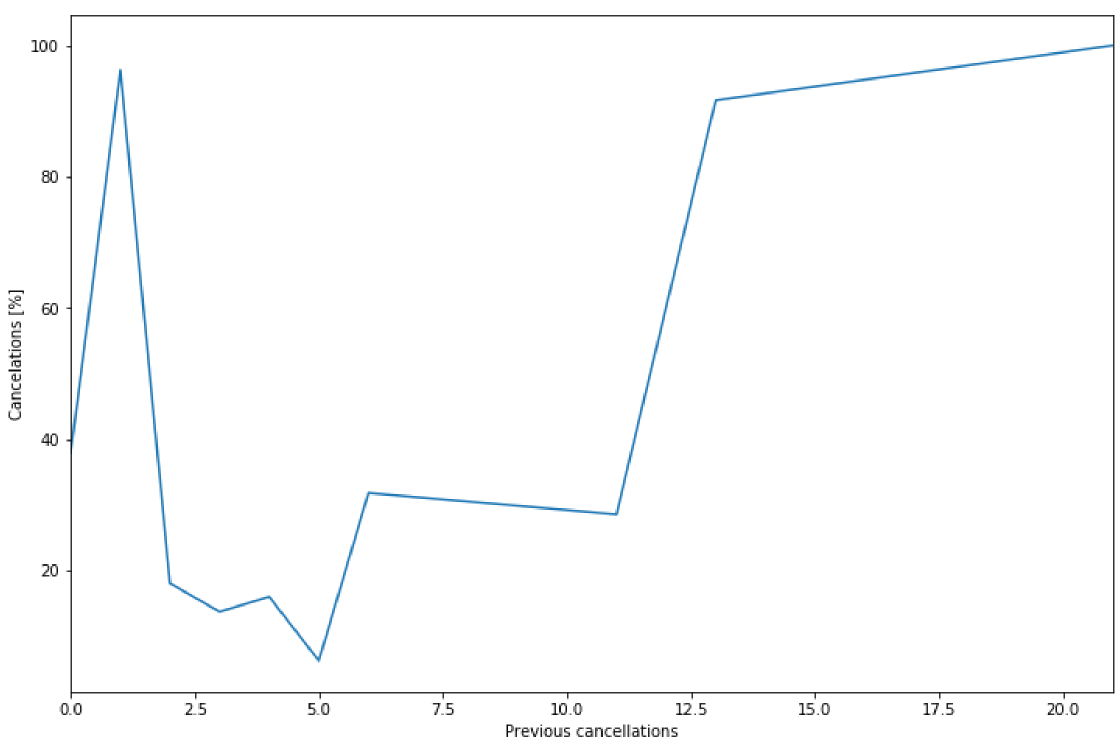
- Nessuna prenotazione per la quale era previsto almeno un posto macchina è mai stata cancellata
  - Chi viene in macchina in genere non cancella la propria prenotazione

Variabile `previous_cancellations`

- Visualizziamo la percentuale di cancellazione per i valori di `previous_cancellations`

[217]:
```
plt.figure(figsize=(12, 8))
plt.xlabel("Previous cancellations")
plt.ylabel("Cancelations [%]")
(100 * (hbd.groupby("previous_cancellations").sum()["is_canceled"] /␣
↪hbd["previous_cancellations"].value_counts())).plot()
```

[217]: `<matplotlib.axes._subplots.AxesSubplot at 0x1d693f4c2c8>`



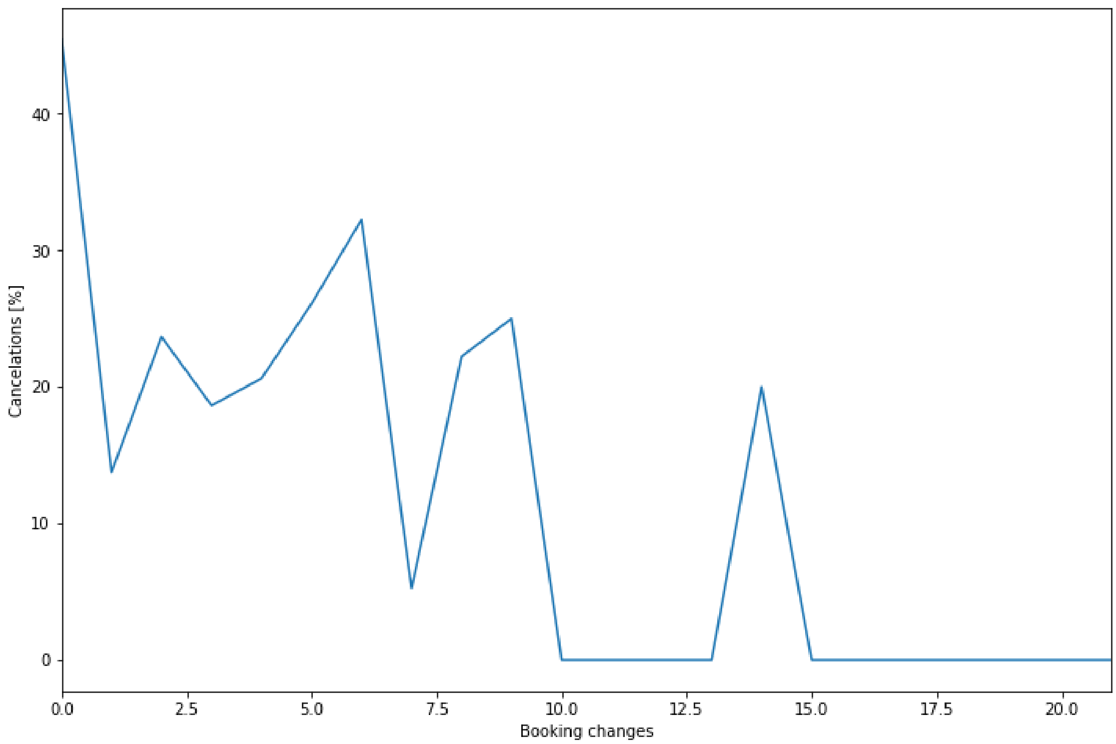
- Eccetto inizialmente, all'aumentare del numero di prenotazioni già cancellate sembra essere sempre più probabile un'ulteriore cancellazione
  - Chi ha già cancellato molte prenotazioni probabilmente lo rifarà, tanto più sono le cancellazioni fatte

Variabile `booking_changes`

- Visualizziamo la percentuale di cancellazione per i valori di `booking_changes`

[218]:
```
plt.figure(figsize=(12, 8))
plt.xlabel("Booking changes")
plt.ylabel("Cancelations [%]")
(100 * (hbd.groupby("booking_changes").sum()["is_canceled"] /␣
 ↪hbd["booking_changes"].value_counts())).plot()
```

[218]: `<matplotlib.axes._subplots.AxesSubplot at 0x1d69486ef88>`

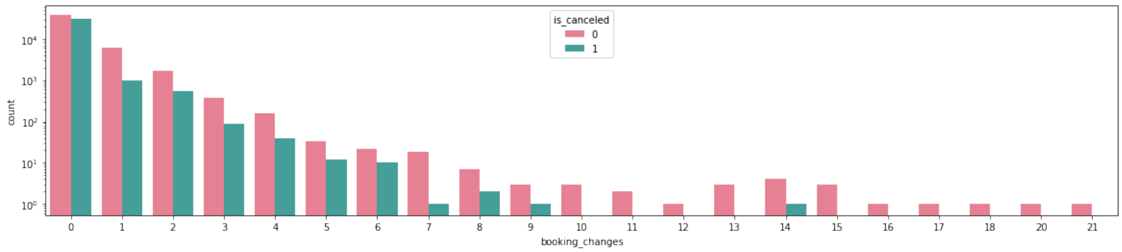


- Visualizziamo un l'istogramma in cui andiamo a quantificare la frequenza delle classi nei valori che la variabile assume

[219]:
```
from matplotlib import rcParams
rcParams['figure.figsize'] = 20, 4
```

```
sns.countplot(x="booking_changes", hue='is_canceled', data = hbd,␣
↪palette="husl", log=True)
```

[219]: <matplotlib.axes._subplots.AxesSubplot at 0x1d692366d08>



- All'aumentare del numero di richieste di cambiamento la percentuale di cancellazioni tende a diminuire
  - Tanti più cambiamenti un cliente richiede, tanto più è improbabile che cancelli la sua prenotazione
- Mostriamo ora la variabile `country`

Variabile `country`

- Valutiamo, per ciascuno stato, il numero di prenotazioni e cancellazioni

[220]:
```
cancellation_by_state = hbd.groupby(['country']).sum()["is_canceled"]
reservation_by_state = hbd.groupby(['country']).size()
```

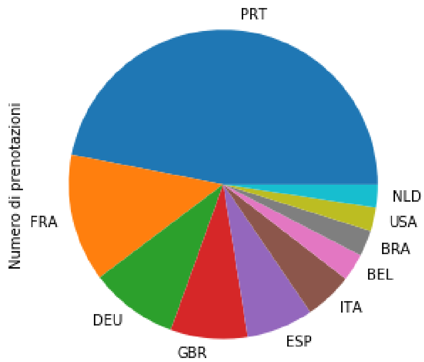
- Memorizziamo i primi 10 stati per numero di prenotazioni

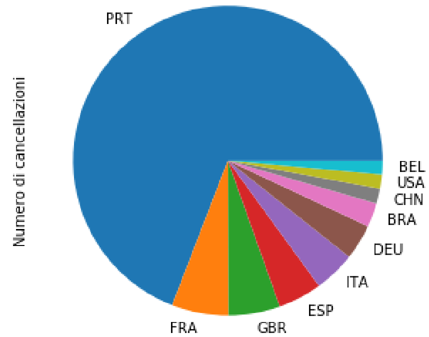
[221]:
```
bigger_states = reservation_by_state.sort_values(ascending=False).head(10)
```

- Visualizziamo due grafici a torta in cui vengono mostrati:
  - Gli stati con più prenotazioni
  - Gli stati con più cancellazioni

[222]:
```
fig = plt.figure(figsize=(16, 5))
ax1 = fig.add_subplot(121)
ax2 = fig.add_subplot(122)
reservation_by_state.sort_values(ascending=False).head(10).plot.pie(ax=ax1)
cancellation_by_state.sort_values(ascending=False).head(10).plot.pie(ax=ax2)
ax1.set(ylabel="Numero di prenotazioni")
ax2.set(ylabel="Numero di cancellazioni")
```

[222]: [Text(0, 0.5, 'Numero di cancellazioni')]





- Lo stato che predomica maggiormente è *PRT* , ovvero il Portogallo
- Poichè l'hotel è situato in Portogallo è un risultato tutto sommato scontato

- Visualizziamo un grafico a barre con la percentuale di cancellazione relativa agli stati
  - Indichiamo colorando in modo diverso gli stati che risultano essere presenti nell'insieme `bigger_states`, ovvero i primi 10 stati per numero di prenotazioni
- Calcoliamo dunque la percentuale di cancellazioni di tutti gli statti

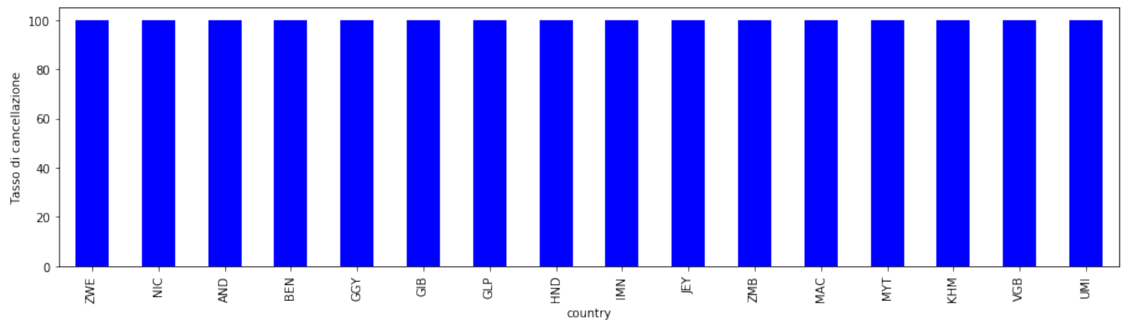
[223]:
```
ratio_cancellation_by_state = (100* cancellation_by_state /␣
↪reservation_by_state).sort_values(ascending=False)
```

- Mostraimo prima l'insieme di stati che presenta percentuale di cancellazione pari al 100%
  - Definisco i colori delle barre in funzione della presenza o meno dello stato in `bigger_states`

[224]:
```
state100 = ratio_cancellation_by_state[ratio_cancellation_by_state==100]
condition = state100.index.isin(bigger_states.index)
colors = ""
for element in condition:
    colors += "b" if element == False else "r"
```

[225]:
```
state100.plot.bar(figsize=(16,4), color = list(colors))
plt.ylabel("Tasso di cancellazione")
```

[225]:
```
Text(0, 0.5, 'Tasso di cancellazione')
```

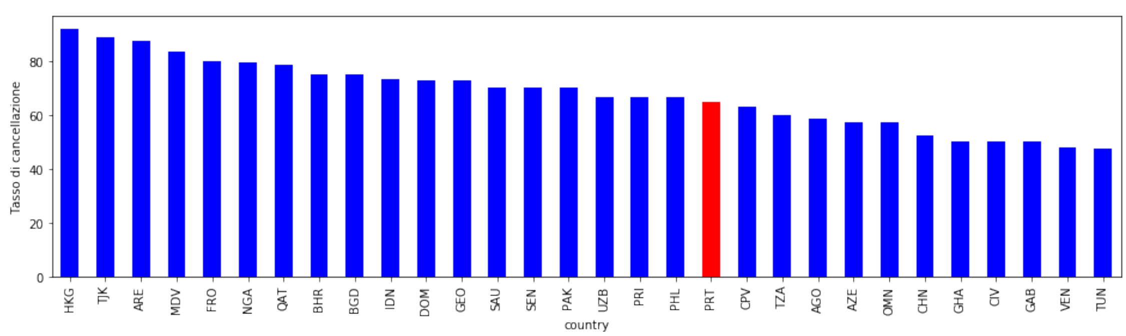


- Nessuno stato con un gran numero di prenotazioni ha percentuale di cancellazione pari a 100%
- Proviamo ora con i 30 stati successivi, replicando lo stesso approccio

[226]:
```
statenot100 = ratio_cancellation_by_state[ratio_cancellation_by_state!=100].
 ↪head(30)
condition = statenot100.index.isin(bigger_states.index)
colors = ""
for element in condition:
    colors += "b" if element == False else "r"
```

[227]:
```
statenot100.plot.bar(figsize=(16,4), color = list(colors))
plt.ylabel("Tasso di cancellazione")
```

[227]: `Text(0, 0.5, 'Tasso di cancellazione')`



- In questo grafico troviamo il Portogallo (*PRT*), nonchè lo stato con maggior numero di prenotazioni (e maggior numero di cancellazioni)
- Mostriamo la percentuale esatta

[228]:
```
ratio_cancellation_by_state["PRT"]
```

[228]: `64.85543530931999`

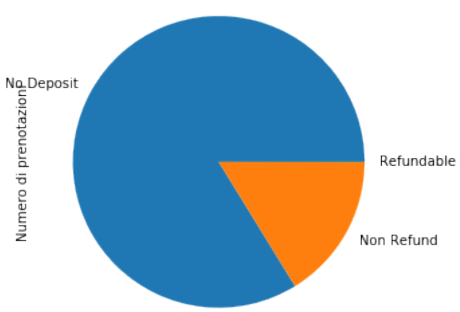
- I portoghesi tendono a cancellare le proprie prenotazioni molto frequentemente
- Andiamo ora ad analizzare la variabile `deposit_type` e tutte le variabili che trattano il periodo di arrivo e la permanenza in albergo, in particolare:
  - `stays_in_weekend_nights`
  - `stays_in_week_nights`
  - `arrival_date_day`
  - `arrival_date_month`,
  - `arrival_date_week_number`

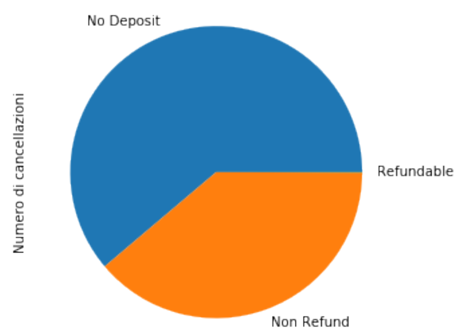
Variabile `deposit_type`

- Visualizziamo due grafici a torta
  - Nel primo per ogni valore è mostrato il numero di prenotazioni
  - Nel secondo per ogni valore è mostrato il numero di cancellazioni

[229]:
```
fig = plt.figure(figsize=(16, 5))
ax1 = fig.add_subplot(121)
ax2 = fig.add_subplot(122)
hbd["deposit_type"].value_counts().plot.pie(ax=ax1)
hbd.groupby("deposit_type").sum()["is_canceled"].plot.pie(ax=ax2)
ax1.set(ylabel="Numero di prenotazioni")
ax2.set(ylabel="Numero di cancellazioni")
```

[229]:
```
[Text(0, 0.5, 'Numero di cancellazioni')]
```





- Il valore Refundable è praticamente inesistente

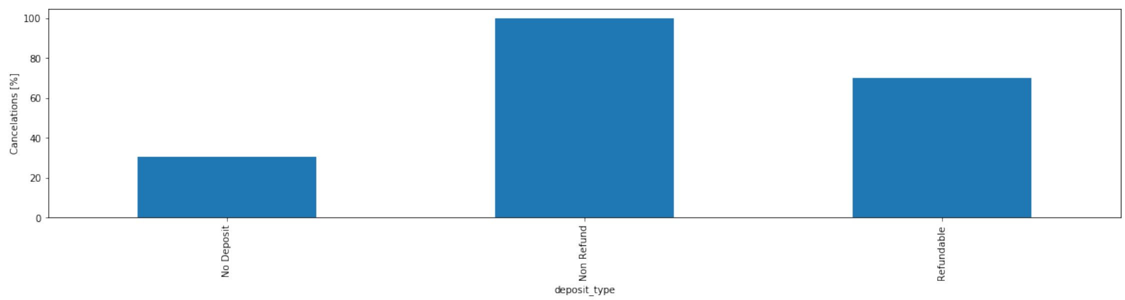
[230]:
```
hbd["deposit_type"].value_counts()
```

[230]:
```
No Deposit     66428
Non Refund     12853
Refundable        20
Name: deposit_type, dtype: int64
```

- Visualizziamo un grafico a barre di `deposit_type`, in cui in viene visualizzato per ciascun valore la percentuale di cancellazioni registrata

[231]:
```
(100 * hbd.groupby("deposit_type").sum()["is_canceled"] / hbd["deposit_type"].
 ↪value_counts()).plot.bar()
plt.ylabel("Cancelations [%]")
```

[231]:
```
Text(0, 0.5, 'Cancelations [%]')
```



- Visualizziamo i valori esatti

[232]:
```
(hbd.groupby("deposit_type").sum()["is_canceled"] / hbd["deposit_type"].
 ↪value_counts())
```

[232]:
```
deposit_type
No Deposit    0.304570
Non Refund    0.998133
Refundable    0.700000
dtype: float64
```

- Il grafico evidenzia che per il valore 'Non Refund' la percentuale di cancellazioni è pari quasi al 100%
- E' un po controintuitivo considerando il suo significato
  - Verifichiamo, per averne certezza, quante istanze con valore `Non Refund` sono state cancellate e quante no

[233]:
```
hbd[hbd["deposit_type"] == "Non Refund"]["is_canceled"].value_counts()
```

[233]:
```
1    12829
0       24
Name: is_canceled, dtype: int64
```

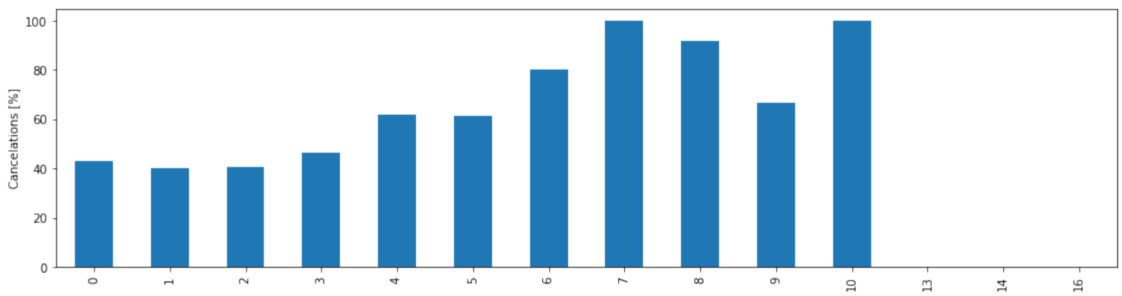
- Effettivamente pare che quasi tutte le prenotazioni *Non Refund* siano state cancellate
  - Poichè pare un fatto particolarmente strano, sarà opportuno verificare in modo attento quanto questa variabile incida sul risultato

Variabili stays_in_weekend_nights, stays_in_week_nights

- Mostriamo due grafici a barre in cui visualizziamo per ogni valore delle variabili `stays_in_weekend_nights` e `stays_in_week_nights`, ovvero il numero di notti prenotate rispettivamente durante il finesettimana e non durante il finesettimana, la percentuale di cancellazioni

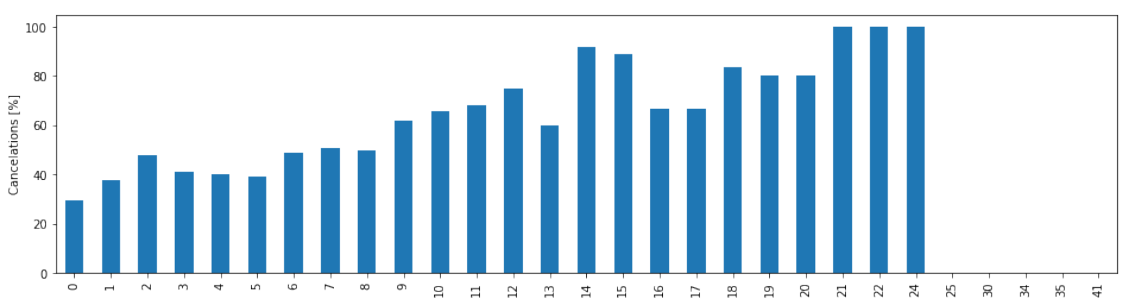
[234]:
```
(100 * hbd.groupby("stays_in_weekend_nights").sum()["is_canceled"] / hbd["stays_in_weekend_nights"].value_counts()).plot.bar(figsize=(16,4))
plt.ylabel("Cancelations [%]")
```

[234]:
```
Text(0, 0.5, 'Cancelations [%]')
```



[235]:
```
(100 * hbd.groupby("stays_in_week_nights").sum()["is_canceled"] / hbd["stays_in_week_nights"].value_counts()).plot.bar(figsize=(16,4))
plt.ylabel("Cancelations [%]")
```

[235]:
```
Text(0, 0.5, 'Cancelations [%]')
```



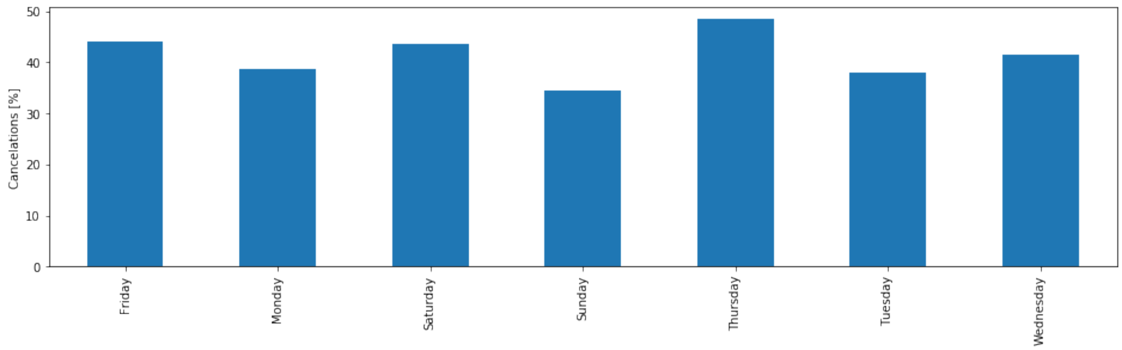
- In entrambi i casi possiamo notare all'aumentare del numero di notti prenotate i clienti tendono a cancellare le prenotazioni con più frequenza
  - Vengono raggiunti picchi pari al 100%

Variabili arrival_date_day, arrival_date_month, arrival_date_week_number

- Mostriamo le percentuali di cancellazione delle variabili `arrival_date_day`, `arrival_date_month`, `arrival_date_week_number`

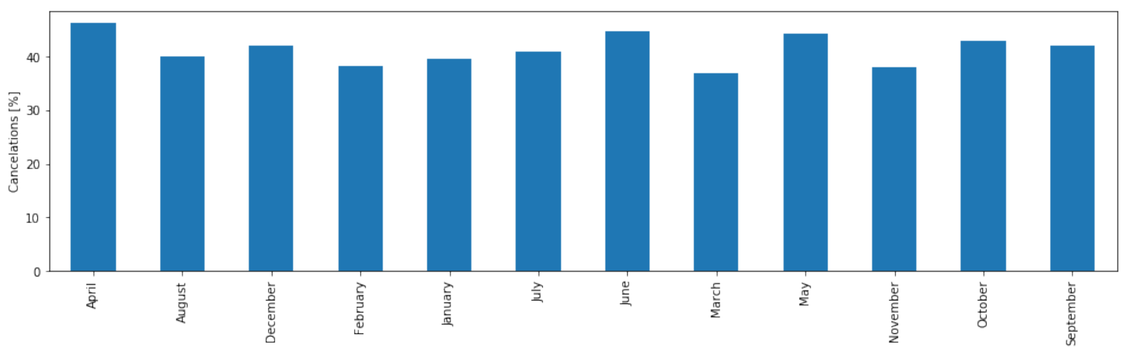
[236]:
```
(100 * hbd.groupby("arrival_date_day").sum()["is_canceled"] /␣
 ↪hbd["arrival_date_day"].value_counts()).plot.bar(figsize=(16,4))
plt.ylabel("Cancelations [%]")
```

[236]: Text(0, 0.5, 'Cancelations [%]')



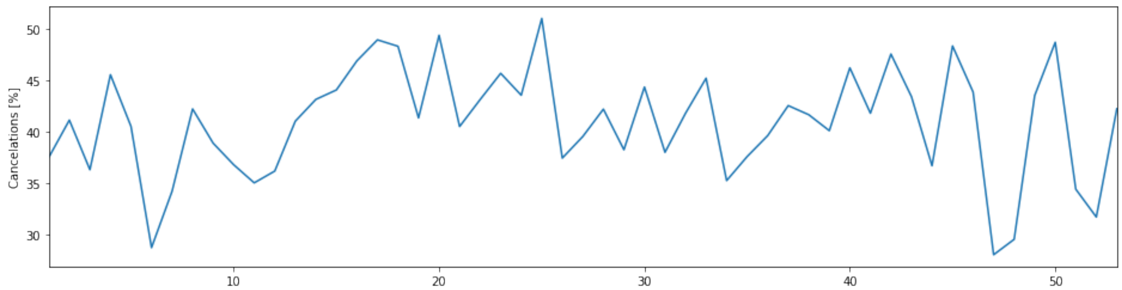
[237]:
```
(100 * hbd.groupby("arrival_date_month").sum()["is_canceled"] /␣
 ↪hbd["arrival_date_month"].value_counts()).plot.bar(figsize=(16,4))
plt.ylabel("Cancelations [%]")
```

[237]: Text(0, 0.5, 'Cancelations [%]')



[238]:
```
(100 * hbd.groupby("arrival_date_week_number").sum()["is_canceled"] /␣
 ↪hbd["arrival_date_week_number"].value_counts()).plot(figsize=(16,4))
plt.ylabel("Cancelations [%]")
```

[238]: Text(0, 0.5, 'Cancelations [%]')



- Per quanto riguarda mese e giorno della settimana sono presenti piccole fluttuazzioni
- Per quanto riguarda il numero della settimana dell'anno, possiamo notare periodi in cui il numero di prenotazioni cancellate rispetto al totale sono considerevoli

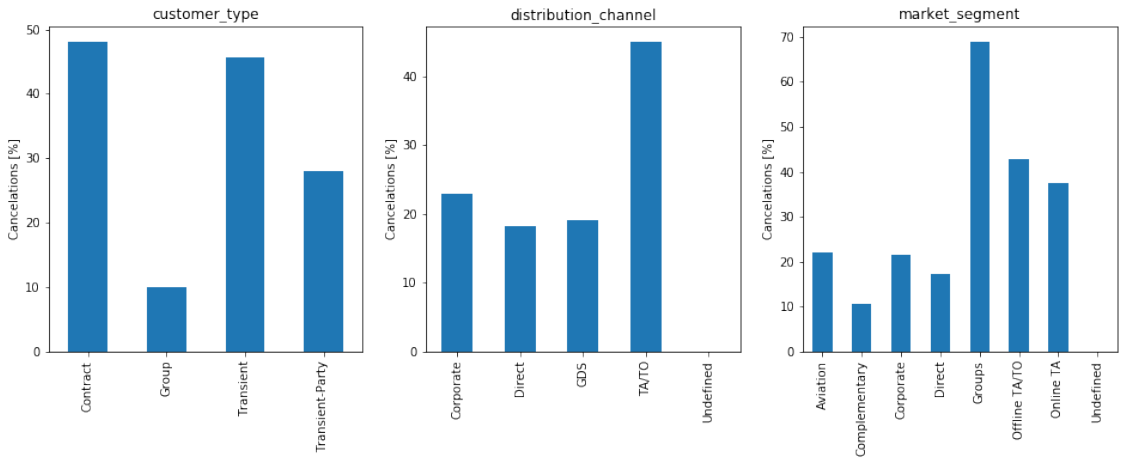
Qualche altra variabile ...

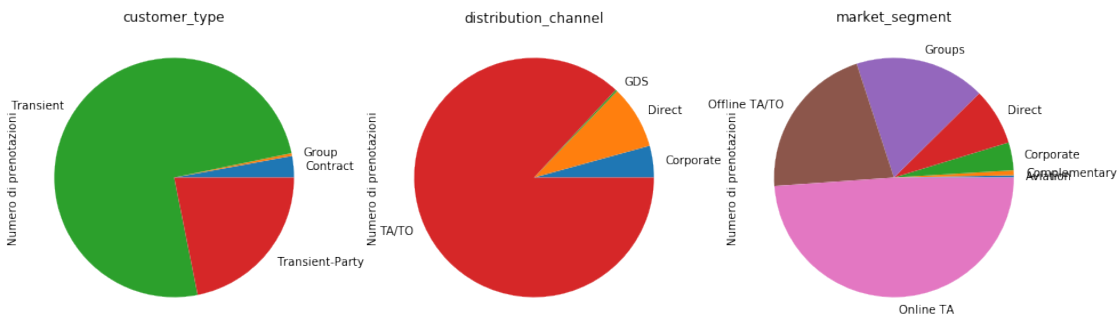
- Mostriamo infine rapidamente la percentuale di prenotazioni cancellate di qualche altra variabile, al fine di comprendere il dominio in cui lavoriamo correttamente
  - Assieme alle percentuali aggiungiamo anche la distribuzione delle prenotazioni

[239]:
```
fig = plt.figure(figsize=(16, 5))
ax1 = fig.add_subplot(131)
ax2 = fig.add_subplot(132)
ax3 = fig.add_subplot(133)
ax1.set(ylabel="Cancelations [%]")
ax2.set(ylabel="Cancelations [%]")
ax3.set(ylabel="Cancelations [%]")
ax1.set_title('customer_type')
ax2.set_title('distribution_channel')
ax3.set_title('market_segment')
(100 * hbd.groupby("customer_type").sum()["is_canceled"] / hbd["customer_type"].
 ↪value_counts()).plot.bar(ax=ax1)
(100 * hbd.groupby("distribution_channel").sum()["is_canceled"] /␣
 ↪hbd["distribution_channel"].value_counts()).plot.bar(ax=ax2)
(100 * hbd.groupby("market_segment").sum()["is_canceled"] /␣
 ↪hbd["market_segment"].value_counts()).plot.bar(ax=ax3)
fig = plt.figure(figsize=(16, 5))
ax4 = fig.add_subplot(131)
ax5 = fig.add_subplot(132)
ax6 = fig.add_subplot(133)
ax4.set_title('customer_type')
ax5.set_title('distribution_channel')
ax6.set_title('market_segment')
hbd.groupby("customer_type").size().plot.pie(ax=ax4)
hbd.groupby("distribution_channel").size().plot.pie(ax=ax5)
hbd.groupby("market_segment").size().plot.pie(ax=ax6)
```

```
ax4.set(ylabel="Numero di prenotazioni")
ax5.set(ylabel="Numero di prenotazioni")
ax6.set(ylabel="Numero di prenotazioni")
```

[239]: [Text(0, 0.5, 'Numero di prenotazioni')]

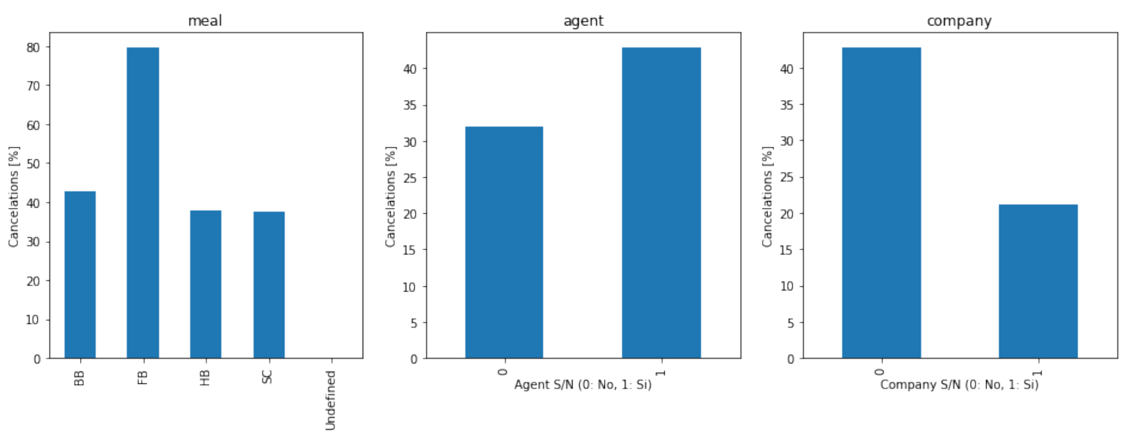


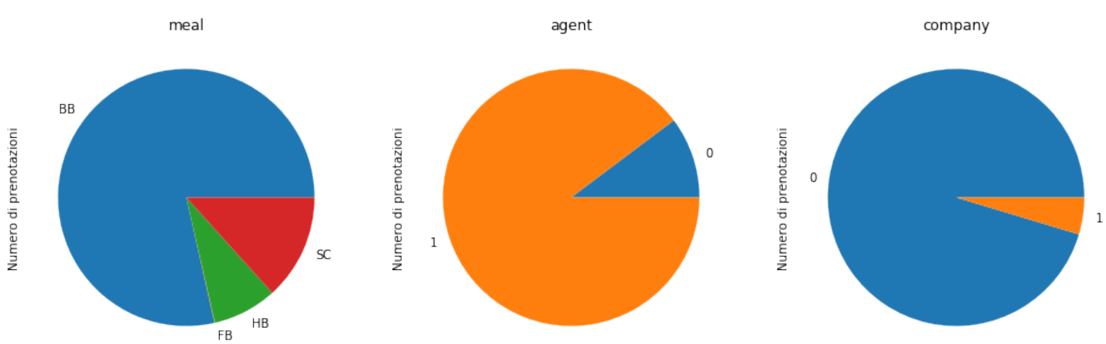


[240]:
```
fig = plt.figure(figsize=(16, 5))
ax4 = fig.add_subplot(131)
ax5 = fig.add_subplot(132)
ax6 = fig.add_subplot(133)
ax4.set_title('meal')
ax5.set_title('agent')
ax6.set_title('company')
ax4.set(ylabel="Cancelations [%]")
ax5.set(ylabel="Cancelations [%]")
ax6.set(ylabel="Cancelations [%]")
(100 * hbd.groupby("meal").sum()["is_canceled"] / hbd["meal"].value_counts()).
↪plot.bar(ax=ax4)
```

```
(100 * hbd.groupby("agent").sum()["is_canceled"] / hbd["agent"].value_counts()).
↪plot.bar(ax=ax5)
(100 * hbd.groupby("company").sum()["is_canceled"] / hbd["company"].
↪value_counts()).plot.bar(ax=ax6)
ax5.set(xlabel="Agent S/N (0: No, 1: Si)")
ax6.set(xlabel="Company S/N (0: No, 1: Si)")
fig = plt.figure(figsize=(16, 5))
ax4 = fig.add_subplot(131)
ax5 = fig.add_subplot(132)
ax6 = fig.add_subplot(133)
ax4.set_title('meal')
ax5.set_title('agent')
ax6.set_title('company')
hbd.groupby("meal").size().plot.pie(ax=ax4)
hbd.groupby("agent").size().plot.pie(ax=ax5)
hbd.groupby("company").size().plot.pie(ax=ax6)
ax4.set(ylabel="Numero di prenotazioni")
ax5.set(ylabel="Numero di prenotazioni")
ax6.set(ylabel="Numero di prenotazioni")
```

[240]: [Text(0, 0.5, 'Numero di prenotazioni')]





- Anche qui esistono valori con una percentuale di cancellazione molto elevata (fino all'80%) e altri con una percentuale molto bassa
- Per esempio...
  - Le prenotazioni con valore `FB` nella variabile `meal` sono state per circa l'80% cancellate

1.4 Classificazione

- Convertiamo, per maggiore chiarezza, i valori della variabile `is_canceled` (ovvero 0 e 1) in `N` e `Y`:
  - `0` diventa `N`, ovvero non cancellata
  - `1` diventa `Y`, ovvero cancellata

[241]:
```
hbd["is_canceled"] = hbd["is_canceled"].map(lambda value: "N" if value is 0␣
↪else "Y")
hbd["is_canceled"].unique()
```

[241]:
```
array(['N', 'Y'], dtype=object)
```

- Impostiamo come variabile da predire la classe `is_canceled` e come variabili predittive tutte le altre

[242]:
```
y = hbd["is_canceled"]
X = hbd.drop(columns="is_canceled")
```

- Molte variabili sono categoriche, è quindi necessario applicare la binarizzazione delle feature, ovvero convertire ciascuna di esse in una o più variabili binarie.
- La conversione viene eseguita in modo molto basilare dal comando `get_dummies`
  - NB: non sono previste variabili per tutti quei valori non presenti nel dataset

[243]:
```
X = pd.get_dummies(X)
```

- Otteniamo un numero di variabili pari a ...

[244]:
```
X.shape[1]
```

[244]:
```
248
```

- Vengono mostrate per completezza tutte le variabili ottenute

[245]:
```
X.columns.tolist()
```

[245]:
```
['lead_time',
 'arrival_date_week_number',
 'stays_in_weekend_nights',
 'stays_in_week_nights',
```

```
'adults',
'children',
'babies',
'is_repeated_guest',
'previous_cancellations',
'previous_bookings_not_canceled',
'booking_changes',
'agent',
'company',
'days_in_waiting_list',
'adr',
'required_car_parking_spaces',
'total_of_special_requests',
'arrival_date_day_Friday',
'arrival_date_day_Monday',
'arrival_date_day_Saturday',
'arrival_date_day_Sunday',
'arrival_date_day_Thursday',
'arrival_date_day_Tuesday',
'arrival_date_day_Wednesday',
'arrival_date_month_April',
'arrival_date_month_August',
'arrival_date_month_December',
'arrival_date_month_February',
'arrival_date_month_January',
'arrival_date_month_July',
'arrival_date_month_June',
'arrival_date_month_March',
'arrival_date_month_May',
'arrival_date_month_November',
'arrival_date_month_October',
'arrival_date_month_September',
'meal_BB',
'meal_FB',
'meal_HB',
'meal_SC',
'meal_Undefined',
'country_ABW',
'country_AGO',
'country_AIA',
'country_ALB',
'country_AND',
'country_ARE',
'country_ARG',
'country_ARM',
'country_ASM',
'country_ATA',
```

```
'country_ATF',
'country_AUS',
'country_AUT',
'country_AZE',
'country_BDI',
'country_BEL',
'country_BEN',
'country_BFA',
'country_BGD',
'country_BGR',
'country_BHR',
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'country_EGY',
'country_ESP',
'country_EST',
'country_ETH',
'country_FIN',
'country_FJI',
'country_FRA',
```

```
'country_FRO',
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'country_LIE',
'country_LKA',
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'country_MAR',
```

```
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'country_MYT',
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'country_NLD',
'country_NOR',
'country_NPL',
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'country_SLV',
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'country_SRB',
'country_STP',
```

```
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'country_URY',
'country_USA',
'country_UZB',
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'country_VGB',
'country_VNM',
'country_ZAF',
'country_ZMB',
'country_ZWE',
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'market_segment_Complementary',
'market_segment_Corporate',
'market_segment_Direct',
'market_segment_Groups',
'market_segment_Offline TA/TO',
'market_segment_Online TA',
'market_segment_Undefined',
'distribution_channel_Corporate',
'distribution_channel_Direct',
'distribution_channel_GDS',
'distribution_channel_TA/TO',
'distribution_channel_Undefined',
'reserved_room_type_A',
'reserved_room_type_B',
'reserved_room_type_C',
'reserved_room_type_D',
'reserved_room_type_E',
'reserved_room_type_F',
'reserved_room_type_G',
'reserved_room_type_H',
```

```
 'reserved_room_type_L',
 'reserved_room_type_P',
 'deposit_type_No Deposit',
 'deposit_type_Non Refund',
 'deposit_type_Refundable',
 'customer_type_Contract',
 'customer_type_Group',
 'customer_type_Transient',
 'customer_type_Transient-Party']
```

- Suddividiamo i dati in un training set e in un validation set con la funzione `train_test_split` con proporzione 66-33

[246]:
```
from sklearn.model_selection import train_test_split
X_train, X_val, y_train, y_val = train_test_split(
    X, y,
    test_size=1/3,
    random_state=42
)
```

- Definiamo un modello di regressione logistica più semplice possibile, configurandone l'implementazione e il seed per la casualità
  - gli altri parametri sono lasciati ai valori di default, ad es. la regolarizzazione applicata è L2 con C=1

[247]:
```
from sklearn.linear_model import LogisticRegression
from sklearn.pipeline import Pipeline

model = LogisticRegression(solver="saga", random_state=42)
```

- Addestriamo il modello sui dati

[248]:
```
%time model.fit(X_train, y_train)
```

```
Wall time: 20 s
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[248]:
```
LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, l1_ratio=None, max_iter=100,
                   multi_class='warn', n_jobs=None, penalty='l2',
                   random_state=42, solver='saga', tol=0.0001, verbose=0,
                   warm_start=False)
```

- Mostriamo le classi previste dal modello

[249]:
```python
model.classes_
```

[249]:
```
array(['N', 'Y'], dtype=object)
```

- NB: Quando effettuiamo una predizione di probabilità otteniamo due valori ([a, b])
  - Il primo valore (a) si riferisce alla probabilità di ottenere la classe `N`
  - Il secondo valore (b) si riferisce alla probabilità di ottenere la classe `Y`
- Come mostrato di seguito...

[250]:
```python
model.predict_proba(X_val[:3])
```

[250]:
```
array([[0.19018121, 0.80981879],
       [0.10774354, 0.89225646],
       [0.88131685, 0.11868315]])
```

[251]:
```python
model.predict(X_val[:3])
```

[251]:
```
array(['Y', 'Y', 'N'], dtype=object)
```

- Definiamo una funzione per ottenere le informazioni utili per valutare un modello di classificazione
- Oltre all'accuratezza come percentuale di classificazioni corrette, esistono altri modi per valutare l'accuratezza di un classificatore
  - Precision e recall sono particolarmente utili in caso di sbilanciamento tra le classi, per cui l'accuratezza può non essere un indicatore affidabile

[252]:
```python
from sklearn.metrics import confusion_matrix
from sklearn.metrics import precision_score, recall_score, f1_score

def print_model_informations(model,  X_train, y_train, X_val, y_val):
    y_pred = model.predict(X_val)
    print("Accuracy =", model.score(X_val, y_val),"        ( Accuracy on␣
 ↪training set =", model.score(X_train, y_train),")")
    print("\nPrecision (Y) =", precision_score(y_val,y_pred, pos_label="Y"))
    print("Precision (N) =", precision_score(y_val,y_pred, pos_label="N"))
    print("Precision =", precision_score(y_val,y_pred, average="macro"))
    print("\nRecall (Y) =", recall_score(y_val,y_pred, pos_label="Y"))
    print("Recall (N) =", recall_score(y_val,y_pred, pos_label="N"))
    print("Recall =", recall_score(y_val,y_pred, average="macro"))
    print("\nF1 Score (Y) =", f1_score(y_val,y_pred, pos_label="Y"))
    print("F1 Score (N) =", f1_score(y_val,y_pred, pos_label="N"))
    print("F1 Score =", f1_score(y_val,y_pred, average="macro"))
    print("\nMatrice di confusione:")
    cm = confusion_matrix(y_val, y_pred)
    print(pd.DataFrame(cm, index=model.classes_, columns=model.classes_))
```

- Calcoliamo le misure del nostro modello

[253]:
```
print_model_informations(model, X_train, y_train, X_val, y_val)
```

```
Accuracy = 0.7946205644246047         ( Accuracy on training set =
0.7960920801255982 )

Precision (Y) = 0.8481325748206777
Precision (N) = 0.7710377152823196
Precision = 0.8095851450514986

Recall (Y) = 0.6201284022063478
Recall (N) = 0.920130081300813
Recall = 0.7701292417535803

F1 Score (Y) = 0.7164272656045966
F1 Score (N) = 0.8390119503009816
F1 Score = 0.777719607952789

Matrice di confusione:
       N     Y
N  14147  1228
Y   4201  6858
```

- Per avere una valutazione più completa del modello ottenuto, possiamo metterlo a confronto con quello che accadrebbe prendendo decisioni casuali, ovvero dotandoci di un modello randomico
  - In questo caso *DummyClassifier*

[254]:
```
from sklearn.dummy import DummyClassifier
```

[255]:
```
random = DummyClassifier(strategy="uniform", random_state=42)
random.fit(X_train, y_train)
```

[255]:
```
DummyClassifier(constant=None, random_state=42, strategy='uniform')
```

[256]:
```
random.score(X_val, y_val)
```

[256]:
```
0.49708708481501096
```

- Abbiamo quindi ottenuto un modello che ci consente di intraprendere decisioni più accurate di come le faremmo casualmente

1.4.1 Standardizzazione

- Possiamo standardizzare i dati per vedere se il modello migliora

[257]:
```
from sklearn.preprocessing import StandardScaler

model_stand = Pipeline([
    ("scaler", StandardScaler()),
```

```
    ("log", LogisticRegression(solver="saga", random_state=42))
])
model_stand.fit(X_train, y_train)
print_model_informations(model_stand, X_train, y_train, X_val, y_val)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

```
Accuracy = 0.8097904214269501         ( Accuracy on training set =
0.8101462159759396 )

Precision (Y) = 0.8362136247073252
Precision (N) = 0.7962210134554824
Precision = 0.8162173190814037

Recall (Y) = 0.6781806673297767
Recall (N) = 0.9044552845528455
Recall = 0.7913179759413111

F1 Score (Y) = 0.7489514679448771
F1 Score (N) = 0.8468940316686967
F1 Score = 0.7979227498067869

Matrice di confusione:
       N     Y
N  13906  1469
Y   3559  7500
```

- La standardizzazione comporta un miglioramento sotto più punti di vista

1.4.2 Regolarizzazione

- Nella regressione logistica possiamo applicare le teniche di regolarizzazione
- Verifichiamo utilizzando la regressione lasso se ci sono coefficienti che si azzerano per valori di alpha non elevati
  - E’ spesso indice di collinearità

[258]:
```
model_reg_1 = Pipeline([
    ("scaler", StandardScaler()),
    ("log", LogisticRegression(solver="saga", random_state=42, penalty="l1",␣
 ↪C=1))
])
%time model_reg_1.fit(X_train, y_train)
```

```
Wall time: 25.4 s
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[258]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('log',
                 LogisticRegression(C=1, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=None, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l1', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

[259]:
```
coeff = pd.Series(model_reg_1.named_steps["log"].coef_[0], index=X.columns)
', '.join(coeff[coeff==0].index)
```

[259]:
```
'meal_Undefined, country_BDI, country_BHS, country_BWA, country_CAF,
country_CYM, country_DJI, country_DMA, country_ESP, country_FJI, country_IMN,
country_KHM, country_KIR, country_LCA, country_MDG, country_MWI, country_NAM,
country_NPL, country_PLW, country_PYF, country_SDN, country_SMR, country_SUR,
country_TGO, country_VGB, country_ZMB, market_segment_Undefined,
distribution_channel_Undefined, reserved_room_type_H, reserved_room_type_L,
reserved_room_type_P'
```

- Sono state rimosse tutte le variabili *undefined*
  - Il valore undefined è un valore utilizzato quando non viene selezionato nessun valore per una certa variabile
    - Nel caso della variabile inziale `meal`, per esempio, viene assegnato se non seleziono nessuna combinazione di pasti
  - Di fatto questo tipo di variabile è deducibile dalle altre variabili ottenute, mediante binarizzazione, dalla stessa variabile categorica
- Per il resto nulla di particolarmente interessante, se non la rimozione di molte delle variabili binarie relative agli stati
  - Poichè sono presenti quasi tutti gli stati del mondo (~196) è un risultato comprensibile
- Applichiamo nuovamente la regolarizzazione lasso, ma questa volta utilizziamo un alpha più elevato al fine di annullare molte più variabili
  - Ci servirà per il prossimo step

[260]:
```
model_reg_2 = Pipeline([
    ("scaler", StandardScaler()),
    ("log", LogisticRegression(solver="saga", random_state=42, penalty="l1",␣
 ↪C=0.002))
])
```

```
%time model_reg_2.fit(X_train, y_train)
```

```
Wall time: 22.8 s

C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[260]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('log',
                 LogisticRegression(C=0.002, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=None, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l1', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- Andiamo a visualizzare i coefficienti più grandi (in valore assoluto) per comprendere quali siano le feature più rilevanti

[261]:
```
pd.Series(model_reg_2.named_steps["log"].coef_[0], index=X.columns).
 ↪sort_values(ascending=False).head(10).append(
pd.Series(model_reg_2.named_steps["log"].coef_[0], index=X.columns).
 ↪sort_values(ascending=False).tail(10))
```

[261]:
```
deposit_type_Non Refund            0.644021
market_segment_Online TA           0.512518
country_PRT                        0.511609
lead_time                          0.436877
previous_cancellations             0.227620
adr                                0.135569
customer_type_Transient            0.116751
stays_in_week_nights               0.110001
distribution_channel_TA/TO         0.051753
country_CHN                        0.051374
company                           -0.038286
market_segment_Offline TA/TO      -0.049784
customer_type_Transient-Party     -0.062018
previous_bookings_not_canceled    -0.079668
country_FRA                       -0.097700
country_DEU                       -0.149741
booking_changes                   -0.159968
required_car_parking_spaces       -0.287879
```

```
total_of_special_requests        -0.517619
deposit_type_No Deposit          -0.645471
dtype: float64
```

- Visualizziamo anche l'intercetta

[262]:
```
model_reg_2.named_steps["log"].intercept_
```

[262]:
```
array([-0.18286659])
```

- Verifichiamo quanti coefficienti hanno valore diverso da zero

[263]:
```
coeff = pd.Series(model_reg_2.named_steps["log"].coef_[0], index=X.columns)
coeff_not_zero = coeff[coeff!=0]
print(len(coeff_not_zero),"coefficienti hanno valore diverso da 0")
```

```
35 coefficienti hanno valore diverso da 0
```

- Le variabili con coefficiente più alto (in valore assoluto) mostrate sopra sono state soggetto di analisi in fase esplorativa in quanto considerate le più rilevanti
  - E' stato quindi tenuto in considerazione anche questo risultato per decidere quali variabili analizzare in fase esplorativa

Variabile `deposit_type`

- Poichè `deposit_type` risulta essere una variabile di rilievo per il modello (e tenuto conto delle osservazioni fatte in fase di analisi esplorativa) si trova opportuno sperimentare l'addestramento di un modello senza essa
  - Effettuiamo una copia dei dataset `X_train` e `X_val` e rimuoviamo la variabile `deposit_type`

[264]:
```
X_train_no_deposit = X_train.copy()
X_val_no_deposit = X_val.copy()
X_train_no_deposit.drop(columns=['deposit_type_No Deposit', 'deposit_type_Non␣
↪Refund','deposit_type_Refundable'], inplace=True)
X_val_no_deposit.drop(columns=['deposit_type_No Deposit', 'deposit_type_Non␣
↪Refund','deposit_type_Refundable'], inplace=True)
```

- Creiamo il nuovo modello con la stessa configurazione di `model_stand` e lo addestriamo con una variabile in meno

[265]:
```
model_no_deposit = Pipeline([
    ("scaler", StandardScaler()),
    ("log", LogisticRegression(solver="saga", random_state=42))
])
model_no_deposit.fit(X_train_no_deposit, y_train)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
```

```
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[265]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('log',
                 LogisticRegression(C=1.0, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=None, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l2', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- Visualizziamo le metriche

[266]:
```
print_model_informations(model_no_deposit, X_train_no_deposit, y_train,␣
↪X_val_no_deposit, y_val)
```

```
Accuracy = 0.8001815843232201         ( Accuracy on training set =
0.7994968505873229 )

Precision (Y) = 0.7922695537792168
Precision (N) = 0.8049060479729322
Precision = 0.7985878008760745

Recall (Y) = 0.7080206166922868
Recall (N) = 0.8664715447154472
Recall = 0.787246080703867

F1 Score (Y) = 0.7477795817018431
F1 Score (N) = 0.834554908225271
F1 Score = 0.7911672449635571

Matrice di confusione:
       N     Y
N  13322  2053
Y   3229  7830
```

- Il modello non sembra aver subito in modo rilevante la mancanza della variabile `deposit_type`

1.4.3 Cross-validation su classificazione

- Quello che vogliamo fare ora è applicare la **Grid Search** e **K-fold cross validation** per trovare gli iperparametri migliori
- Poichè il dataset è molto ampio e le variabili sono molte, la ricerca degli iperparametri ottimali risulta essere molto dispendiosa.

- Riduciamo la dimensione del dataset in termini di variabili
- Realizzo una copia dei dataset di training e validation

[267]:
```
X_train_v2 = X_train.copy()
y_train_v2 = y_train.copy()
X_val_v2 = X_val.copy()
y_val_v2 = y_val.copy()
```

- Attualmente presentano le seguenti dimensioni…

[268]:
```
X_train_v2.shape, X_val_v2.shape
```

[268]:
```
((52867, 248), (26434, 248))
```

- Utilizziamo la serie `coeff_not_zero` ottenuta precedentemente
  - Contiene i coefficienti diversi da zero ottenuti dall'addestramento di un modello di regressione logistica con regolarizzazione Lasso, alpha = 0.003 e variabili standardizzate
- Rimuoviamo dalle copie dei dataset tutte le variabili non presenti all'interno della serie `coeff_not_zero`
  - Vengono quindi rimosse dai nostri dataset le variabili meno rilevanti per il modello precedente

[269]:
```
X_train_v2 = X_train_v2[coeff_not_zero.index]
X_val_v2 = X_val_v2[coeff_not_zero.index]
print("Ho scartato", X_train.shape[1] - coeff_not_zero.shape[0], "variabili")
```

```
Ho scartato 213 variabili
```

- Le nuove dimensioni sono:

[270]:
```
X_train_v2.shape, X_val_v2.shape
```

[270]:
```
((52867, 35), (26434, 35))
```

- Addestriamo un modello su questo nuovo training set
  - Viene utilizzata la configurazione di `model_stand`

[271]:
```
model_stand_v2 = Pipeline([
    ("scaler", StandardScaler()),
    ("log", LogisticRegression(solver="saga", random_state=42))
])
model_stand_v2.fit(X_train_v2, y_train_v2)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[271]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('log',
                 LogisticRegression(C=1.0, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=None, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l2', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- Visulizziamone le metriche...

[272]:
```
print_model_informations(model_stand_v2, X_train_v2, y_train_v2, X_val_v2,␣
↪y_val_v2)
```

```
Accuracy = 0.8071801467806613          ( Accuracy on training set =
0.8045472601055479 )

Precision (Y) = 0.8381352087114338
Precision (N) = 0.7916903167215348
Precision = 0.8149127627164843

Recall (Y) = 0.668143593453296
Recall (N) = 0.9071869918699187
Recall = 0.7876652926616073

F1 Score (Y) = 0.7435471698113209
F1 Score (N) = 0.8455126845088352
F1 Score = 0.7945299271600781

Matrice di confusione:
       N     Y
N  13948  1427
Y   3670  7389
```

- E confrontiamole con quelle ottenute dalla stessa configurazione addestrata però sul dataset completo di tutte le variabili

[273]:
```
print_model_informations(model_stand, X_train, y_train, X_val, y_val)
```

```
Accuracy = 0.8097904214269501          ( Accuracy on training set =
0.8101462159759396 )

Precision (Y) = 0.8362136247073252
Precision (N) = 0.7962210134554824
Precision = 0.8162173190814037
```

```
Recall (Y) = 0.6781806673297767
Recall (N) = 0.9044552845528455
Recall = 0.7913179759413111

F1 Score (Y) = 0.7489514679448771
F1 Score (N) = 0.8468940316686967
F1 Score = 0.7979227498067869

Matrice di confusione:
       N     Y
N  13906  1469
Y   3559  7500
```

- Il modello non sembra aver subito la mancanza delle variabili, le metriche sono estremamente simili
- Definiamo uno `StatifiedKFold` per effettuare la cross-validation
  - Dovendo addestrare un modello a riconoscere delle classi, è opportuno che le proporzioni di ciascuna classe nei fold siano uguali
  - `StratifiedKFold` è una variante di `KFold` che garantisce uguale distribuzione delle classi tra un fold e l'altro

[274]:
```python
from sklearn.model_selection import GridSearchCV, StratifiedKFold
from sklearn.metrics import f1_score
skf = StratifiedKFold(5, shuffle=True, random_state=42)
```

[275]:
```python
for train, val in skf.split(X_train_v2, y_train_v2):
    print(y_train.iloc[val].value_counts())
```

```
N    6171
Y    4404
Name: is_canceled, dtype: int64
N    6170
Y    4403
Name: is_canceled, dtype: int64
N    6170
Y    4403
Name: is_canceled, dtype: int64
N    6170
Y    4403
Name: is_canceled, dtype: int64
N    6170
Y    4403
Name: is_canceled, dtype: int64
```

- Definiamo una “griglia” con liste di valori possibili per gli iperparametri di un modello, al fine di testare tutte le combinazioni possibili mediante la grid search

- Il numero di istanze combinato al numero di variabili rende impraticabile l'uso di feature polinomiali all'interno della Grid Search

[276]:
```
mod = Pipeline([
    ("scaler", None),
    ("lr", LogisticRegression(solver="saga", random_state=42))
])
grid = [
    {
        "scaler": [None, StandardScaler()],
        "lr__penalty": ["none"]
    },
    {
        "scaler": [None, StandardScaler()],
        "lr__penalty": ["l2", "l1"],
        "lr__C": np.logspace(-3, 3, 7)
    },
    {
        "scaler": [None, StandardScaler()],
        "lr__penalty": ["elasticnet"],
        "lr__C": np.logspace(-3, 3, 7),
        "lr__l1_ratio": [0.2, 0.5, 0.7]
    }
]
```

- Definiamo la grid search, specificando il modello, la lista di griglie e lo splitter per la cross-validation (usiamo lo `StratifiedKFold` creato sopra)

[277]:
```
gs = GridSearchCV(mod, grid, cv=skf)
```

- Effettuiamo quindi la ricerca sui dati

[278]:
```
%time gs.fit(X_train_v2, y_train_v2)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
```

```
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
```

```
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
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packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
```

```
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

```
Wall time: 18min 56s
```

[278]:
```
GridSearchCV(cv=StratifiedKFold(n_splits=5, random_state=42, shuffle=True),
             error_score='raise-deprecating',
             estimator=Pipeline(memory=None,
                                steps=[('scaler', None),
                                       ('lr',
                                        LogisticRegression(C=1.0,
                                                           class_weight=None,
                                                           dual=False,
                                                           fit_intercept=True,
                                                           intercept_scaling=1,
                                                           l1_ratio=None,
                                                           max_iter=100,
                                                           multi_class='warn',
                                                           n_jobs=None,
                                                           penalty='l2',
                                                           random_state=42,
                                                           solve…
                          'scaler': [None,
                                     StandardScaler(copy=True, with_mean=True,
                                                    with_std=True)]},
                         {'lr__C': array([1.e-03, 1.e-02, 1.e-01, 1.e+00,
1.e+01, 1.e+02, 1.e+03]),
                          'lr__l1_ratio': [0.2, 0.5, 0.7],
                          'lr__penalty': ['elasticnet'],
                          'scaler': [None,
                                     StandardScaler(copy=True, with_mean=True,
                                                    with_std=True)]}],
             pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
             scoring=None, verbose=0)
```

- Possiamo verificare la migliore combinazione di iperparametri
  - La metrica di riferimento di default è l'accuratezza, cioè la percentuale di classificazioni corrette

[279]:
```
gs.best_params_
```

[279]:
```
{'lr__C': 0.01,
 'lr__penalty': 'l2',
 'scaler': StandardScaler(copy=True, with_mean=True, with_std=True)}
```

- E vedere tutti i dettagli
  - Selezioniamo le 5 parametrizzazioni con accuratezza migliore

[280]:
```
result = pd.DataFrame(gs.cv_results_)
result.sort_values(by="rank_test_score", inplace=True)
result.reset_index(inplace=True, drop=True)
result.head(5)
```

[280]:
```
   mean_fit_time  std_fit_time  mean_score_time  std_score_time  \
0       1.013004      0.095674         0.025397        0.001021
1       3.936015      0.025648         0.025385        0.001026
2       1.391806      0.202484         0.025594        0.001024
3       4.008807      0.110087         0.024992        0.000009
4       3.244015      0.020951         0.024585        0.000484

  param_lr__penalty                                     param_scaler  \
0                l2  StandardScaler(copy=True, with_mean=True, with…
1        elasticnet  StandardScaler(copy=True, with_mean=True, with…
2        elasticnet  StandardScaler(copy=True, with_mean=True, with…
3        elasticnet  StandardScaler(copy=True, with_mean=True, with…
4                l1  StandardScaler(copy=True, with_mean=True, with…

  param_lr__C param_lr__l1_ratio  \
0        0.01                NaN
1         0.1                0.5
2        0.01                0.2
3         0.1                0.2
4           1                NaN

                                              params  split0_test_score  \
0  {'lr__C': 0.01, 'lr__penalty': 'l2', 'scaler':…           0.805390
1  {'lr__C': 0.1, 'lr__l1_ratio': 0.5, 'lr__penal…           0.805863
2  {'lr__C': 0.01, 'lr__l1_ratio': 0.2, 'lr__pena…           0.804634
3  {'lr__C': 0.1, 'lr__l1_ratio': 0.2, 'lr__penal…           0.805863
4  {'lr__C': 1.0, 'lr__penalty': 'l1', 'scaler': …           0.805863

   split1_test_score  split2_test_score  split3_test_score  split4_test_score  \
0           0.810839           0.801759           0.804407           0.800719
1           0.810934           0.801854           0.802894           0.799962
2           0.810366           0.801948           0.803840           0.800719
3           0.811123           0.801570           0.802989           0.799868
4           0.811217           0.801759           0.802894           0.799678
```

```
   mean_test_score  std_test_score  rank_test_score
0         0.804623        0.003542                1
1         0.804301        0.003827                2
2         0.804301        0.003331                2
3         0.804282        0.003945                4
4         0.804282        0.004002                4
```

- Andiamo a visualizzare le misure del miglior modello ottenuto

[281]:
```
print_model_informations(gs, X_train_v2, y_train_v2, X_val_v2, y_val_v2)
```

```
Accuracy = 0.8072179768479988         ( Accuracy on training set =
0.8049255679346284 )

Precision (Y) = 0.8405482581382068
Precision (N) = 0.7907121443520561
Precision = 0.8156302012451314

Recall (Y) = 0.6654308707839769
Recall (N) = 0.9092032520325203
Recall = 0.7873170614082485

F1 Score (Y) = 0.7428081154739073
F1 Score (N) = 0.8458280389665396
F1 Score = 0.7943180772202234

Matrice di confusione:
       N     Y
N  13979  1396
Y   3700  7359
```

- Possiamo notare un valore leggermente più basso degli altri per quanto riguarda `Recall (Y)`, ovvero la percentuale di istanze cancellate che sono state classificate come tali.
  - Dal suo valore sappiamo che di tutte le prenotazioni cancellate il modello è in grado di trovarne il 67% circa
  - In compenso `Precision (Y)` è alta, sappiamo quindi che circa l'84% delle istanze che vengono classificate come cancellate lo sono veramente

1.4.4 Test polinomiale con la riduzione delle feature

- Proviamo come ultima strada a vedere se è possibile ottenere un modello migliore utilizzando le feature polinomiali
  - Come detto precedentemente il numero di istanze combinato al numero di variabili rende impraticabile l'uso di feature polinomiali
  - Riduciamo quindi ulteriormente il numero di feature
    * Per farlo utilizziamo il medesimo approccio proposto precedentemente: utilizziamo la regressione Lasso con un valore molto alto per rimuovere più variabili possibili, mantenendo le più rilevanti

[282]:
```
model_reg_extreme = Pipeline([
    ("scaler", StandardScaler()),
    ("log", LogisticRegression(solver="saga", random_state=42, penalty="l1",␣
 ↪C=0.0005))
])
%time model_reg_extreme.fit(X_train, y_train)
```

```
Wall time: 15.2 s
```

[282]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('log',
                 LogisticRegression(C=0.0005, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=None, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l1', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- In numero di coefficienti diversi da 0 è…

[283]:
```
coeff = pd.Series(model_reg_extreme.named_steps["log"].coef_[0], index=X.
 ↪columns)
coeff_not_zero = coeff[coeff!=0]
len(coeff_not_zero)
```

[283]:
```
11
```

- Viene realizzata una copia del dataset binarizzato iniziale, rimuovendo tutte le variabili non presenti fra quelle con coefficiente diverso da 0

[284]:
```
X_train_poly = X_train[coeff_not_zero.index]
X_val_poly = X_val[coeff_not_zero.index]
```

- Si propone una Grid Search con features polinomiali, giusto per provare un paio di gradi possibili

[285]:
```
from sklearn.preprocessing import PolynomialFeatures
polynomial_model = Pipeline([
    ("poly", PolynomialFeatures(include_bias=False)),
    ("scale",  StandardScaler()),
    ("linreg", LogisticRegression(solver="saga", random_state=42))
])
grid = {
    "poly__degree": [2,3]
```

```
    }
gs_poly = GridSearchCV(polynomial_model, param_grid=grid)
%time gs_poly.fit(X_train_poly, y_train)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\model_selection\_split.py:1978: FutureWarning: The default
value of cv will change from 3 to 5 in version 0.22. Specify it explicitly to
silence this warning.
  warnings.warn(CV_WARNING, FutureWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

```
Wall time: 1min 18s
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[285]:
```
GridSearchCV(cv='warn', error_score='raise-deprecating',
             estimator=Pipeline(memory=None,
                                steps=[('poly',
                                        PolynomialFeatures(degree=2,
                                                           include_bias=False,
interaction_only=False,
                                                           order='C')),
```

```
                                          ('scale',
                                           StandardScaler(copy=True,
                                                          with_mean=True,
                                                          with_std=True)),
                                          ('linreg',
                                           LogisticRegression(C=1.0,
                                                              class_weight=None,
                                                              dual=False,
                                                              fit_intercept=True,
                                                              intercept_scaling=1,
                                                              l1_ratio=None,
                                                              max_iter=100,
                                                              multi_class='warn',
                                                              n_jobs=None,
                                                              penalty='l2',
                                                              random_state=42,
                                                              solver='saga',
                                                              tol=0.0001,
                                                              verbose=0,
                                                              warm_start=False))],
                                   verbose=False),
             iid='warn', n_jobs=None, param_grid={'poly__degree': [2, 3]},
             pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
             scoring=None, verbose=0)
```

- Mostriamo tutte le parametrizzazioni ottenute

[286]:
```
result_poly = pd.DataFrame(gs_poly.cv_results_)
result_poly.sort_values(by="rank_test_score", inplace=True)
result_poly.reset_index(inplace=True, drop=True)
result_poly
```

[286]:
```
   mean_fit_time  std_fit_time  mean_score_time  std_score_time  \
0       4.670328      0.072898         0.065332        0.001246
1      18.762003      0.097495         0.235662        0.001252

  param_poly__degree                 params  split0_test_score  \
0                  2  {'poly__degree': 2}           0.809170
1                  3  {'poly__degree': 3}           0.808432

   split1_test_score  split2_test_score  mean_test_score  std_test_score  \
0           0.802247           0.802735         0.804717        0.003155
1           0.801566           0.802508         0.804169        0.003039

   rank_test_score
0                1
1                2
```

- Prendiamo il miglior modello e visualizziamone le metriche

[287]:
```python
print_model_informations(gs_poly, X_train_poly, y_train, X_val_poly, y_val)
```

```
Accuracy = 0.8048725126730726         ( Accuracy on training set =
0.8044148523653697 )

Precision (Y) = 0.8214402440352979
Precision (N) = 0.7960591133004926
Precision = 0.8087496786678953

Recall (Y) = 0.6817976308888688
Recall (N) = 0.8933983739837399
Recall = 0.7875980024363043

F1 Score (Y) = 0.7451329182725565
F1 Score (N) = 0.8419246092552866
F1 Score = 0.7935287637639215

Matrice di confusione:
       N     Y
N  13736  1639
Y   3519  7540
```

- Le feature polinomiali non hanno portato a grossi benefici

1.5 Valutazione dei modelli di classificazione

1.5.1 Intervallo di confidenza sui modelli

[288]:
```python
from scipy.stats import norm
```

- Definiamo una funzione `conf_interval` che calcoli gli estremi dell'intervallo di confidenza e restituisca una tupla con i due estremi, dove:
  - a è l'accuratezza del modello misurata sul validation set
  - N è il numero di osservazioni nel validation set
  - Z è il valore tale per cui l'area sottesa dalla densità di probabilità $\varphi(x)$ della distribuzione normale standard tra -Z e Z sia il livello di confidenza 1-
- Poichè a noi interessa valutare i modelli con una condifidenza del 95%, possiamo ricavare dalle apposite tabelle di valori che, per 1- = 0.95 (=0.05), Z = 1.96

[289]:
```python
def conf_interval(a, N, Z=1.96):
    c = (2 * N * a + Z**2) / (2 * (N + Z**2))
    d = Z * np.sqrt(Z**2 + 4*N*a - 4*N*a**2) / (2 * (N + Z**2))
    return c - d, c + d
```

- Definisco ora una funzione `model_conf_interval` in modo che:
  - prenda in input un modello addestrato `model`, un validation set `X, y` e un livello di confidenza `level` (default 0.95)

- restituisca l'intervallo di confidenza dell'accuratezza del modello, servendosi della funzione `conf_interval` sopra

[290]:
```
def model_conf_interval(model, X, y, level=0.95):
    a = model.score(X, y)
    N = X.shape[0]
    Z = norm.ppf((1 + level) / 2)
    return conf_interval(a, N, Z)
```

1.5.2 Confronto tra modelli

- Dati due modelli diversi, vogliamo poter valutare se l'accuratezza 1 misurata su uno sia significativamente migliore della 2 misurata sull'altro.
- Implementiamo la funzione `diff_interval` in modo che
  - prenda in input le accuratezze `a1` e `a2`, i numeri di osservazioni `N1` e `N2` e il coefficiente `Z`
  - calcoli l'intervallo di confidenza della differenza tra due modelli secondo la formula sopra

[291]:
```
def diff_interval(a1, a2, N1, N2, Z):
    d = abs(a1 - a2)
    sd = np.sqrt(a1 * (1-a1) / N1 + a2 * (1-a2) / N2)
    return d - Z * sd, d + Z * sd
```

- Implementiamo la funzione `model_diff_interval` in modo che
  - prenda in input due modelli `m1, m2`, un validation set `X, y` e un livello di confidenza `level` (default 0.95)
  - restituisca l'intervallo di confidenza della differenza di accuratezza tra i due modelli, valutati entrambi sul validation set dato

[292]:
```
def model_diff_interval(m1, m2, X, y, level=0.95):
    a1 = m1.score(X, y)
    a2 = m2.score(X, y)
    N = len(X)
    Z = norm.ppf((1 + level) / 2)
    return diff_interval(a1, a2, N, N, Z)
```

1.5.3 Miglior modello Grid Search

- Andiamo a prendere i parametri dei tre modelli testati che hanno ottenuto i valori *rank_test_score* più alti nella prima Grid Search
- Primo in classifica

[293]:
```
result.loc[0, 'params']
```

[293]:
```
{'lr__C': 0.01,
 'lr__penalty': 'l2',
 'scaler': StandardScaler(copy=True, with_mean=True, with_std=True)}
```

- Secondo in classifica

[294]:
```
result.loc[1, 'params']
```

[294]:
```
{'lr__C': 0.1,
 'lr__l1_ratio': 0.5,
 'lr__penalty': 'elasticnet',
 'scaler': StandardScaler(copy=True, with_mean=True, with_std=True)}
```

- Terzo in classifica

[295]:
```
result.loc[2, 'params']
```

[295]:
```
{'lr__C': 0.01,
 'lr__l1_ratio': 0.2,
 'lr__penalty': 'elasticnet',
 'scaler': StandardScaler(copy=True, with_mean=True, with_std=True)}
```

- Dai parametri mostrati genero tre modelli, i tre modelli ipoteticamente migliori

[296]:
```
import copy
model_1 = copy.deepcopy(gs.best_estimator_.set_params(**result.loc[0,␣
 ↪'params']))
model_2 = copy.deepcopy(gs.best_estimator_.set_params(**result.loc[1,␣
 ↪'params']))
model_3 = copy.deepcopy(gs.best_estimator_.set_params(**result.loc[2,␣
 ↪'params']))
```

- Usiamo la funzione `model_conf_interval` per calcolare l'intervallo di confidenza al 95% dell'accuratezza dei tre modelli ottenuti stimata sul validation set

[297]:
```
model_conf_interval(model_1, X_val_v2, y_val_v2)
```

[297]:
```
(0.8024179829857884, 0.8119286922258914)
```

[298]:
```
model_conf_interval(model_2, X_val_v2, y_val_v2)
```

[298]:
```
(0.8025707020902547, 0.8120785696859919)
```

[299]:
```
model_conf_interval(model_3, X_val_v2, y_val_v2)
```

[299]:
```
(0.8025707020902547, 0.8120785696859919)
```

- Utilizziamo `model_diff_interval` per calcolare l'intervallo in cui si colloca la differenza di accuratezza dei tre modelli ottenuti, calcolata sul validation set, al 95% di confidenza

[300]:
```
model_diff_interval(model_1, model_2, X_val_v2, y_val_v2)
```

[300]:
```
(-0.006572954172123877, 0.006875594710823983)
```

[301]:
```
model_diff_interval(model_2, model_3, X_val_v2, y_val_v2)
```

[301]:
```
(-0.006723269430056764, 0.006723269430056764)
```

[302]:
```
model_diff_interval(model_1, model_3, X_val_v2, y_val_v2)
```

[302]:
```
(-0.006572954172123877, 0.006875594710823983)
```

- In tutti e tre i casi non abbiamo la certezza che un modello sia meglio dell'altro
  - Poichè l'intervallo ottenuto include lo zero (l'estremo inferiore è negativo), non abbiamo la certezza al 95% che il modello con accuratezza stimata maggiore sia effettivamente migliore
  - Alle volte può essere meglio uno alle vole l'altro
- Prendiamo quindi come riferimento il primo, in quanto tale

Addestramento delle migliori configurazioni su tutte le variabili

- Come parte di questo studio possiamo prendere la migliore configurazione ottenuta dalla grid search ed addestrarla su tutte le variabili invece che solo su una parte di esse

[303]:
```
# Primo modello
model_1_completo = Pipeline([
    ("scaler", result.loc[0, 'param_scaler']),
    ("lr", LogisticRegression(solver="saga", penalty=result.loc[0,␣
↪'param_lr__penalty'], l1_ratio=result.loc[0, 'param_lr__l1_ratio'], C=result.
↪loc[0, 'param_lr__C'], random_state=42))
])
```

- Addestriamo il modello su tutte le variabili

[304]:
```
%time model_1_completo.fit(X_train, y_train)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\logistic.py:1506: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  "(penalty={})".format(self.penalty))
```

```
Wall time: 19.9 s
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\sag.py:337: ConvergenceWarning: The max_iter was
reached which means the coef_ did not converge
  "the coef_ did not converge", ConvergenceWarning)
```

[304]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('lr',
                 LogisticRegression(C=0.01, class_weight=None, dual=False,
```

```
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=nan, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l2', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- Vogliamo confrontare il modello ottenuto con la sua stessa configurazione addestrata solo su parte delle variabili
  - Per fare questo è necessario definire una nuova funzione che chiamiamo `model_diff_interval_v2`
    - Implementiamo la funzione `model_diff_interval_v2` in modo che prenda in input due validation set, `Xm1, ym1` e `Xm2, ym2`, uno per ciascun modello.
    - Questo è necessario perchè i due modelli sono stati addestrati due dataset di training diversi, uno con più variabili ed uno con meno
      - Il confronto è valido se i due validation set passati sono uguali, ciò che può cambiare è solo il numero di variabili.

[305]:
```python
def model_diff_interval_v2(m1, m2, Xm1, ym1, Xm2, ym2, level=0.95):
    a1 = m1.score(Xm1, ym1)
    a2 = m2.score(Xm2, ym2)
    N = len(Xm1)
    Z = norm.ppf((1 + level) / 2)
    return diff_interval(a1, a2, N, N, Z)
```

- Per ciascuna differenza vogliamo visualizzare:
  - le accurattezze di entrambi i modelli
  - se la differenza di accuratezza è statisticamente significativa
- Definiamo la funzione `valuate_complete_model` a cui passiamo:
  - Il primo modello e il suo validation set: `X_val_1`, `y_val_1`, `model_1`
  - Il secondo modello e il suo validation set: `X_val_2`, `y_val_2`, `model_2`

[306]:
```python
def valuate_complete_model(model_1, X_val_1, y_val_1, model_2, X_val_2,␣
 ↪y_val_2):
    print("Accuratezza del primo modello: ", model_1.score(X_val_1, y_val_1))
    print("Accuratezza del secondo modello: ", model_2.score(X_val_2, y_val_2))
    print("Intervallo di confidenza: ", model_diff_interval_v2(model_1,␣
 ↪model_2, X_val_1, y_val_1, X_val_2, y_val_2))
```

- Verichiamo la differenza del modello appena addestrato su tutte le variabili con la sua versione addestrata solo su parte delle variabili

[307]:
```python
valuate_complete_model(model_1_completo, X_val, y_val, model_1, X_val_v2,␣
 ↪y_val_v2)
```

```
Accuratezza del primo modello:  0.80948778088825
Accuratezza del secondo modello:  0.8072179768479988
```

```
Intervallo di confidenza:  (-0.004440334474141178, 0.008979942554643645)
```

- La differenza non è statisticamente significativa
  - L'uso di più variabili non porta benefici apprezzabili
- Sono stati creati diversi modelli oltre a `model_1`
  - Verifichiamo se fra quelli ottenuti se ne cela uno migliore
  - Vengono confrontati in ordine, dal primo all'ultimo creato

[308]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model, X_val, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.7946205644246047
Intervallo di confidenza:  (0.005790712703276409, 0.019404112143511735)
```

[339]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, random, X_val, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.49708708481501096
Intervallo di confidenza:  (0.3024533846743816, 0.31780839939159405)
```

[309]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model_stand, X_val, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.8097904214269501
Intervallo di confidenza:  (-0.004135664148745229, 0.009280553306647905)
```

[310]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model_reg_1, X_val, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.8100552318983127
Intervallo di confidenza:  (-0.0038690754819621243, 0.00954358558259004)
```

[311]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model_reg_2, X_val, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.7961337671181055
Intervallo di confidenza:  (0.004287059396476157, 0.01788136006331049)
```

[312]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model_no_deposit,␣
↪X_val_no_deposit, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.8001815843232201
Intervallo di confidenza:  (0.0002650945393703093, 0.013807690510187137)
```

[313]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, model_stand_v2, X_val_v2,␣
↪y_val_v2)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.8071801467806613
Intervallo di confidenza:  (-0.0066877003499082694, 0.006763360484583324)
```

[314]:
```
valuate_complete_model(model_1, X_val_v2, y_val_v2, gs_poly, X_val_poly, y_val)
```

```
Accuratezza del primo modello:  0.8072179768479988
Accuratezza del secondo modello:  0.8048725126730726
Intervallo di confidenza:  (-0.004395308196781005, 0.009086236546633413)
```

- Nessuno si è dimostrato migliore in modo statisticamente significativo di `model_1`
- Visualizziamo in dettaglio le metriche dei modelli che non si sono dimostrati peggiori in modo statisticamente significativo

[315]:
```
print_model_informations(model_1, X_train_v2, y_train_v2, X_val_v2, y_val_v2)
```

```
Accuracy = 0.8072179768479988         ( Accuracy on training set =
0.8049255679346284 )

Precision (Y) = 0.8405482581382068
Precision (N) = 0.7907121443520561
Precision = 0.8156302012451314

Recall (Y) = 0.6654308707839769
Recall (N) = 0.9092032520325203
Recall = 0.7873170614082485

F1 Score (Y) = 0.7428081154739073
F1 Score (N) = 0.8458280389665396
F1 Score = 0.7943180772202234

Matrice di confusione:
       N     Y
N  13979  1396
Y   3700  7359
```

[340]:
```
print_model_informations(model_stand, X_train, y_train, X_val, y_val)
```

```
Accuracy = 0.8097904214269501         ( Accuracy on training set =
0.8101462159759396 )

Precision (Y) = 0.8362136247073252
Precision (N) = 0.7962210134554824
Precision = 0.8162173190814037

Recall (Y) = 0.6781806673297767
Recall (N) = 0.9044552845528455
Recall = 0.7913179759413111
```

```
F1 Score (Y) = 0.7489514679448771
F1 Score (N) = 0.8468940316686967
F1 Score = 0.7979227498067869

Matrice di confusione:
       N     Y
N  13906  1469
Y   3559  7500
```

[316]:
```
print_model_informations(model_reg_1, X_train, y_train, X_val, y_val)
```

```
Accuracy = 0.8100552318983127         ( Accuracy on training set =
0.8101273005844856 )

Precision (Y) = 0.8366413916146298
Precision (N) = 0.7964044429176687
Precision = 0.8165229172661492

Recall (Y) = 0.6784519395967086
Recall (N) = 0.9047154471544715
Recall = 0.79158369337559

F1 Score (Y) = 0.7492884605782194
F1 Score (N) = 0.8471118419049358
F1 Score = 0.7982001512415776

Matrice di confusione:
       N     Y
N  13910  1465
Y   3556  7503
```

[317]:
```
print_model_informations(model_stand_v2, X_train_v2, y_train_v2, X_val_v2,␣
 ↪y_val_v2)
```

```
Accuracy = 0.8071801467806613         ( Accuracy on training set =
0.8045472601055479 )

Precision (Y) = 0.8381352087114338
Precision (N) = 0.7916903167215348
Precision = 0.8149127627164843

Recall (Y) = 0.668143593453296
Recall (N) = 0.9071869918699187
Recall = 0.7876652926616073

F1 Score (Y) = 0.7435471698113209
F1 Score (N) = 0.8455126845088352
```

```
F1 Score = 0.7945299271600781

Matrice di confusione:
       N     Y
N  13948  1427
Y   3670  7389
```

[318]:
```
print_model_informations(gs_poly, X_train_poly, y_train, X_val_poly, y_val)
```

```
Accuracy = 0.8048725126730726         ( Accuracy on training set =
0.8044148523653697 )

Precision (Y) = 0.8214402440352979
Precision (N) = 0.7960591133004926
Precision = 0.8087496786678953

Recall (Y) = 0.6817976308888688
Recall (N) = 0.8933983739837399
Recall = 0.7875980024363043

F1 Score (Y) = 0.7451329182725565
F1 Score (N) = 0.8419246092552866
F1 Score = 0.7935287637639215

Matrice di confusione:
       N     Y
N  13736  1639
Y   3519  7540
```

- Non abbiamo ottenuto nessun modello con una accuratezza più alta di `model_1` che presenta una differenza di accuratezza statisticamente significativa
  - Quello che presenta le metriche leggermente più alte ora potrebbe ottenere metriche peggiori su un altro validation set
    - Mantengo quindi come modello di riferimento `model_1`

1.6 Interpretazione della conoscenza appresa

- Interpretiamo ora la conoscenza appresa attraverso l'analisi dei parametri (o coefficienti degli iperpiani) appresi
- Analizziamo quali feature sono più positivamente o negativamente correlate ed in che misura con la variabile da predire

[319]:
```
model_1
```

[319]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('lr',
```

```
                   LogisticRegression(C=0.01, class_weight=None, dual=False,
                                      fit_intercept=True, intercept_scaling=1,
                                      l1_ratio=None, max_iter=100,
                                      multi_class='warn', n_jobs=None,
                                      penalty='l2', random_state=42,
                                      solver='saga', tol=0.0001, verbose=0,
                                      warm_start=False))],
         verbose=False)
```

- Visualizziamo prima di tutto l'intercetta di questo modello

[320]:
```
model_1.named_steps["lr"].intercept_
```

[320]:
```
array([-0.048368])
```

- La probabilità di partenza è molto vicina a 0 (ovvero la classe `N`)
- Mostriamo tutti i coefficienti ordinati in ordine decrescente (non in valore assoluto)

[321]:
```
coeff = pd.Series(model_1.named_steps["lr"].coef_[0], index=X_train_v2.columns)
coeff.sort_values(ascending=False)
```

[321]:
```
deposit_type_Non Refund           0.896440
country_PRT                       0.606842
previous_cancellations            0.603048
market_segment_Online TA          0.555759
lead_time                         0.548031
adr                               0.237249
customer_type_Transient           0.223267
stays_in_week_nights              0.170751
country_CHN                       0.094427
distribution_channel_TA/TO        0.092039
country_AGO                       0.085336
stays_in_weekend_nights           0.080352
country_ITA                       0.074243
meal_FB                           0.065896
country_ARE                       0.062770
meal_SC                           0.062374
adults                            0.056063
country_HKG                       0.054410
country_BRA                       0.052870
arrival_date_day_Saturday         0.044088
customer_type_Transient-Party    -0.035458
country_CHE                      -0.061560
company                          -0.064601
country_SWE                      -0.066275
country_BEL                      -0.071726
country_NLD                      -0.083775
```

```
country_AUT                       -0.089376
market_segment_Offline TA/TO     -0.135829
country_FRA                       -0.163278
country_DEU                       -0.221865
booking_changes                   -0.237910
previous_bookings_not_canceled   -0.501188
total_of_special_requests        -0.629042
required_car_parking_spaces      -0.640118
deposit_type_No Deposit           -0.888439
dtype: float64
```

- Analizzando i coefficienti possiamo ritrovare tutte le considerazioni fatte in fase di analisi esplorativa
- Facciamo dunque notare solo qualche dettaglio:
  - La variabili relative alle diverse nazioni ricoprono, per la maggior parte, un ruolo non di primo piano
    - Non tutte sono state annullate in quanto, evidentemente, alcune hanno rilevanza per effettuare una predizione
    - Tra queste la variabile *PRT* assume un ruolo di estremo rilievo
      - Si era visto in fase esplorativa che la variabile `country` presentava una alto tasso di cancellazioni da parte dei clienti provenienti dal Portogallo (ovvero la maggior parte essendo l'hotel portoghese)
      - Il modello ha appreso questa informazione, aumentando di molto la probabilità che la prenotazione venga cancellata se questa è effettuata da un cliente portoghese
  - Le variabili `deposit_type_No Deposit` e `deposit_type_Non Refund` assumono anche esse un ruolo di particolare rilievo
    - `deposit_type` con valore *Non Refund* aumenta la probabilità che la prenotazione venga considerata come cancellata
    - `deposit_type` con valore *No Deposit* , che presenta a differenza di *Non Refund* una bassa percentuale di cancellazioni, agisce esattamente nel senso opposto
  - Avevamo visto che la variabile `required_car_parking_spaces` quando maggiore di 0 presentava zero cancellazioni, e dai coefficienti apprendiamo che tale conoscenza è tenuta in cosiderazione dal modello
    - La probabilità che una prenotazione venga cancellata tende a diminuire tante più sono le macchine
- Notiamo che la probabilità che una prenotazione venga cancellata dimuisce…
  - tanto più sono le richieste speciali
  - tanto più sono le prenotazioni non cancellate
  - tanto più sono le modifiche alla prenotazione
- Notiamo che la probabilità che una prenotazione venga cancellata aumenta…
  - tanto più sono le prenotazione cancellate
  - tanto più è il tempo che intercorre dalla prenotazione all'arrivo in hotel

    - tanto più è il costo medio per notte
- Il resto delle variabili può essere intepretato nel medesimo modo

1.6.1 Addestramento miglior configurazione su entrambi i dataset

- Per curiosità addestriamo la configurazione migliore su tutto il dataset, comprensivo di entrambi gli hotel
    - Dobbiamo aggiungere tutte le istanze dell'hotel *Resort Hotel* al dataset di training in nostro possesso, contenente sole istanze di *City Hotel*
    - Ripetiamo le operazioni effettuate nel paragrafo *Classificazione Lineare* per ottenere la parte del dataset mancante
        * Rimuoviamo le istanze di *City Hotel*
        * Rimuoviamo la variabile *hotel* , in quanto inutile
        * Cambiamo in *Y* e *N* le istanze della variabile da predire
        * Separiamo la variabile da predire dalle altre variabili
        * Binarizziamo tutte le variabili categoriche
            · Manteniamo solo il sottoinsieme di variabili utilizzato nei modelli precedenti

[322]:
```
hbd_resort = hbd_complete[hbd_complete["hotel"] == "Resort Hotel"].copy()
hbd_resort.drop(inplace=True, axis=1, labels=['hotel'])
hbd_resort["is_canceled"] = hbd_resort["is_canceled"].map(lambda value: "N" if␣
↪value is 0 else "Y")
y_resortHotel = hbd_resort["is_canceled"]
X_resortHotel = hbd_resort.drop(columns="is_canceled")
X_resortHotel = pd.get_dummies(X_resortHotel)
X_resortHotel = X_resortHotel[X_train_v2.columns]
```

- Prendo le variabili `X_resortHotel` e `y_resortHotel` definite, che contengono tutte le istanze del dataset *Resort Hotel* già private di tutte le variabili meno rilevanti, e le unisco rispettivamente a `X_train_v2` e `y_train_v2`
    - In questo modo mantengo un validation set identico ai test precedenti, e al tempo stesso aggiungo le istanze del `Resort_Hotel` al training set
        * Il nostro obiettivo è sempre realizzare un modello per *City Hotel* , dunque il nostro validation set non deve comprendere istanze di *Resort Hotel*

[323]:
```
y_train_all = y_train_v2.append(y_resortHotel)
X_train_all = X_train_v2.append(X_resortHotel)
```

- Riporto la configurazione del primo modello

[324]:
```
model_1_both_dataset = Pipeline([
    ("scaler", result.loc[0, 'param_scaler']),
    ("lr", LogisticRegression(solver="saga", penalty=result.loc[0,␣
↪'param_lr__penalty'], l1_ratio=result.loc[0, 'param_lr__l1_ratio'], C=result.
↪loc[0, 'param_lr__C'], random_state=42))
])
```

- Lo addesto sul dataset…

[325]:
```
%time model_1_both_dataset.fit(X_train_all, y_train_all)
```

```
C:\Users\alessandr.lombardin3\AppData\Local\Continuum\anaconda3\lib\site-
packages\sklearn\linear_model\logistic.py:1506: UserWarning: l1_ratio parameter
is only used when penalty is 'elasticnet'. Got (penalty=l2)
  "(penalty={})".format(self.penalty))
```

```
Wall time: 6.97 s
```

[325]:
```
Pipeline(memory=None,
         steps=[('scaler',
                 StandardScaler(copy=True, with_mean=True, with_std=True)),
                ('lr',
                 LogisticRegression(C=0.01, class_weight=None, dual=False,
                                    fit_intercept=True, intercept_scaling=1,
                                    l1_ratio=nan, max_iter=100,
                                    multi_class='warn', n_jobs=None,
                                    penalty='l2', random_state=42,
                                    solver='saga', tol=0.0001, verbose=0,
                                    warm_start=False))],
         verbose=False)
```

- Visualizziamone le metriche

[326]:
```
print_model_informations(model_1_both_dataset, X_train_all, y_train_all,␣
↪X_val_v2, y_val_v2)
```

```
Accuracy = 0.7981765907543316          ( Accuracy on training set =
0.8088100104906828 )

Precision (Y) = 0.8412830908657286
Precision (N) = 0.7781471631205674
Precision = 0.809715126993148

Recall (Y) = 0.6379419477348766
Recall (N) = 0.9134308943089431
Recall = 0.7756864210219099

F1 Score (Y) = 0.7256364103882746
F1 Score (N) = 0.8403793794692277
F1 Score = 0.7830078949287511

Matrice di confusione:
       N     Y
N  14044  1331
Y   4004  7055
```

- Verichiamo il suo intervallo di confidenza

[327]:
```
model_conf_interval(model_1_both_dataset, X_val_v2, y_val_v2)
```

[327]: (0.7932950212054458, 0.8029715092733697)

- Confrontiamolo con il modello migliore in nostro possesso, quello addestrato solo su istanze di *City Hotel*

[328]:
```
valuate_complete_model(model_1_both_dataset, X_val_v2, y_val_v2, model_1,␣
↪X_val_v2, y_val_v2)
```

```
Accuratezza del primo modello:  0.7981765907543316
Accuratezza del secondo modello:  0.8072179768479988
Intervallo di confidenza:  (0.00225722655771183, 0.01582554562962262)
```

- Abbiamo ottenuto un modello con una accuratezza inferiore, la cui differenza con quella del nostro miglior modello risulta essere statisticamente significativa
  - Possiamo quindi affermare che non è conveniente addestrare il modello su tutte le istanze se questo è destinato alla sola struttura *City Hotel*

1.7 (Plus) Classificazione con reti neurali

- Quello che possiamo fare ora è creare un modello di classificazione di tipo *multi-layer perceptron*
- Per creare un modello di classificazione di questo tipo usiamo la classe `MLPClassifier`
  - con `hidden_layer_sizes` specifichiamo il numero di variabili nascoste da introdurre
  - con `activation="identity"` specifichiamo che tali variabili sono lineari
- Addestriamo il modello su tutte le istanze dell'hotel *City Hotel* , con tutte le variabili ottenute dalla binarizzazione
- Per prima cosa realizziamo un modello con sole funzioni di attivazione *identity*

[329]:
```
from sklearn.neural_network import MLPClassifier
```

[330]:
```
model_linear = MLPClassifier(hidden_layer_sizes=(16,8,4,2),␣
↪activation="identity")
%time model_linear.fit(X_train, y_train)
print_model_informations(model_linear,  X_train, y_train, X_val, y_val)
```

```
Wall time: 9.43 s
Accuracy = 0.8099039116289627         ( Accuracy on training set =
0.8085005769194393 )

Precision (Y) = 0.8459069020866774
Precision (N) = 0.7921747967479674
Precision = 0.8190408494173225

Recall (Y) = 0.6671489284745457
Recall (N) = 0.9125853658536586
```

```
Recall = 0.7898671471641021

F1 Score (Y) = 0.7459683534705022
F1 Score (N) = 0.8481276634327681
F1 Score = 0.7970480084516351

Matrice di confusione:
       N     Y
N  14031  1344
Y   3681  7378
```

- Questo modello è quasi identico al nostro miglior modello
- Andiamo a verificare il suo intervallo di confidenza

[331]:
```python
model_conf_interval(model_linear, X_val, y_val)
```

[331]:
```
(0.8051289150836776, 0.8145888491490623)
```

- Confrontiamo con il nostro miglior modello non basato su una rete neurale

[332]:
```python
valuate_complete_model(model_linear, X_val, y_val, model_1, X_val_v2, y_val_v2)
```

```
Accuratezza del primo modello:  0.8099039116289627
Accuratezza del secondo modello:  0.8072179768479988
Intervallo di confidenza:  (-0.004021412106746672 5, 0.009393281668674484)
```

- Poichè l'intervallo ottenuto include lo zero (l'estremo inferiore è negativo), non abbiamo la certezza al 95% che il modello con accuratezza stimata maggiore sia effettivamente migliore
  - La differenza non è statisticamente significativa
- Proviamo a fare di meglio
- L'output finale è anche qui una combinazione lineare dell'input
- Possiamo aggiungere espressività al modello introducendo trasformazioni non lineari
  - La funzione *ReLU* (*rectified linear unit*) è un esempio di funzione che introduce non linearità
- Le reti neurali durante il loro addestramento identificano, di fatto, una funzione Kernel.
  - Non dovendo calcolare alcuna feature non abbiamo alcun problema ad applicare trasformazioni non lineari al dataset completo

[333]:
```python
model_not_linear = MLPClassifier(hidden_layer_sizes=8, batch_size=50,␣
 ↪activation="relu", random_state=42)
%time model_not_linear.fit(X_train, y_train)
print_model_informations(model_not_linear, X_train, y_train,  X_val, y_val)
```

```
Wall time: 1min 21s
Accuracy = 0.8409623969130665         ( Accuracy on training set =
0.8456314903436927 )
```

```
Precision (Y) = 0.8201176800224153
Precision (N) = 0.855153557576143
Precision = 0.8376356187992791

Recall (Y) = 0.7940139253097025
Recall (N) = 0.8747317073170732
Recall = 0.8343728163133879

F1 Score (Y) = 0.8068547275567399
F1 Score (N) = 0.8648318436113434
F1 Score = 0.8358432855840416

Matrice di confusione:
       N     Y
N  13449  1926
Y   2278  8781
```

- Verichiamo il suo intervallo di confidenza

[334]:
```
model_conf_interval(model_not_linear, X_val, y_val)
```

[334]:
```
(0.8365042543388092, 0.8453214547712599)
```

- Confrontiamolo ora con il nostro migliore modello senza rete neurale

[335]:
```
print_model_informations(model_1, X_train_v2, y_train_v2, X_val_v2, y_val_v2)
```

```
Accuracy = 0.8072179768479988         ( Accuracy on training set =
0.8049255679346284 )

Precision (Y) = 0.8405482581382068
Precision (N) = 0.7907121443520561
Precision = 0.8156302012451314

Recall (Y) = 0.6654308707839769
Recall (N) = 0.9092032520325203
Recall = 0.7873170614082485

F1 Score (Y) = 0.7428081154739073
F1 Score (N) = 0.8458280389665396
F1 Score = 0.7943180772202234

Matrice di confusione:
       N     Y
N  13979  1396
Y   3700  7359
```

- Applichiamo il confronto sull'accuratezza

[336]:
```
valuate_complete_model(model_not_linear, X_val, y_val, model_1, X_val_v2,␣
↪y_val_v2)
```

```
Accuratezza del primo modello:  0.8409623969130665
Accuratezza del secondo modello:  0.8072179768479988
Intervallo di confidenza:  (0.027259759983788632, 0.040229080146346824)
```

- Poichè l'intervallo ottenuto non include lo zero (l'estremo inferiore è positivio), abbiamo la certezza al 95% che il modello con accuratezza stimata maggiore sia effettivamente migliore
  - La differenza è statisticamente significativa
- Mostriamo coefficienti e intercette

[337]:
```
model_not_linear.coefs_
```

[337]:
```
[array([[ 7.18113655e-03,  6.55512857e-03,  4.43700556e-02, …,
         -3.26398515e-01, -8.56035662e-02,  2.70048887e-03],
        [ 3.65784384e-02,  1.20535844e-01,  9.81561800e-02, …,
         -6.91123771e-03,  9.42045373e-02, -9.18279540e-03],
        [-4.81001105e-01, -1.51023713e-01,  1.83385681e-01, …,
         -1.90153697e-01,  3.05962924e-01, -4.03060257e-02],
        …,
        [ 2.33676861e-01,  7.71001692e-01, -1.18282363e-01, …,
         -1.72480991e-01,  4.59267783e-01,  3.53492206e+00],
        [ 1.00070180e+00, -7.53483986e-01, -7.34250157e-02, …,
          2.65901243e-01,  7.96848440e-01, -4.76132999e-01],
        [-2.82783910e+00,  2.53973015e+00, -1.72098236e+00, …,
         -2.68042324e-01, -1.74190402e+00, -3.18200508e-03]]),
 array([[ 0.33065989],
        [-0.28393118],
        [ 0.19851285],
        [ 0.37427723],
        [ 0.34274162],
        [-0.61334057],
        [-0.30045459],
        [-1.59868305]])]
```

[338]:
```
model_not_linear.intercepts_
```

[338]:
```
[array([-0.18476474,  0.33361153, -0.374455  ,  0.31003749,  0.34980676,
         0.29620993,  0.37467228, -0.21018972]), array([-0.56713692])]
```

- Con la funzione *ReLu* abbiamo ottenuto il miglior modello in nostro possesso
  - Osservando i coefficienti posso però affermare di non essere in grado di comprendere su cosa il modello si basi per trovare il risultato
  - Se volessi adottare questo modello rispetto dovrei rinunciare alla possibilità di sapere su cosa le nostre decisioni si basano