# Assignment: Linear regression on the Advertising data

*Fraida Fund*

**Submit answers to the questions in PrairieLearn as you work through this notebook.**

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**To illustrate principles of linear regression, we are going to use some data from the textbook "An Introduction to Statistical Learning withApplications in R" (Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani) (available via NYU Library).**

**The dataset is described as follows:**

> **Suppose that we are statistical consultants hired by a client to provide advice on how to improve sales of a particular product. The `Advertising` data set consists of the sales of that product in 200 different markets, along with advertising budgets for the product in each of those markets for three different media: TV, radio, and newspaper.**
>
> **...**
>
> **It is not possible for our client to directly increase sales of the product. On the other hand, they can control the advertising expenditure in each of the three media. Therefore, if we determine that there is an association between advertising and sales, then we can instruct our client to adjust advertising budgets, thereby indirectly increasing sales. In other words, our goal is to develop an accurate model that can be used to predict sales on the basis of the three media budgets.**

**Sales are reported in thousands of units, and TV, radio, and newspaper budgets, are reported in thousands of dollars.**

**For this assignment, you will fit a linear regression model to a small dataset. You will iteratively improve your linear regression model by examining the residuals at each stage, in order to identify problems with the model.**

**Make sure to include your name and net ID in a text cell at the top of the notebook.**

In [1]:

```
from sklearn import metrics
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import train_test_split

import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import seaborn as sns
sns.set()

from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all"
```

## 0. Read in and pre-process data

**In this section, you will read in the "Advertising" data, and make sure it is loaded correctly. Visually inspect the data using a pairplot, and note any meaningful observations. In particular, comment on which features appear to be correlated with product sales, and which features appear to be correlated with one another. Then, split the data into training data (70%) and test data (30%).**

**The code in this section is provided for you .**

### Read in data

In [2]:

```
!wget 'https://www.statlearning.com/s/Advertising.csv' -O 'Advertising.csv'
```

```
--2024-02-17 22:15:35--  https://www.statlearning.com/s/Advertising.csv
Resolving www.statlearning.com (www.statlearning.com)... 198.185.159.144, 198.49.23.145,
198.185.159.145, ...
Connecting to www.statlearning.com (www.statlearning.com)|198.185.159.144|:443... connect
ed.
HTTP request sent, awaiting response... 302 Found
Location: https://static1.squarespace.com/static/5ff2adbe3fe4fe33db902812/t/5fffe03b40910
76ff5b30c72/1610604603901/Advertising.csv [following]
--2024-02-17 22:15:35--  https://static1.squarespace.com/static/5ff2adbe3fe4fe33db902812/
t/5fffe03b4091076ff5b30c72/1610604603901/Advertising.csv
Resolving static1.squarespace.com (static1.squarespace.com)... 151.101.0.238, 151.101.64.
238, 151.101.128.238, ...
Connecting to static1.squarespace.com (static1.squarespace.com)|151.101.0.238|:443... con
nected.
HTTP request sent, awaiting response... 200 OK
Length: 4555 (4.4K) [text/csv]
Saving to: 'Advertising.csv'

Advertising.csv     100%[===================>]   4.45K  --.-KB/s    in 0s

2024-02-17 22:15:35 (51.6 MB/s) - 'Advertising.csv' saved [4555/4555]
```

In [3]:

```
df  = pd.read_csv('Advertising.csv', index_col=0)
df.head()
```

Out[3]:

| | TV | radio | newspaper | sales |
|---|---|---|---|---|
| **1** | 230.1 | 37.8 | 69.2 | 22.1 |
| **2** | 44.5 | 39.3 | 45.1 | 10.4 |
| **3** | 17.2 | 45.9 | 69.3 | 9.3 |
| **4** | 151.5 | 41.3 | 58.5 | 18.5 |
| **5** | 180.8 | 10.8 | 58.4 | 12.9 |

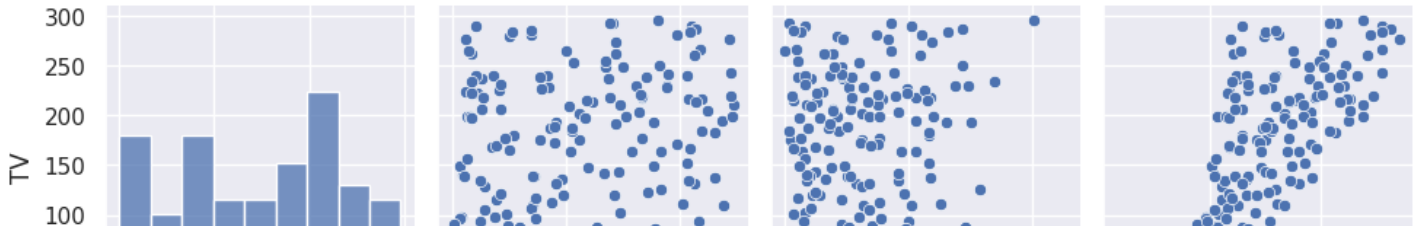
**Note that in this dataset, the first column in the data file is the row label; that's why we use `index_col=0` in the `read_csv` command. If we would omit that argument, then we would have an additional (unnamed) column in the dataset, containing the row number.**

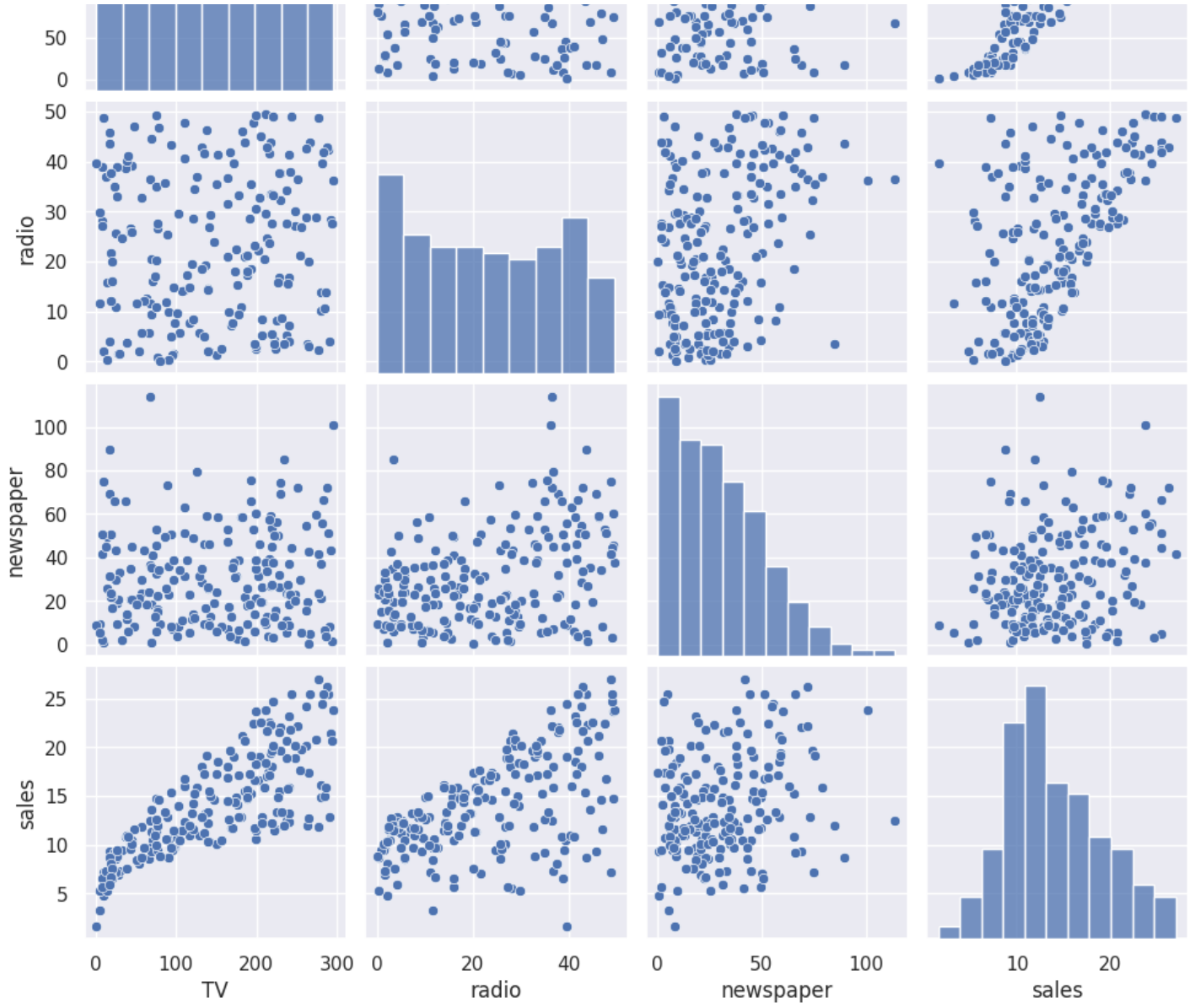
**(You can try removing the `index_col` argument and re-running the cell above, to see the effect and to understand why we used this argument.)**

### Visually inspect the data

In [4]:

```
sns.pairplot(df);
```






**The most important panels here are on the bottom row, where `sales` is on the vertical axis and the advertising budgets are on the horizontal axes.**

**Looking at this row, it appears that TV ad spending and radio ad spending are likely to be useful predictive features for `sales`; for newspaper ad spending, it is not clear from the pairplot whether there is a relationship.**

### Split up data

**We will use 70% of the data for training and the remaining 30% to evaluate the regression model on data *not* used for training.**

In [5]:

```
train, test = train_test_split(df, test_size=0.3, random_state=9)
```

**We will set the `random_state` to a constant so that every time you run this notebook, exactly the same data points will be assigned to test vs. training sets. This is helpful in the debugging stage.**

In [6]:

```
train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 140 entries, 134 to 127
Data columns (total 4 columns):
 #   Column     Non-Null Count  Dtype
---  ------     --------------  -----
 0   TV         140 non-null    float64
```

```
 1   radio      140 non-null    float64
 2   newspaper  140 non-null    float64
 3   sales      140 non-null    float64
dtypes: float64(4)
memory usage: 5.5 KB
```

In [7]:

```
test.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 60 entries, 85 to 7
Data columns (total 4 columns):
 #   Column     Non-Null Count  Dtype  
---  ------     --------------  -----  
 0   TV         60 non-null     float64
 1   radio      60 non-null     float64
 2   newspaper  60 non-null     float64
 3   sales      60 non-null     float64
dtypes: float64(4)
memory usage: 2.3 KB
```

## 1. Fit simple linear regression models

**Use the training data to fit a simple linear regression to predict product sales, for each of three features: TV ad budget, radio ad budget, and newspaper ad budget. In other words, you will fit *three* regression models, with each model being trained on one feature. For each of the three regression models, create a plot of the training data and the regression line, with product sales ($y$) on the vertical axis and the feature on which the model was trained ($x$) on the horizontal axis.**

**Also, for each regression model, print the intercept and coefficients, and compute the MSE and R2 on the training data, and MSE and R2 on the test data.**

**Comment on the results. Which type of ad spending seems to be associated with the largest increase in product sales? Which regression model is most effective at predicting product sales?**

**The code in this section is provided for you. However, you will need to add comments, observations, and answers to the questions.**

#### Fit a simple linear regression

In [8]:

```
reg_tv    = LinearRegression().fit(train[['TV']], train['sales'])
reg_radio = LinearRegression().fit(train[['radio']], train['sales'])
reg_news  = LinearRegression().fit(train[['newspaper']], train['sales'])
```

#### Look at coefficients

In [9]:

```
print("TV       : ", reg_tv.coef_[0], reg_tv.intercept_)
print("Radio    : ", reg_radio.coef_[0], reg_radio.intercept_)
print("Newspaper: ", reg_news.coef_[0], reg_news.intercept_)
```

```
TV       :  0.04964468781898984 6.711432632336138
Radio    :  0.21062312839115208 8.997640913704718
Newspaper:  0.046574464282301664 12.375549417451523
```

#### Plot data and regression line

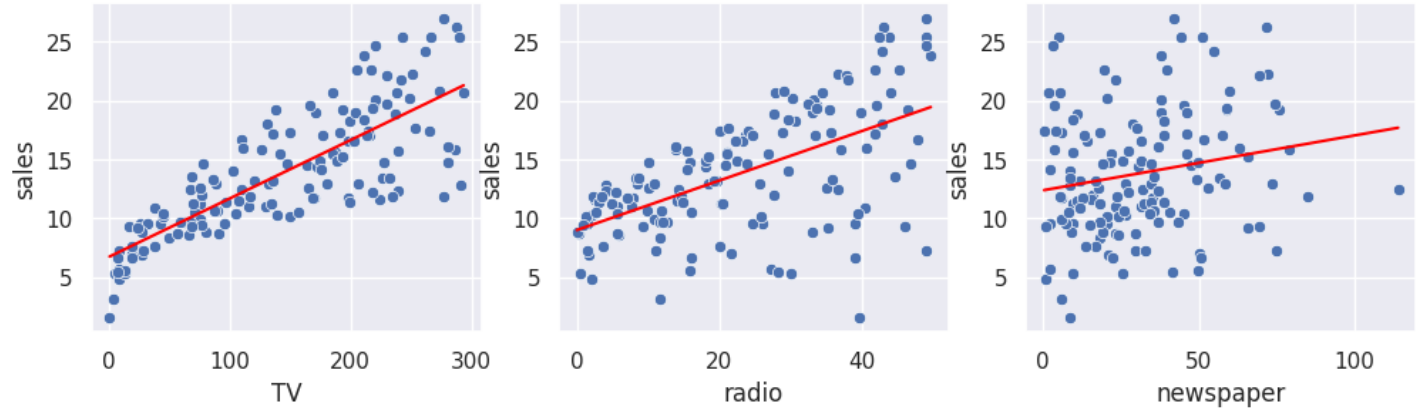
In [10]:

```
fig = plt.figure(figsize=(12,3))
```

```
plt.subplot(1,3,1)
sns.scatterplot(data=train, x="TV", y="sales");
sns.lineplot(data=train, x="TV", y=reg_tv.predict(train[['TV']]), color='red');

plt.subplot(1,3,2)
sns.scatterplot(data=train, x="radio", y="sales");
sns.lineplot(data=train, x="radio", y=reg_radio.predict(train[['radio']]), color='red');

plt.subplot(1,3,3)
sns.scatterplot(data=train, x="newspaper", y="sales");
sns.lineplot(data=train, x="newspaper", y=reg_news.predict(train[['newspaper']]), color=
'red');
```




**Compute R2, MSE for simple regression**

In [11]:

```
y_pred_tr_tv    = reg_tv.predict(train[['TV']])
y_pred_tr_radio = reg_radio.predict(train[['radio']])
y_pred_tr_news  = reg_news.predict(train[['newspaper']])
```

In [12]:

```
r2_tr_tv    = metrics.r2_score(train['sales'], y_pred_tr_tv)
r2_tr_radio = metrics.r2_score(train['sales'], y_pred_tr_radio)
r2_tr_news  = metrics.r2_score(train['sales'], y_pred_tr_news)
print("TV       : ", r2_tr_tv)
print("Radio    : ", r2_tr_radio)
print("Newspaper: ", r2_tr_news)
```

```
TV       :  0.6462575775839753
Radio    :  0.33630082549935214
Newspaper:  0.0373981756207491
```

In [13]:

```
mse_tr_tv    = metrics.mean_squared_error(train['sales'], y_pred_tr_tv)
mse_tr_radio = metrics.mean_squared_error(train['sales'], y_pred_tr_radio)
mse_tr_news  = metrics.mean_squared_error(train['sales'], y_pred_tr_news)
print("TV       : ", mse_tr_tv)
print("Radio    : ", mse_tr_radio)
print("Newspaper: ", mse_tr_news)
```

```
TV       :  9.798510609335318
Radio    :  18.384177273212142
Newspaper:  26.663650133692155
```

In [14]:

```
y_pred_ts_tv    = reg_tv.predict(test[['TV']])
y_pred_ts_radio = reg_radio.predict(test[['radio']])
y_pred_ts_news  = reg_news.predict(test[['newspaper']])
```

In [15]:

```
r2_ts_tv    = metrics.r2_score(test['sales'], y_pred_ts_tv)
```

```
r2_ts_radio = metrics.r2_score(test['sales'], y_pred_ts_radio)
r2_ts_news  = metrics.r2_score(test['sales'], y_pred_ts_news)
print("TV       : ", r2_ts_tv)
print("Radio    : ", r2_ts_radio)
print("Newspaper: ", r2_ts_news)
```

```
TV       :  0.5138892470208256
Radio    :  0.3072356147167632
Newspaper:  0.06497948830922318
```

In [16]:

```
mse_ts_tv    = metrics.mean_squared_error(test['sales'], y_pred_ts_tv)
mse_ts_radio = metrics.mean_squared_error(test['sales'], y_pred_ts_radio)
mse_ts_news  = metrics.mean_squared_error(test['sales'], y_pred_ts_news)
print("TV       : ", mse_ts_tv)
print("Radio    : ", mse_ts_radio)
print("Newspaper: ", mse_ts_news)
```

```
TV       :  12.288041294264643
Radio    :  17.511888641395615
Newspaper:  23.635705625160178
```

## 2. Explore the residuals for the single linear regression models

**We know that computing MSE or R2 is not sufficient to diagnose a problem with a linear regression.**

**Create some additional plots as described below to help you identify any problems with the regression. Use training data for all of the items below.**

**For each of the three regression models, you will compute the residuals ( $y - \hat{y}$). Then, you'll create three plots - each with three subplots, one for each regression model - as follows:**

**Plot 1: Create a scatter plot of predicted sales ( $\hat{y}$) on the vertical axis, and actual sales ( $y$) on the horizontal axis. Make sure both axes use the same scale (the range of the vertical axis should be the same as the range of the horizontal axis) *and* that all three subplots use the same scale. Label each axes, and each plot. What would you expect this plot to look like for a model that explains the data well?**

**Plot 2: Create a scatter plot with the residuals ( $y - \hat{y}$) on the vertical axis, and actual sales ( $y$) on the horizontal axis. Use the same vertical scale for all three subplots, and the same horizontal scale for all three subplots (but the vertical scale and the horizontal scale will not be the same as one another!). Comment on your observations. Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to actual sales?**

**Plot 3: For each of the three regression models AND each of the three features, create a scatter plot with the residuals ($y - \hat{y}$) on the vertical axis, and the feature ( $x$) on the horizontal axis. This plot will include nine subplots in total, for every combination of regression model and feature. Use the same vertical scale for all subplots (but the horizontal scale will depend on the feature!) Make sure to clearly label each axis, and also label each subplot with a title that indicates which regression model it uses. Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to each of the three features?**

**The code in this section is not provided for you . You will need to write code, as well as comments, observations, and answers to the questions.**

---

**Note that in general, to earn full credit, plots must:**

- **Be readable (especially text size).**
- **Have a label on each axis.**
- **Have an appropriate range for each axis. When there are multiple subplots, if the goal is to compare similar things in different subplots, in most cases it is appropriate for them all to use the same range.**
- **If there are multiple subplots, or multiple data series in the same plot, it must be made clear which is which.**

**L2.5. Simple regression residuals: predicted values vs true values visualization**

In [17]:

```
import matplotlib.pyplot as plt
```

In [18]:

```
fig = plt.figure(figsize=(12,3))

plt.subplot(1,3,1)
sns.scatterplot(data=train, x="sales", y=y_pred_tr_tv);
plt.xlabel('actual sales')
plt.ylabel('predict sales')
plt.title('TV')
plt.xlim(0,30) #same range for all the plots
plt.ylim(0,22)

plt.subplot(1,3,2)
sns.scatterplot(data=train, x="sales", y=y_pred_tr_radio);
plt.xlabel('actual sales')
plt.ylabel('predict sales')
plt.title('radio')
plt.xlim(0,30)
plt.ylim(0,22)

plt.subplot(1,3,3)
sns.scatterplot(data=train, x="sales", y=y_pred_tr_news);
plt.xlabel('actual sales')
plt.ylabel('predict sales')
plt.title('Newspaper')
plt.xlim(0,30)
plt.ylim(0,22)
```

Out[18]:

```
<Axes: >
```

Out[18]:

```
<Axes: xlabel='sales'>
```

Out[18]:

```
Text(0.5, 0, 'actual sales')
```

Out[18]:

```
Text(0, 0.5, 'predict sales')
```

Out[18]:

```
Text(0.5, 1.0, 'TV')
```

Out[18]:

```
(0.0, 30.0)
```

Out[18]:

```
(0.0, 22.0)
```

Out[18]:

```
<Axes: >
```

Out[18]:

```
<Axes: xlabel='sales'>
```

Out[18]:

```
Text(0.5, 0, 'actual sales')
```

Out[18]:

```
Text(0, 0.5, 'predict sales')
```

Out[18]:

```
Text(0.5, 1.0, 'radio')
```

Out[18]:

```
(0.0, 30.0)
```

Out[18]:

```
(0.0, 22.0)
```

Out[18]:

```
<Axes: >
```

Out[18]:

```
<Axes: xlabel='sales'>
```

Out[18]:

```
Text(0.5, 0, 'actual sales')
```

Out[18]:

```
Text(0, 0.5, 'predict sales')
```

Out[18]:

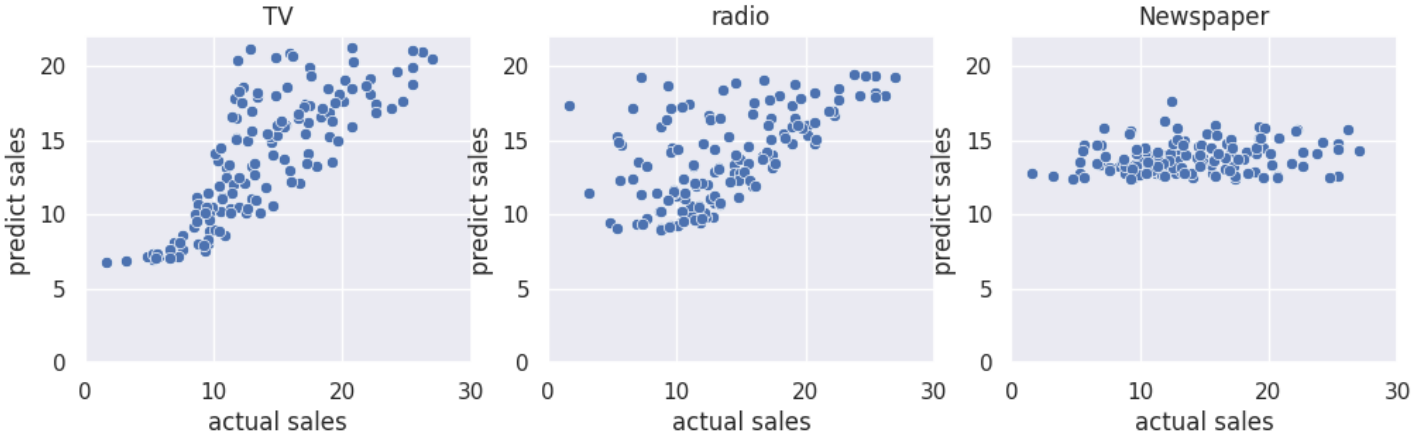
```
Text(0.5, 1.0, 'Newspaper')
```

Out[18]:

```
(0.0, 30.0)
```

Out[18]:

```
(0.0, 22.0)
```




**What would you expect this plot to look like for a model that explains the data well? Answer: It should be looked like a diagnal line which explains better.**

### L2.7. Simple regression residuals: residuals vs true values visualization

In [19]:

```
#calculating the residual of each feature
residual_tv=train['sales']-y_pred_tr_tv
residual_radio=train['sales']-y_pred_tr_radio
residual_news=train['sales']-y_pred_tr_news

fig = plt.figure(figsize=(12,3))

plt.subplot(1,3,1)
sns.scatterplot(data=train, x="sales", y=residual_tv);
plt.xlabel('actual sales')
plt.ylabel('residuals')
plt.title('TV')
plt.ylim(-15,15)
```

```
plt.subplot(1,3,2)
sns.scatterplot(data=train, x="sales", y=residual_radio);
plt.xlabel('actual sales')
plt.ylabel('residuals')
plt.title('radio')
plt.ylim(-15,15)

plt.subplot(1,3,3)
sns.scatterplot(data=train, x="sales", y=residual_news);
plt.xlabel('actual sales')
plt.ylabel('residuals')
plt.title('Newspaper')
plt.ylim(-15,15)
plt.tight_layout() #have a more visible illustration
```

Out[19]:

```
<Axes: >
```

Out[19]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[19]:

```
Text(0.5, 0, 'actual sales')
```

Out[19]:

```
Text(0, 0.5, 'residuals')
```

Out[19]:

```
Text(0.5, 1.0, 'TV')
```

Out[19]:

```
(-15.0, 15.0)
```

Out[19]:

```
<Axes: >
```

Out[19]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[19]:

```
Text(0.5, 0, 'actual sales')
```

Out[19]:

```
Text(0, 0.5, 'residuals')
```

Out[19]:

```
Text(0.5, 1.0, 'radio')
```

Out[19]:

```
(-15.0, 15.0)
```

Out[19]:

```
<Axes: >
```

Out[19]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[19]:

```
Text(0.5, 0, 'actual sales')
```

Out[19]:

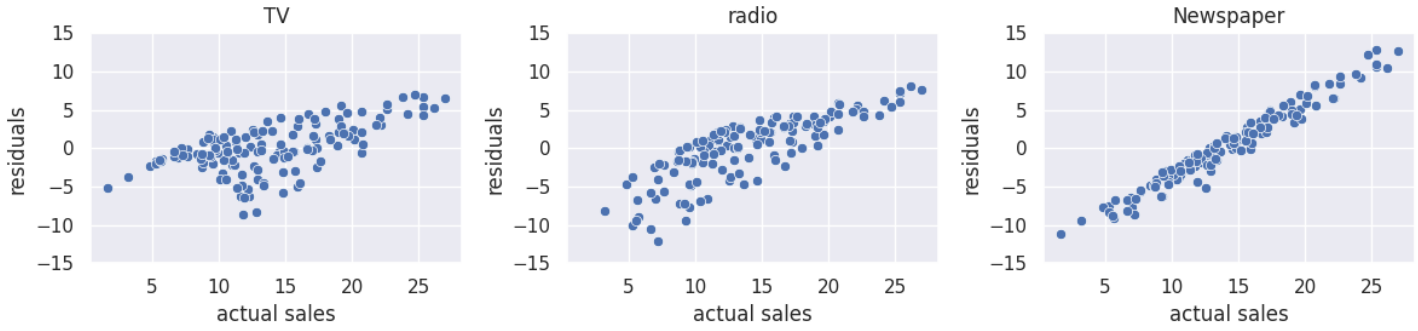
```
Text(0, 0.5, 'residuals')
```

Out[19]:

```
Text(0.5, 1.0, 'Newspaper')
```

Out[19]:

```
(-15.0, 15.0)
```




**Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to actual sales?**

**Answer: They are also looked like a diagnal line.**

#### L2.9. Simple regression residuals: residuals vs features visualization

In [41]:

```
fig = plt.figure(figsize=(12,6))
plt.subplot(3,3,1)
sns.scatterplot(data=train, x="TV", y=residual_tv,color='blue');
plt.title('Model of TV(blue)',fontsize=15)
plt.ylabel('residuals')

plt.subplot(3,3,2)
sns.scatterplot(data=train, x="TV", y=residual_radio,color='red');
plt.title('Model of radio(red)',fontsize=15)
plt.ylabel('residuals')

plt.subplot(3,3,3)
sns.scatterplot(data=train, x="TV", y=residual_news,color='green');
plt.title('Model of newspaper(red)',fontsize=15)
plt.ylabel('residuals')

plt.subplot(3,3,4)
sns.scatterplot(data=train, x="radio", y=residual_tv,color='blue');
plt.ylabel('residuals')

plt.subplot(3,3,5)
sns.scatterplot(data=train, x="radio", y=residual_radio,color='red');
plt.ylabel('residuals')

plt.subplot(3,3,6)
sns.scatterplot(data=train, x="radio", y=residual_news,color='green');
plt.ylabel('residuals')

plt.subplot(3,3,7)
sns.scatterplot(data=train, x="newspaper", y=residual_tv,color='blue');
plt.ylabel('residuals')

plt.subplot(3,3,8)
sns.scatterplot(data=train, x="newspaper", y=residual_radio,color='red');
plt.ylabel('residuals')

plt.subplot(3,3,9)
sns.scatterplot(data=train, x="newspaper", y=residual_news,color='green');
plt.ylabel('residuals')

plt.tight_layout()
```

Out[41]:

```
<Axes: >
```

Out[41]:

<Axes: xlabel='TV', ylabel='sales'>

Out[41]:

Text(0.5, 1.0, 'Model of TV(blue)')

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='TV', ylabel='sales'>

Out[41]:

Text(0.5, 1.0, 'Model of radio(red)')

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='TV', ylabel='sales'>

Out[41]:

Text(0.5, 1.0, 'Model of newspaper(red)')

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='radio', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='radio', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='radio', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='newspaper', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

<Axes: >

Out[41]:

<Axes: xlabel='newspaper', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

Out[41]:

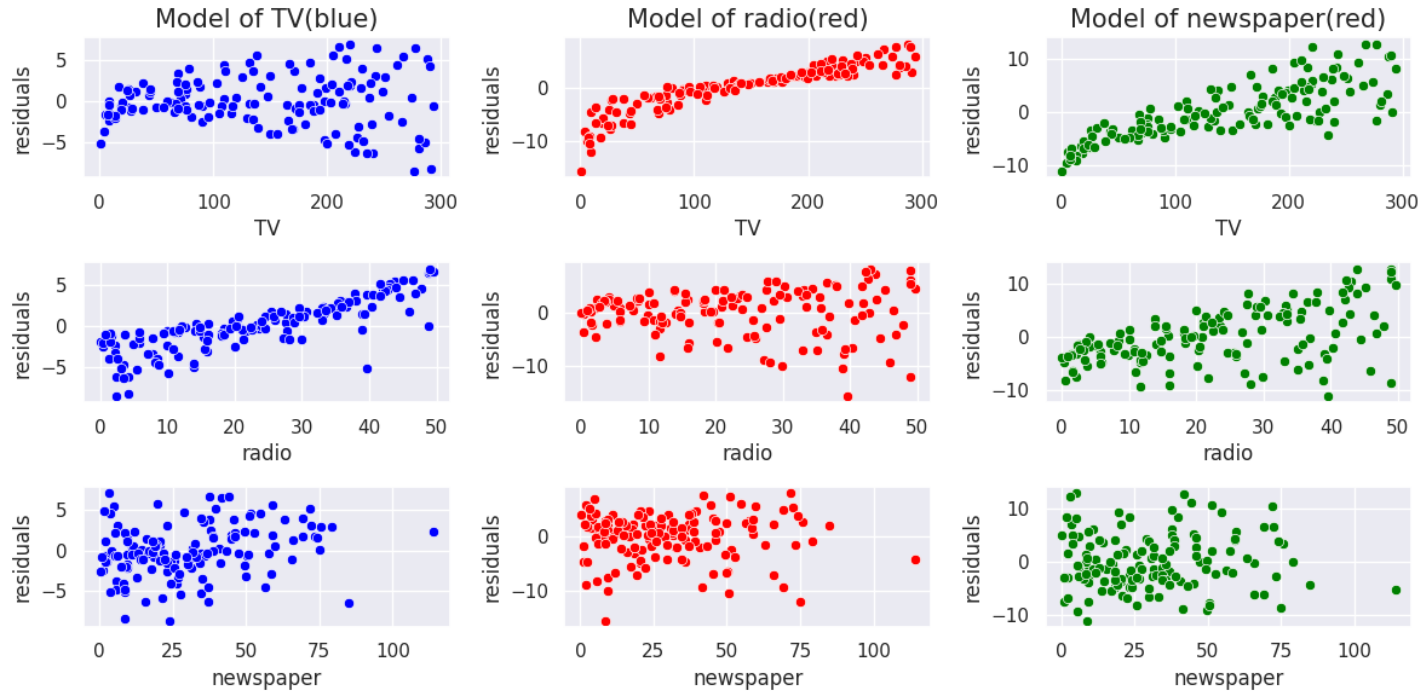
<Axes: >

Out[41]:

<Axes: xlabel='newspaper', ylabel='sales'>

Out[41]:

Text(0, 0.5, 'residuals')

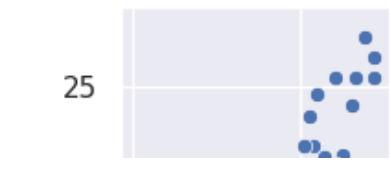


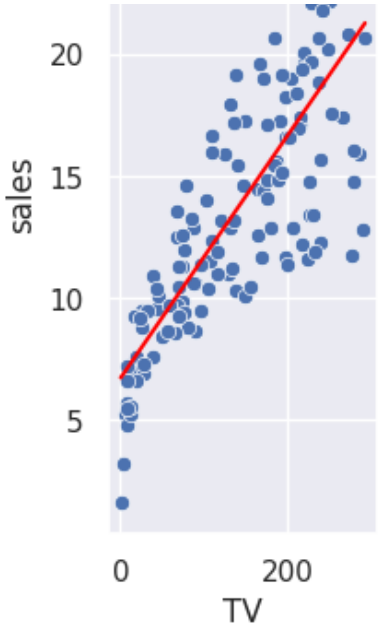

**Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to each of the three features?**

***Answer:From my perspective, it correlated to the model that who trained the feature, and kinds of showing some correlation between features that what it looks like when a relevant feature is excluded from a model.***

In [21]:

```
plt.subplot(1,3,1)
sns.scatterplot(data=train, x="TV", y="sales");
sns.lineplot(data=train, x="TV", y=reg_tv.predict(train[['TV']]), color='red');
```






## 3. Try a multiple linear regression

**Next, fit a multiple linear regression to predict product sales, using all three features to train a single model: TV ad budget, radio ad budget, and newspaper ad budget.**

**Print the intercept and coefficients, and compute the MSE and R2 on the training data, and MSE and R2 on the test data. Comment on the results. Make sure to explain any differences between the coefficients of the multiple regression model, and the coefficients of the three simple linear regression models. If they are different, why?**

**The code in the first part of this section is provided for you . However, you will need to add comments, observations, and answers to the questions.**

**Also repeat the analysis of part (3) for this regression model. Use training data for all of these items:**

**Plot 1: Create a scatter plot of predicted sales ( $\hat{y}$) on the vertical axis, and actual sales ( $y$) on the horizontal axis. Make sure both axes use the same scale (the range of the vertical axis should be the same as the range of the horizontal axis). Label each axes. Does this model explain the data more effectively than the simple linear regressions from the previous section?**

**Plot 2: Create a scatter plot with the residuals ( $y - \hat{y}$) on the vertical axis, and actual sales ( $y$) on the horizontal axis. Comment on your observations. Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to actual sales?**

**Plot 3: For each of the three features, plot the residuals ( $y - \hat{y}$) on the vertical axis, and the feature ( $x$) on the horizontal axis. Make sure to clearly label each axis. Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to each of the three features?**

---

**Note that in general, to earn full credit, plots must:**

- **Be readable (especially text size).**
- **Have a label on each axis.**
- **Have an appropriate range for each axis. When there are multiple subplots, if the goal is to compare similar things in different subplots, in most cases it is appropriate for them all to use the same range.**
- **If there are multiple subplots, or multiple data series in the same plot, it must be made clear which is which.**

**Fit a multiple linear regression**

In [22]:

```
reg_multi = LinearRegression().fit(train[['TV', 'radio', 'newspaper']], train['sales'])
```

#### Look at coefficients

In [23]:

```
print("Coefficients (TV, radio, newspaper):", reg_multi.coef_)
print("Intercept: ", reg_multi.intercept_)
```

```
Coefficients (TV, radio, newspaper): [ 0.04636712  0.18249225 -0.00196151]
Intercept:  3.0762941463550604
```

#### Compute R2, MSE for multiple regression

In [24]:

```
y_pred_tr_multi = reg_multi.predict(train[['TV', 'radio', 'newspaper']])

r2_tr_multi  = metrics.r2_score(train['sales'], y_pred_tr_multi)
mse_tr_multi = metrics.mean_squared_error(train['sales'], y_pred_tr_multi)

print("Multiple regression R2:  ", r2_tr_multi)
print("Multiple regression MSE: ", mse_tr_multi)
```

```
Multiple regression R2:   0.8934006397815405
Multiple regression MSE:  2.952755722412376
```

In [25]:

```
y_pred_ts_multi = reg_multi.predict(test[['TV', 'radio', 'newspaper']])

r2_ts_multi  = metrics.r2_score(test['sales'], y_pred_ts_multi)
mse_ts_multi = metrics.mean_squared_error(test['sales'], y_pred_ts_multi)

print("Multiple regression R2:  ", r2_ts_multi)
print("Multiple regression MSE: ", mse_ts_multi)
```

```
Multiple regression R2:   0.9034495005656622
Multiple regression MSE:  2.4406300760885373
```

#### Visualization

#### L2.15. Multiple regression: predicted values vs true values visualization

In [26]:

```
plt.subplot(1,2,1)
sns.scatterplot(data=train, x="sales", y=y_pred_tr_multi);
plt.xlabel('actual sales')
plt.ylabel('predicted sales')
plt.title('train set')
plt.ylim(0,27)

plt.subplot(1,2,2)
sns.scatterplot(data=test, x="sales", y=y_pred_ts_multi,color="red");
plt.xlabel('actual sales')
plt.ylabel('predicted sales')
plt.title('test set')
plt.ylim(0,27)
plt.tight_layout()
```

Out[26]:

```
<Axes: >
```

Out[26]:

```
<Axes: xlabel='sales'>
```

Out[26]:

```
Text(0.5, 0, 'actual sales')
```

Out[26]:

```
Text(0, 0.5, 'predicted sales')
```

Out[26]:

```
Text(0.5, 1.0, 'train set')
```

Out[26]:

```
(0.0, 27.0)
```

Out[26]:

```
<Axes: >
```

Out[26]:

```
<Axes: xlabel='sales'>
```

Out[26]:

```
Text(0.5, 0, 'actual sales')
```

Out[26]:

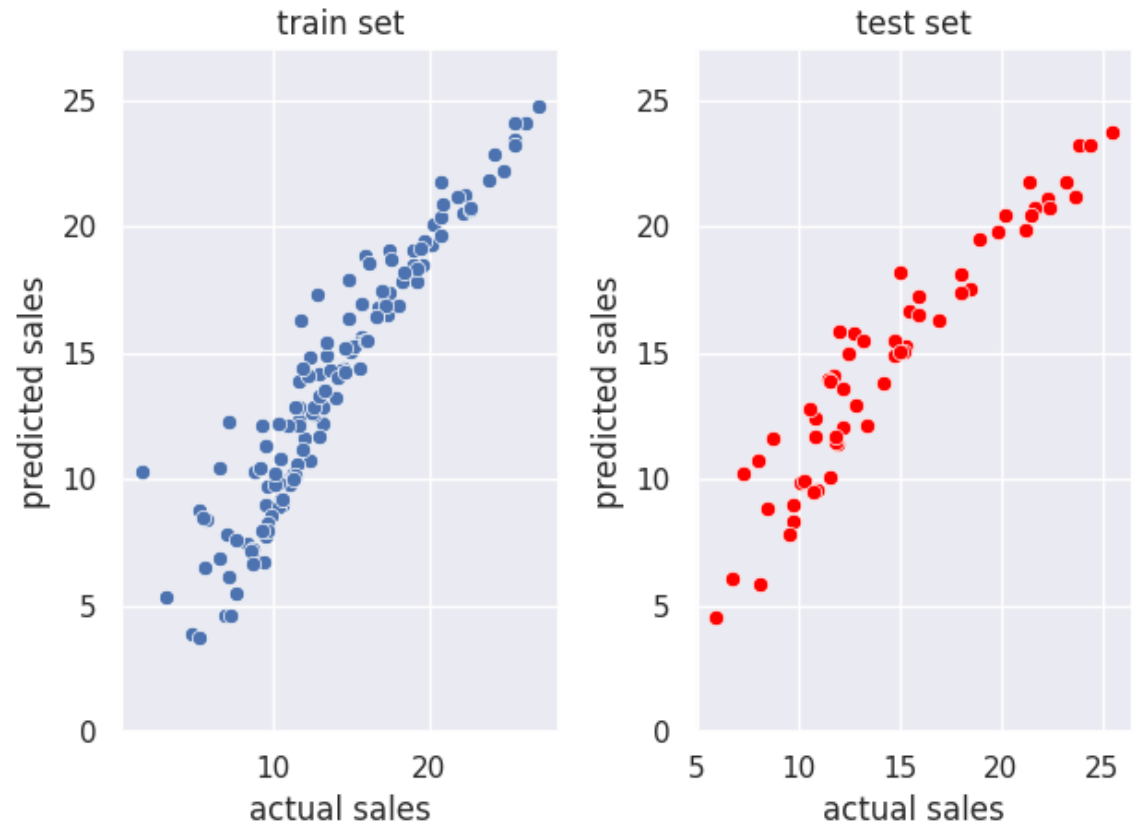
```
Text(0, 0.5, 'predicted sales')
```

Out[26]:

```
Text(0.5, 1.0, 'test set')
```

Out[26]:

```
(0.0, 27.0)
```




**Does this model explain the data more effectively than the simple linear regressions from the previous section?**

**Answer: Just from the plot it is.**

#### L2.16. Multiple regression: residuals vs true values visualization

In [27]:

```
residual_tr=train['sales']-y_pred_tr_multi
residual_ts=test['sales']-y_pred_ts_multi
```

```
plt.subplot(1,2,1)
sns.scatterplot(data=train, x="sales", y=residual_tr);
plt.xlabel('actual sales')
plt.ylabel('residual')
plt.title('train set')
plt.ylim(-6,4)

plt.subplot(1,2,2)
sns.scatterplot(data=test, x="sales", y=residual_ts,color="red");
plt.xlabel('actual sales')
plt.ylabel('residual')
plt.title('test set')
plt.ylim(-6,4)
plt.tight_layout()
```

Out[27]:

```
<Axes: >
```

Out[27]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[27]:

```
Text(0.5, 0, 'actual sales')
```

Out[27]:

```
Text(0, 0.5, 'residual')
```

Out[27]:

```
Text(0.5, 1.0, 'train set')
```

Out[27]:

```
(-6.0, 4.0)
```

Out[27]:

```
<Axes: >
```

Out[27]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[27]:

```
Text(0.5, 0, 'actual sales')
```

Out[27]:

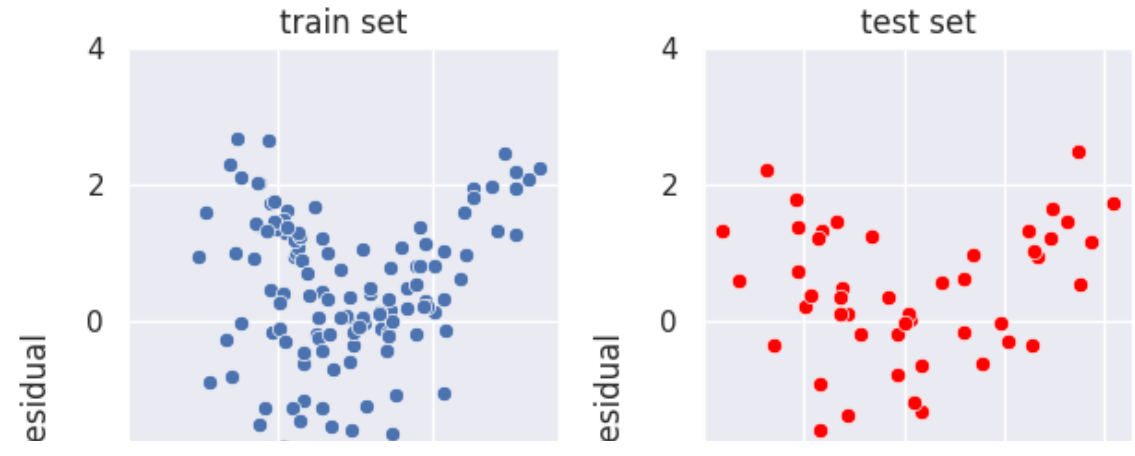
```
Text(0, 0.5, 'residual')
```

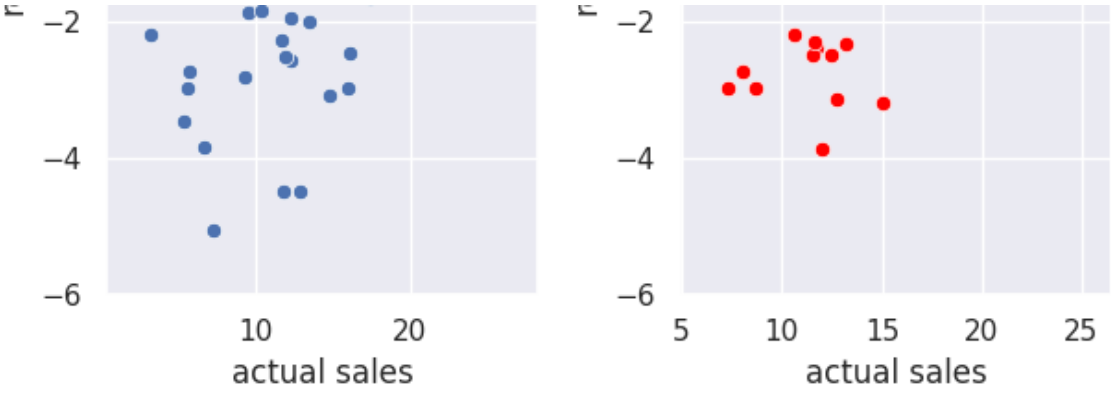
Out[27]:

```
Text(0.5, 1.0, 'test set')
```

Out[27]:

```
(-6.0, 4.0)
```






**Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to actual sales?**

**Answer No, I think.**

#### L2.17. Multiple regression: residuals vs features visualization

In [28]:

```
plt.figure(figsize=(12, 6))
plt.subplot(1,3,1)
sns.scatterplot(data=train, x="TV", y=residual_tr);
plt.xlabel('TV')
plt.ylabel('residual')
plt.title('TV')


plt.subplot(1,3,2)
sns.scatterplot(data=train, x="radio", y=residual_tr,color='red');
plt.xlabel('radio')
plt.ylabel('residual')
plt.title('radio')



plt.subplot(1,3,3)
sns.scatterplot(data=train, x="newspaper", y=residual_tr,color='green');
plt.xlabel('newspaper')
plt.ylabel('residual')
plt.title('TV')
plt.tight_layout()
```

Out[28]:

```
<Figure size 1200x600 with 0 Axes>
```

Out[28]:

```
<Axes: >
```

Out[28]:

```
<Axes: xlabel='TV', ylabel='sales'>
```

Out[28]:

```
Text(0.5, 0, 'TV')
```

Out[28]:

```
Text(0, 0.5, 'residual')
```

Out[28]:

```
Text(0.5, 1.0, 'TV')
```

Out[28]:

```
<Axes: >
```

Out[28]:

```
<Axes: xlabel='radio', ylabel='sales'>
```

Out[28]:

```
Text(0.5, 0, 'radio')
```

Out[28]:

```
Text(0, 0.5, 'residual')
```

Out[28]:

```
Text(0.5, 1.0, 'radio')
```

Out[28]:

```
<Axes: >
```

Out[28]:

```
<Axes: xlabel='newspaper', ylabel='sales'>
```

Out[28]:

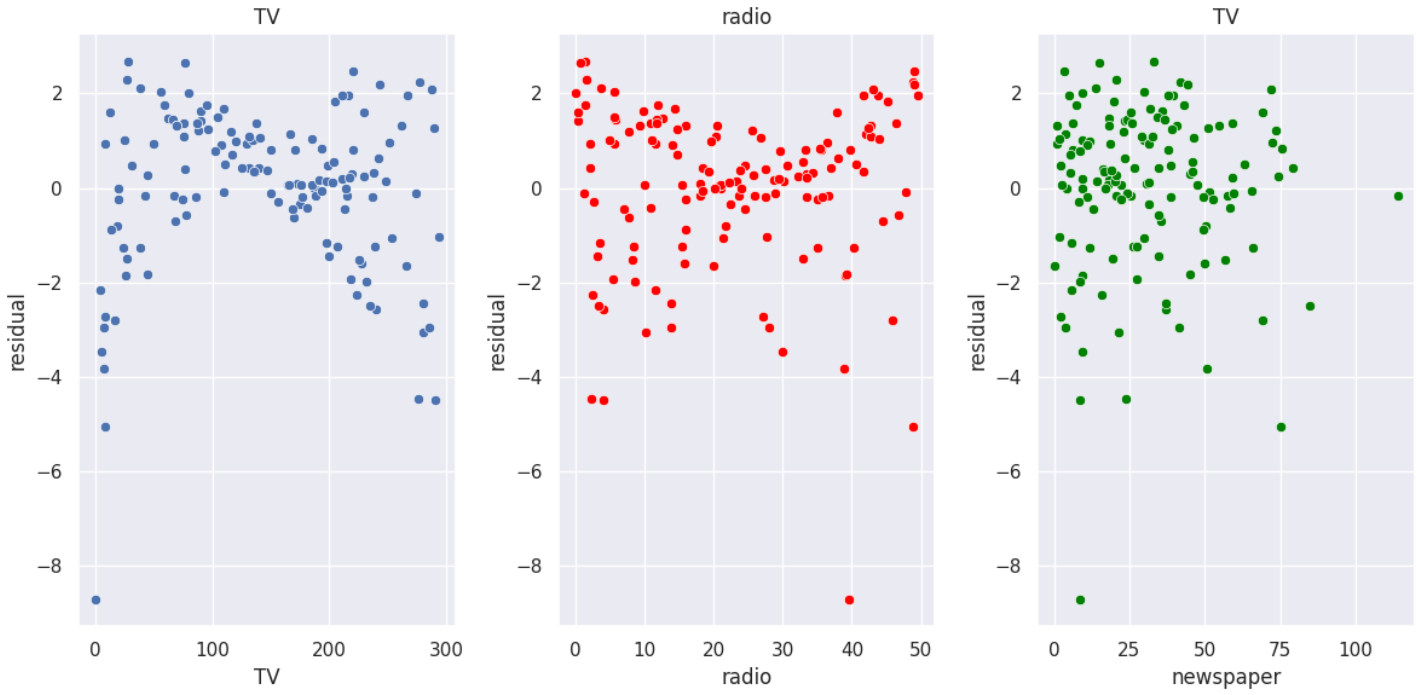
```
Text(0.5, 0, 'newspaper')
```

Out[28]:

```
Text(0, 0.5, 'residual')
```

Out[28]:

```
Text(0.5, 1.0, 'TV')
```




**Is there a pattern in the residuals (and if so, what might it indicate), or do they appear to have no pattern with respect to each of the three features?**

**Answer:Not clear at all.**

In [29]:

```
train[['TV', 'radio', 'newspaper']].corr()
```

Out[29]:

| | TV | radio | newspaper |
|---|---|---|---|
| **TV** | 1.000000 | 0.106568 | 0.057997 |
| **radio** | 0.106568 | 1.000000 | 0.314422 |

| | | | |
|---|---|---|---|
| newspaper | 0.057977 | 0.314483 | 1.000000 |

## 4. Linear regression with interaction terms

**Our multiple linear regression includes additive effects of all three types of advertising media. However, it does not include *interaction* effects, in which combining different types of advertising media together results in a bigger boost in sales than just the additive effect of the individual media.**

**The pattern in the residuals plots from parts (1) through (3) suggest that a model including an interaction effect may explain sales data better than a model including additive effects. Add four columns to each data frame (`train` and `test`):**

- `newspaper` × `radio` **(name this column** `newspaper_radio`**)**
- `TV` × `radio` **(name this column** `TV_radio`**)**
- `newspaper` × `TV` **(name this column** `newspaper_TV`**)**
- `newspaper` × `radio` × `TV` **(name this column** `newspaper_radio_TV`**)**

**Note: you can use the `assign` function in `pandas` (documentation here) to create a new column and assign a value to it using operations on other columns.**

**Then, train a linear regression model on all seven features: the three types of ad budgets, and the four interaction effects. Repeat the analysis of part (3) for the model including interaction effects. Are the interaction effects helpful for explaining the effect of ads on product sales? Are there any patterns evident in the residual plots that suggest further opportunities for improving the model?**

**The code in this section is not provided for you. You will need to write code, in addition to comments, observations, and answers to the questions.**

---

**Note that in general, to earn full credit, plots must:**

- **Be readable (especially text size).**
- **Have a label on each axis.**
- **Have an appropriate range for each axis. When there are multiple subplots, if the goal is to compare similar things in different subplots, in most cases it is appropriate for them all to use the same range.**
- **If there are multiple subplots, or multiple data series in the same plot, it must be made clear which is which.**

#### L2.18. Interaction terms: adding features to the data frame

In [30]:

```
train=train.assign(newspaper_radio=train['newspaper']*train['radio'],TV_radio=train['TV'
]*train['radio'],newspaper_TV=train['newspaper']*train['TV'],newspaper_radio_TV=train['n
ewspaper']*train['radio']*train['TV'])
test=test.assign(newspaper_radio=test['newspaper']*test['radio'],TV_radio=test['TV']*test
['radio'],newspaper_TV=test['newspaper']*test['TV'],newspaper_radio_TV=test['newspaper']
*test['radio']*test['TV'])
```

In [31]:

```
reg_new = LinearRegression().fit(train[['TV', 'radio', 'newspaper', 'newspaper_radio', '
TV_radio', 'newspaper_TV', 'newspaper_radio_TV']], train['sales'])
print("Coefficients (TV, radio, newspaper,newspaper_radio,TV_radio,newspaper_TV,newspaper
_radio_TV):", reg_new.coef_)
print("Intercept: ", reg_new.intercept_)
```

```
Coefficients (TV, radio, newspaper,newspaper_radio,TV_radio,newspaper_TV,newspaper_radio_
TV): [ 2.07581277e-02  1.19519832e-02  2.03755245e-02 -2.46384818e-05
  1.18859985e-03 -8.06743937e-05 -7.25626214e-07]
Intercept:  6.378007972477893
```

In [32]:

```
y_pred_tr_multi_e = reg_new.predict(train[['TV', 'radio', 'newspaper', 'newspaper_radio'
```

```
, 'TV_radio', 'newspaper_TV', 'newspaper_radio_TV']])
r2_tr_multi_e  = metrics.r2_score(train['sales'], y_pred_tr_multi_e)
mse_tr_multi_e = metrics.mean_squared_error(train['sales'], y_pred_tr_multi_e)
print("Multiple regression with interaction R2:  ", r2_tr_multi_e)
print("Multiple regression MSE: ", mse_tr_multi_e)
```

```
Multiple regression with interaction R2:   0.9639737928022052
Multiple regression MSE:  0.997910205484344
```

In [33]:

```
y_pred_ts_multi_e = reg_new.predict(test[['TV', 'radio', 'newspaper', 'newspaper_radio',
'TV_radio', 'newspaper_TV', 'newspaper_radio_TV']])
r2_ts_multi_e  = metrics.r2_score(test['sales'], y_pred_ts_multi_e)
mse_ts_multi_e = metrics.mean_squared_error(test['sales'], y_pred_ts_multi_e)
print("Multiple regression with interaction R2:  ", r2_ts_multi_e)
print("Multiple regression MSE: ", mse_ts_multi_e)
```

```
Multiple regression with interaction R2:   0.978290346306146
Multiple regression MSE:  0.5487825962280087
```

#### L2.21. Interaction terms: predicted values vs true values visualization

In [34]:

```
plt.subplot(1,2,1)
sns.scatterplot(data=train, x="sales", y=y_pred_tr_multi_e);
plt.xlabel('actual sales')
plt.ylabel('predicted sales')
plt.title('train set')
plt.ylim(0,30)

plt.subplot(1,2,2)
sns.scatterplot(data=test, x="sales", y=y_pred_ts_multi_e,color="red");
plt.xlabel('actual sales')
plt.ylabel('predicted sales')
plt.title('test set')
plt.ylim(0,30)
plt.tight_layout()
```

Out[34]:

```
<Axes: >
```

Out[34]:

```
<Axes: xlabel='sales'>
```

Out[34]:

```
Text(0.5, 0, 'actual sales')
```

Out[34]:

```
Text(0, 0.5, 'predicted sales')
```

Out[34]:

```
Text(0.5, 1.0, 'train set')
```

Out[34]:

```
(0.0, 30.0)
```

Out[34]:

```
<Axes: >
```

Out[34]:

```
<Axes: xlabel='sales'>
```

Out[34]:

```
Text(0.5, 0, 'actual sales')
```

Out[34]:

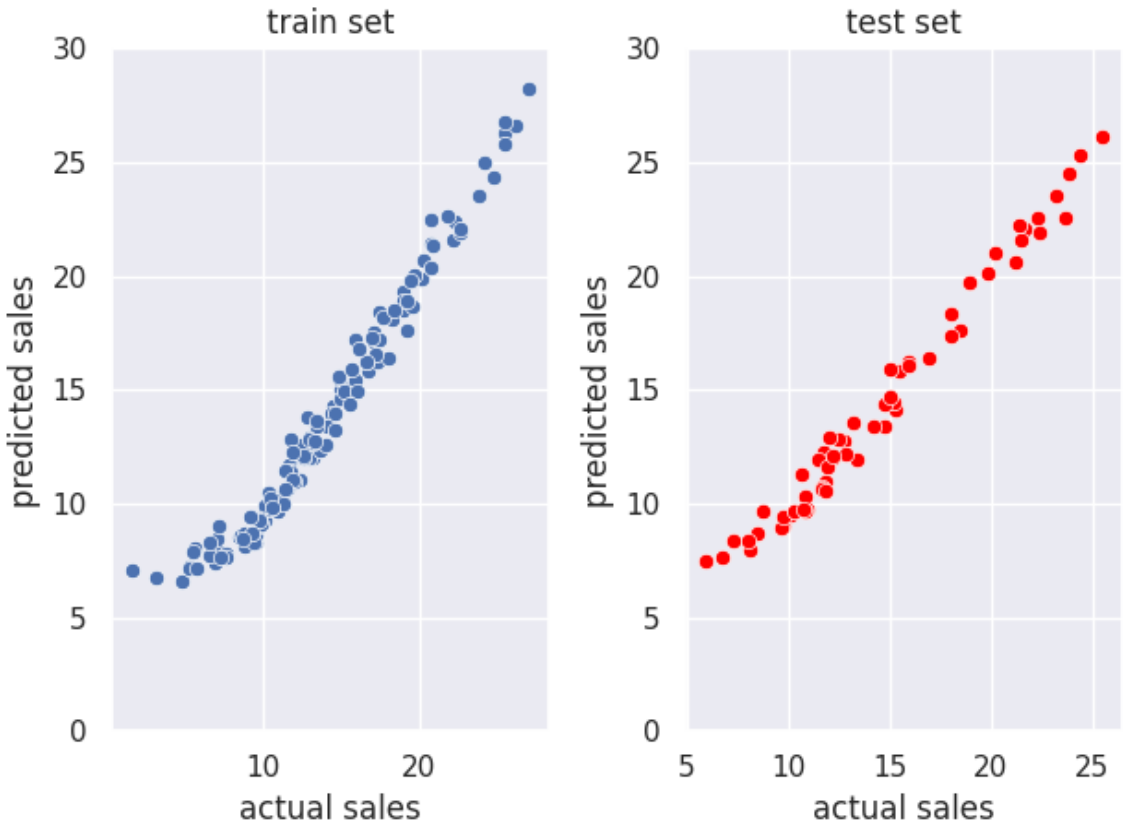
```
Text(0, 0.5, 'predicted sales')
```

Out[34]:

```
Text(0.5, 1.0, 'test set')
```

Out[34]:

```
(0.0, 30.0)
```




**L2.22. Interaction terms: residuals vs true values visualization**

In [35]:

```
residuall_tr=train['sales']-y_pred_tr_multi_e
residuall_ts=test['sales']-y_pred_ts_multi_e

plt.subplot(1,2,1)
sns.scatterplot(data=train, x="sales", y=residuall_tr);
plt.xlabel('actual sales')
plt.ylabel('residual')
plt.title('train set')
plt.ylim(-6,2)

plt.subplot(1,2,2)
sns.scatterplot(data=test, x="sales", y=residuall_ts,color="red");
plt.xlabel('actual sales')
plt.ylabel('residual')
plt.title('test set')
plt.ylim(-6,2)

plt.tight_layout()
```

Out[35]:

```
<Axes: >
```

Out[35]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[35]:

```
Text(0.5, 0, 'actual sales')
```

Out[35]:

```
Text(0, 0.5, 'residual')
```

Out[35]:

```
Text(0.5, 1.0, 'train set')
```

Out[35]:

```
(-6.0, 2.0)
```

Out[35]:

```
<Axes: >
```

Out[35]:

```
<Axes: xlabel='sales', ylabel='sales'>
```

Out[35]:

```
Text(0.5, 0, 'actual sales')
```

Out[35]:

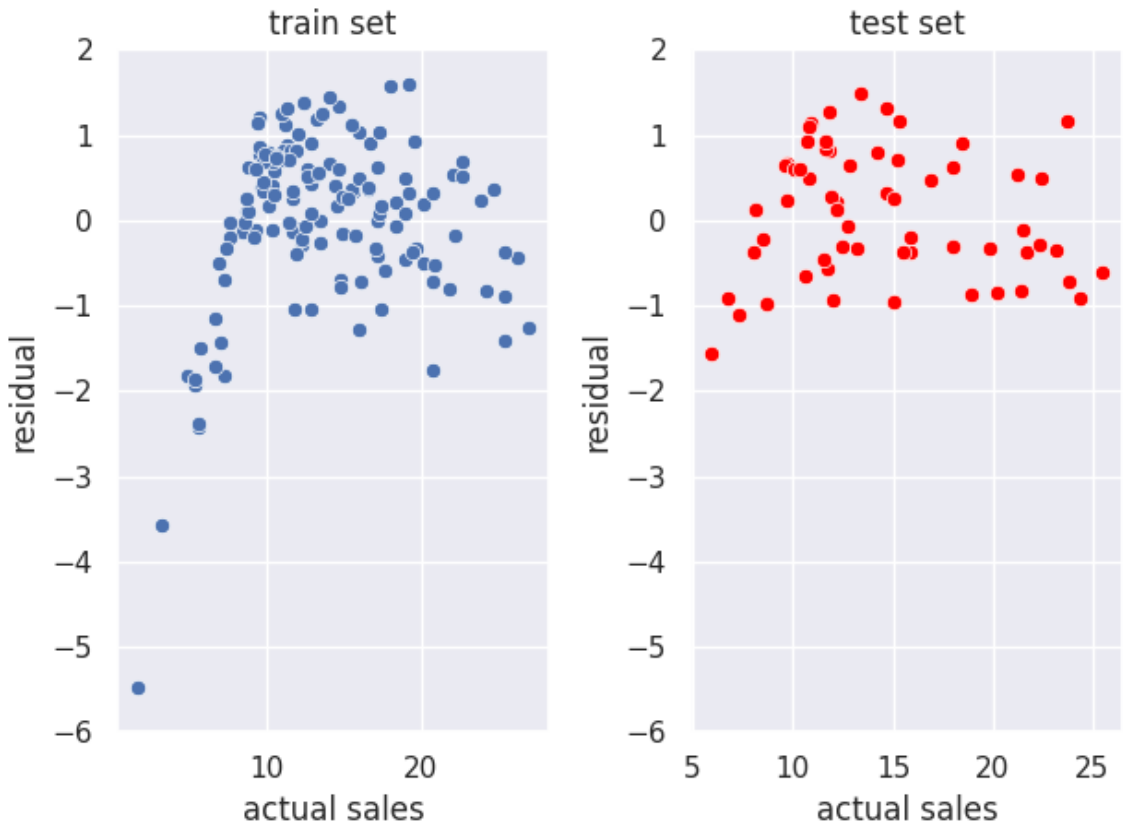
```
Text(0, 0.5, 'residual')
```

Out[35]:

```
Text(0.5, 1.0, 'test set')
```

Out[35]:

```
(-6.0, 2.0)
```




**L2.23. Interaction terms: residuals vs features visualization**

In [36]:

```
plt.figure(figsize=(16, 8))

plt.subplot(2,4,1)
sns.scatterplot(data=train, x="TV", y=residuall_tr);
plt.xlabel('TV')
plt.ylabel('residual')
```

```
plt.subplot(2,4,2)
sns.scatterplot(data=train, x="radio", y=residuall_tr,color="red");
plt.xlabel('radio')
plt.ylabel('residual')

plt.subplot(2,4,3)
sns.scatterplot(data=train, x="newspaper", y=residuall_tr,color="green");
plt.xlabel('newspaper')
plt.ylabel('residual')

plt.subplot(2,4,4)
sns.scatterplot(data=train, x="newspaper_radio", y=residuall_tr,color="blue");
plt.xlabel('newspaper_radio')
plt.ylabel('residual')

plt.subplot(2,4,5)
sns.scatterplot(data=train, x="newspaper_TV", y=residuall_tr,color="black");
plt.xlabel('newspaper_TV')
plt.ylabel('residual')

plt.subplot(2,4,6)
sns.scatterplot(data=train, x="TV_radio", y=residuall_tr,color="purple");
plt.xlabel('TV_radio')
plt.ylabel('residual')

plt.subplot(2,4,7)
sns.scatterplot(data=train, x="newspaper_radio_TV", y=residuall_tr,color="pink");
plt.xlabel('newspaper_radio_TV')
plt.ylabel('residual')
plt.tight_layout()
```

Out[36]:

```
<Figure size 1600x800 with 0 Axes>
```

Out[36]:

```
<Axes: >
```

Out[36]:

```
<Axes: xlabel='TV', ylabel='sales'>
```

Out[36]:

```
Text(0.5, 0, 'TV')
```

Out[36]:

```
Text(0, 0.5, 'residual')
```

Out[36]:

```
<Axes: >
```

Out[36]:

```
<Axes: xlabel='radio', ylabel='sales'>
```

Out[36]:

```
Text(0.5, 0, 'radio')
```

Out[36]:

```
Text(0, 0.5, 'residual')
```

Out[36]:

```
<Axes: >
```

Out[36]:

```
<Axes: xlabel='newspaper', ylabel='sales'>
```

Out[36]:

```
Text(0.5, 0, 'newspaper')
```

Text(0.5, 0, 'newspaper')

Out[36]:

Text(0, 0.5, 'residual')

Out[36]:

<Axes: >

Out[36]:

<Axes: xlabel='newspaper_radio', ylabel='sales'>

Out[36]:

Text(0.5, 0, 'newspaper_radio')

Out[36]:

Text(0, 0.5, 'residual')

Out[36]:

<Axes: >

Out[36]:

<Axes: xlabel='newspaper_TV', ylabel='sales'>

Out[36]:

Text(0.5, 0, 'newspaper_TV')

Out[36]:

Text(0, 0.5, 'residual')

Out[36]:

<Axes: >

Out[36]:

<Axes: xlabel='TV_radio', ylabel='sales'>

Out[36]:

Text(0.5, 0, 'TV_radio')

Out[36]:

Text(0, 0.5, 'residual')

Out[36]:

<Axes: >

Out[36]:

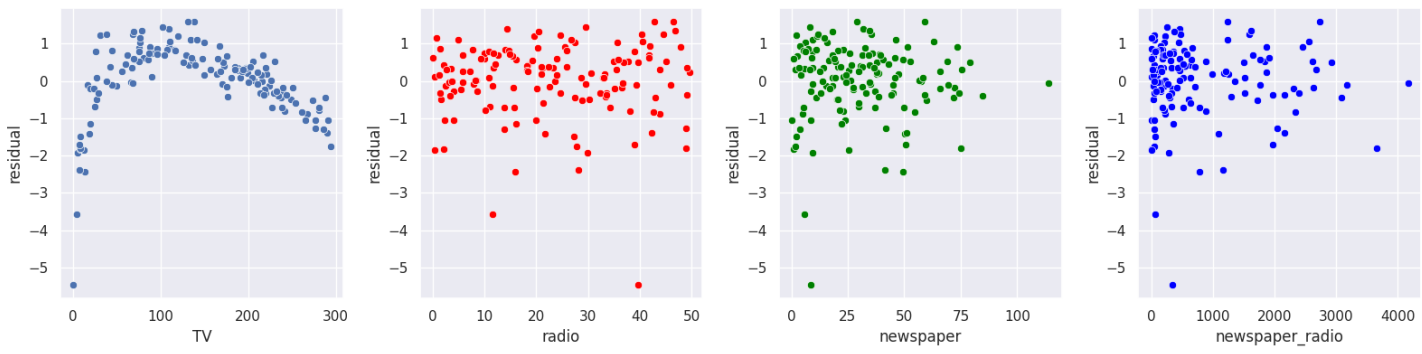
<Axes: xlabel='newspaper_radio_TV', ylabel='sales'>

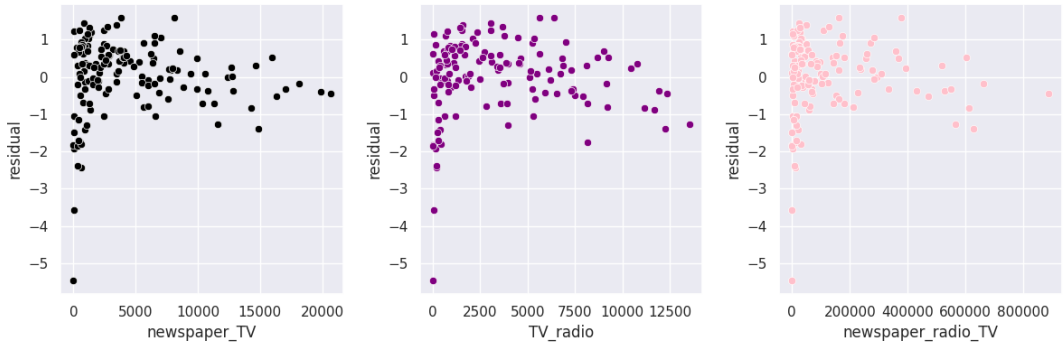
Out[36]:

Text(0.5, 0, 'newspaper_radio_TV')

Out[36]:

Text(0, 0.5, 'residual')






# PDF

In [37]:

```
!apt-get update
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
```

```
Get:1 https://cloud.r-project.org/bin/linux/ubuntu jammy-cran40/ InRelease [3,626 B]
Hit:2 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64  InRelea
se
Hit:3 http://archive.ubuntu.com/ubuntu jammy InRelease
Get:4 http://security.ubuntu.com/ubuntu jammy-security InRelease [110 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy-updates InRelease [119 kB]
Hit:6 http://archive.ubuntu.com/ubuntu jammy-backports InRelease
Get:7 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64 Packages [1,796 k
B]
Get:8 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages [1,343 kB]
Hit:9 https://ppa.launchpadcontent.net/c2d4u.team/c2d4u4.0+/ubuntu jammy InRelease
Hit:10 https://ppa.launchpadcontent.net/deadsnakes/ppa/ubuntu jammy InRelease
Get:11 http://security.ubuntu.com/ubuntu jammy-security/main amd64 Packages [1,463 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy-updates/multiverse amd64 Packages [50.4 kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [1,742 kB]
Hit:14 https://ppa.launchpadcontent.net/graphics-drivers/ppa/ubuntu jammy InRelease
Get:15 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 Packages [1,070 kB
]
Get:16 http://archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 Packages [1,834 kB
]
Hit:17 https://ppa.launchpadcontent.net/ubuntugis/ppa/ubuntu jammy InRelease
Fetched 9,532 kB in 1s (6,768 kB/s)
Reading package lists... Done
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
pandoc is already the newest version (2.9.2.1-3ubuntu2).
pandoc set to manually installed.
The following additional packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  fonts-urw-base35 libapache-pom-java libcommons-logging-java libcommons-parent-java
  libfontbox-java libfontenc1 libgs9 libgs9-common libidn12 libijs-0.35 libjbig2dec0 libk
pathsea6
  libpdfbox-java libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2
libwoff1
  libzzip-0-13 lmodern poppler-data preview-latex-style rake ruby ruby-net-telnet ruby-ru
bygems
  ruby-webrick ruby-xmlrpc ruby3.0 rubygems-integration t1utils teckit tex-common tex-gyr
e
  texlive-base texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa xfonts-encodings
  xfonts-utils
Suggested packages:
  fonts-noto fonts-freefont-otf | fonts-freefont-ttf libavalon-framework-java
  libcommons-logging-java-doc libexcalibur-logkit-java liblog4j1.2-java poppler-utils gho
stscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic | fonts-ipafont-goth
ic
  fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri ruby-dev bundler debhelper gv
  | postscript-viewer perl-tk xpdf | pdf-viewer xzdec texlive-fonts-recommended-doc
```

```
  texlive-latex-base-doc python3-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc texlive-latex-recommended-doc
  texlive-luatex texlive-pstricks dot2tex prerex texlive-pictures-doc vprerex default-jre
-headless
  tipa-doc
The following NEW packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  fonts-urw-base35 libapache-pom-java libcommons-logging-java libcommons-parent-java
  libfontbox-java libfontenc1 libgs9 libgs9-common libidn12 libijs-0.35 libjbig2dec0 libk
pathsea6
  libpdfbox-java libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2
libwoff1
  libzzip-0-13 lmodern poppler-data preview-latex-style rake ruby ruby-net-telnet ruby-ru
bygems
  ruby-webrick ruby-xmlrpc ruby3.0 rubygems-integration t1utils teckit tex-common tex-gyr
e texlive
  texlive-base texlive-binaries texlive-fonts-recommended texlive-latex-base texlive-late
x-extra
  texlive-latex-recommended texlive-pictures texlive-plain-generic texlive-xetex tipa
  xfonts-encodings xfonts-utils
0 upgraded, 55 newly installed, 0 to remove and 43 not upgraded.
Need to get 182 MB of archives.
After this operation, 572 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-droid-fallback all 1:6.0.1r
16-1.1build1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-lato all 2.0-2.1 [2,696 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy/main amd64 poppler-data all 0.4.11-1 [2,171
kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-common all 6.17 [33.7 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-urw-base35 all 20200910-1 [
6,367 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9-common all 9.55.0~
dfsg1-0ubuntu5.6 [751 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libidn12 amd64 1.38-4ubun
tu1 [60.0 kB]
Get:8 http://archive.ubuntu.com/ubuntu jammy/main amd64 libijs-0.35 amd64 0.35-15build2 [
16.5 kB]
Get:9 http://archive.ubuntu.com/ubuntu jammy/main amd64 libjbig2dec0 amd64 0.19-3build2 [
64.7 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9 amd64 9.55.0~dfsg
1-0ubuntu5.6 [5,031 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libkpathsea6 amd64 2021.
20210626.59705-1ubuntu0.1 [60.3 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwoff1 amd64 1.0.2-1build4 [45
.2 kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy/universe amd64 dvisvgm amd64 2.13.1-1 [1,22
1 kB]
Get:14 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-lmodern all 2.004.5-6.
1 [4,532 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-noto-mono all 20201225-1bu
ild1 [397 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-texgyre all 20180621-3
.1 [10.2 MB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libapache-pom-java all 18-1
[4,720 B]
Get:18 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-parent-java all 4
3-1 [10.8 kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-logging-java all
1.2-2 [60.3 kB]
Get:20 http://archive.ubuntu.com/ubuntu jammy/main amd64 libfontenc1 amd64 1:1.1.4-1build
3 [14.7 kB]
Get:21 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libptexenc1 amd64 2021.2
0210626.59705-1ubuntu0.1 [39.1 kB]
Get:22 http://archive.ubuntu.com/ubuntu jammy/main amd64 rubygems-integration all 1.18 [5
,336 B]
Get:23 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby3.0 amd64 3.0.2-7ubu
ntu2.4 [50.1 kB]
Get:24 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-rubygems all 3.3.5-2 [228 k
B]
Get:25 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby amd64 1:3.0~exp1 [5,100 B]
Get:26 http://archive.ubuntu.com/ubuntu jammy/main amd64 rake all 13.0.6-2 [61.7 kB]
Get:27 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-net-telnet all 0.1.1-2 [12.
```

```
6 kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy/universe amd64 ruby-webrick all 1.7.0-3 [51
.8 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-xmlrpc all 0.3.2-1u
buntu0.1 [24.9 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libruby3.0 amd64 3.0.2-7
ubuntu2.4 [5,113 kB]
Get:31 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsynctex2 amd64 2021.2
0210626.59705-1ubuntu0.1 [55.5 kB]
Get:32 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libteckit0 amd64 2.5.11+ds1-
1 [421 kB]
Get:33 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexlua53 amd64 2021.2
0210626.59705-1ubuntu0.1 [120 kB]
Get:34 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexluajit2 amd64 2021
.20210626.59705-1ubuntu0.1 [267 kB]
Get:35 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libzzip-0-13 amd64 0.13.72+d
fsg.1-1.1 [27.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-encodings all 1:1.0.5-0ub
untu2 [578 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-utils amd64 1:7.7+6build2
[94.6 kB]
Get:38 http://archive.ubuntu.com/ubuntu jammy/universe amd64 lmodern all 2.004.5-6.1 [9,4
71 kB]
Get:39 http://archive.ubuntu.com/ubuntu jammy/universe amd64 preview-latex-style all 12.2
-1ubuntu1 [185 kB]
Get:40 http://archive.ubuntu.com/ubuntu jammy/main amd64 t1utils amd64 1.41-4build2 [61.3
kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 teckit amd64 2.5.11+ds1-1 [6
99 kB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-gyre all 20180621-3.1 [6
,209 kB]
Get:43 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 texlive-binaries amd
64 2021.20210626.59705-1ubuntu0.1 [9,848 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-base all 2021.202202
04-1 [21.0 MB]
Get:45 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-fonts-recommended al
l 2021.20220204-1 [4,972 kB]
Get:46 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-base all 2021.
20220204-1 [1,128 kB]
Get:47 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-recommended al
l 2021.20220204-1 [14.4 MB]
Get:48 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive all 2021.20220204-1
[14.3 kB]
Get:49 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libfontbox-java all 1:1.8.16
-2 [207 kB]
Get:50 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libpdfbox-java all 1:1.8.16-
2 [5,199 kB]
Get:51 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-pictures all 2021.20
220204-1 [8,720 kB]
Get:52 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-extra all 2021
.20220204-1 [13.9 MB]
Get:53 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-plain-generic all 20
21.20220204-1 [27.5 MB]
Get:54 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tipa all 2:1.3-21 [2,967 kB]
Get:55 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-xetex all 2021.20220
204-1 [12.4 MB]
Fetched 182 MB in 5s (34.8 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-droid-fallback.
(Reading database ... 121749 files and directories currently installed.)
Preparing to unpack .../00-fonts-droid-fallback_1%3a6.0.1r16-1.1build1_all.deb ...
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1build1) ...
Selecting previously unselected package fonts-lato.
Preparing to unpack .../01-fonts-lato_2.0-2.1_all.deb ...
Unpacking fonts-lato (2.0-2.1) ...
Selecting previously unselected package poppler-data.
Preparing to unpack .../02-poppler-data_0.4.11-1_all.deb ...
Unpacking poppler-data (0.4.11-1) ...
Selecting previously unselected package tex-common.
Preparing to unpack .../03-tex-common_6.17_all.deb ...
Unpacking tex-common (6.17) ...
```

```
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack .../04-fonts-urw-base35_20200910-1_all.deb ...
Unpacking fonts-urw-base35 (20200910-1) ...
Selecting previously unselected package libgs9-common.
Preparing to unpack .../05-libgs9-common_9.55.0~dfsg1-0ubuntu5.6_all.deb ...
Unpacking libgs9-common (9.55.0~dfsg1-0ubuntu5.6) ...
Selecting previously unselected package libidn12:amd64.
Preparing to unpack .../06-libidn12_1.38-4ubuntu1_amd64.deb ...
Unpacking libidn12:amd64 (1.38-4ubuntu1) ...
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack .../07-libijs-0.35_0.35-15build2_amd64.deb ...
Unpacking libijs-0.35:amd64 (0.35-15build2) ...
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack .../08-libjbig2dec0_0.19-3build2_amd64.deb ...
Unpacking libjbig2dec0:amd64 (0.19-3build2) ...
Selecting previously unselected package libgs9:amd64.
Preparing to unpack .../09-libgs9_9.55.0~dfsg1-0ubuntu5.6_amd64.deb ...
Unpacking libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.6) ...
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack .../10-libkpathsea6_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack .../11-libwoff1_1.0.2-1build4_amd64.deb ...
Unpacking libwoff1:amd64 (1.0.2-1build4) ...
Selecting previously unselected package dvisvgm.
Preparing to unpack .../12-dvisvgm_2.13.1-1_amd64.deb ...
Unpacking dvisvgm (2.13.1-1) ...
Selecting previously unselected package fonts-lmodern.
Preparing to unpack .../13-fonts-lmodern_2.004.5-6.1_all.deb ...
Unpacking fonts-lmodern (2.004.5-6.1) ...
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack .../14-fonts-noto-mono_20201225-1build1_all.deb ...
Unpacking fonts-noto-mono (20201225-1build1) ...
Selecting previously unselected package fonts-texgyre.
Preparing to unpack .../15-fonts-texgyre_20180621-3.1_all.deb ...
Unpacking fonts-texgyre (20180621-3.1) ...
Selecting previously unselected package libapache-pom-java.
Preparing to unpack .../16-libapache-pom-java_18-1_all.deb ...
Unpacking libapache-pom-java (18-1) ...
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack .../17-libcommons-parent-java_43-1_all.deb ...
Unpacking libcommons-parent-java (43-1) ...
Selecting previously unselected package libcommons-logging-java.
Preparing to unpack .../18-libcommons-logging-java_1.2-2_all.deb ...
Unpacking libcommons-logging-java (1.2-2) ...
Selecting previously unselected package libfontenc1:amd64.
Preparing to unpack .../19-libfontenc1_1%3a1.1.4-1build3_amd64.deb ...
Unpacking libfontenc1:amd64 (1:1.1.4-1build3) ...
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack .../20-libptexenc1_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package rubygems-integration.
Preparing to unpack .../21-rubygems-integration_1.18_all.deb ...
Unpacking rubygems-integration (1.18) ...
Selecting previously unselected package ruby3.0.
Preparing to unpack .../22-ruby3.0_3.0.2-7ubuntu2.4_amd64.deb ...
Unpacking ruby3.0 (3.0.2-7ubuntu2.4) ...
Selecting previously unselected package ruby-rubygems.
Preparing to unpack .../23-ruby-rubygems_3.3.5-2_all.deb ...
Unpacking ruby-rubygems (3.3.5-2) ...
Selecting previously unselected package ruby.
Preparing to unpack .../24-ruby_1%3a3.0~exp1_amd64.deb ...
Unpacking ruby (1:3.0~exp1) ...
Selecting previously unselected package rake.
Preparing to unpack .../25-rake_13.0.6-2_all.deb ...
Unpacking rake (13.0.6-2) ...
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack .../26-ruby-net-telnet_0.1.1-2_all.deb ...
Unpacking ruby-net-telnet (0.1.1-2) ...
Selecting previously unselected package ruby-webrick.
Preparing to unpack .../27-ruby-webrick_1.7.0-3_all.deb ...
Unpacking ruby-webrick (1.7.0-3) ...
```

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Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack .../28-ruby-xmlrpc_0.3.2-1ubuntu0.1_all.deb ...
Unpacking ruby-xmlrpc (0.3.2-1ubuntu0.1) ...
Selecting previously unselected package libruby3.0:amd64.
Preparing to unpack .../29-libruby3.0_3.0.2-7ubuntu2.4_amd64.deb ...
Unpacking libruby3.0:amd64 (3.0.2-7ubuntu2.4) ...
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack .../30-libsynctex2_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack .../31-libteckit0_2.5.11+ds1-1_amd64.deb ...
Unpacking libteckit0:amd64 (2.5.11+ds1-1) ...
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack .../32-libtexlua53_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack .../33-libtexluajit2_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack .../34-libzzip-0-13_0.13.72+dfsg.1-1.1_amd64.deb ...
Unpacking libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) ...
Selecting previously unselected package xfonts-encodings.
Preparing to unpack .../35-xfonts-encodings_1%3a1.0.5-0ubuntu2_all.deb ...
Unpacking xfonts-encodings (1:1.0.5-0ubuntu2) ...
Selecting previously unselected package xfonts-utils.
Preparing to unpack .../36-xfonts-utils_1%3a7.7+6build2_amd64.deb ...
Unpacking xfonts-utils (1:7.7+6build2) ...
Selecting previously unselected package lmodern.
Preparing to unpack .../37-lmodern_2.004.5-6.1_all.deb ...
Unpacking lmodern (2.004.5-6.1) ...
Selecting previously unselected package preview-latex-style.
Preparing to unpack .../38-preview-latex-style_12.2-1ubuntu1_all.deb ...
Unpacking preview-latex-style (12.2-1ubuntu1) ...
Selecting previously unselected package t1utils.
Preparing to unpack .../39-t1utils_1.41-4build2_amd64.deb ...
Unpacking t1utils (1.41-4build2) ...
Selecting previously unselected package teckit.
Preparing to unpack .../40-teckit_2.5.11+ds1-1_amd64.deb ...
Unpacking teckit (2.5.11+ds1-1) ...
Selecting previously unselected package tex-gyre.
Preparing to unpack .../41-tex-gyre_20180621-3.1_all.deb ...
Unpacking tex-gyre (20180621-3.1) ...
Selecting previously unselected package texlive-binaries.
Preparing to unpack .../42-texlive-binaries_2021.20210626.59705-1ubuntu0.1_amd64.deb ...
Unpacking texlive-binaries (2021.20210626.59705-1ubuntu0.1) ...
Selecting previously unselected package texlive-base.
Preparing to unpack .../43-texlive-base_2021.20220204-1_all.deb ...
Unpacking texlive-base (2021.20220204-1) ...
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack .../44-texlive-fonts-recommended_2021.20220204-1_all.deb ...
Unpacking texlive-fonts-recommended (2021.20220204-1) ...
Selecting previously unselected package texlive-latex-base.
Preparing to unpack .../45-texlive-latex-base_2021.20220204-1_all.deb ...
Unpacking texlive-latex-base (2021.20220204-1) ...
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack .../46-texlive-latex-recommended_2021.20220204-1_all.deb ...
Unpacking texlive-latex-recommended (2021.20220204-1) ...
Selecting previously unselected package texlive.
Preparing to unpack .../47-texlive_2021.20220204-1_all.deb ...
Unpacking texlive (2021.20220204-1) ...
Selecting previously unselected package libfontbox-java.
Preparing to unpack .../48-libfontbox-java_1%3a1.8.16-2_all.deb ...
Unpacking libfontbox-java (1:1.8.16-2) ...
Selecting previously unselected package libpdfbox-java.
Preparing to unpack .../49-libpdfbox-java_1%3a1.8.16-2_all.deb ...
Unpacking libpdfbox-java (1:1.8.16-2) ...
Selecting previously unselected package texlive-pictures.
Preparing to unpack .../50-texlive-pictures_2021.20220204-1_all.deb ...
Unpacking texlive-pictures (2021.20220204-1) ...
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack .../51-texlive-latex-extra_2021.20220204-1_all.deb ...
Unpacking texlive-latex-extra (2021.20220204-1) ...
```

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Selecting previously unselected package texlive-plain-generic.
Preparing to unpack .../52-texlive-plain-generic_2021.20220204-1_all.deb ...
Unpacking texlive-plain-generic (2021.20220204-1) ...
Selecting previously unselected package tipa.
Preparing to unpack .../53-tipa_2%3a1.3-21_all.deb ...
Unpacking tipa (2:1.3-21) ...
Selecting previously unselected package texlive-xetex.
Preparing to unpack .../54-texlive-xetex_2021.20220204-1_all.deb ...
Unpacking texlive-xetex (2021.20220204-1) ...
Setting up fonts-lato (2.0-2.1) ...
Setting up fonts-noto-mono (20201225-1build1) ...
Setting up libwoff1:amd64 (1.0.2-1build4) ...
Setting up libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Setting up libijs-0.35:amd64 (0.35-15build2) ...
Setting up libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Setting up libfontbox-java (1:1.8.16-2) ...
Setting up rubygems-integration (1.18) ...
Setting up libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) ...
Setting up fonts-urw-base35 (20200910-1) ...
Setting up poppler-data (0.4.11-1) ...
Setting up tex-common (6.17) ...
update-language: texlive-base not installed and configured, doing nothing!
Setting up libfontenc1:amd64 (1:1.1.4-1build3) ...
Setting up libjbig2dec0:amd64 (0.19-3build2) ...
Setting up libteckit0:amd64 (2.5.11+ds1-1) ...
Setting up libapache-pom-java (18-1) ...
Setting up ruby-net-telnet (0.1.1-2) ...
Setting up xfonts-encodings (1:1.0.5-0ubuntu2) ...
Setting up t1utils (1.41-4build2) ...
Setting up libidn12:amd64 (1.38-4ubuntu1) ...
Setting up fonts-texgyre (20180621-3.1) ...
Setting up libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Setting up ruby-webrick (1.7.0-3) ...
Setting up fonts-lmodern (2.004.5-6.1) ...
Setting up fonts-droid-fallback (1:6.0.1r16-1.1build1) ...
Setting up ruby-xmlrpc (0.3.2-1ubuntu0.1) ...
Setting up libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Setting up libgs9-common (9.55.0~dfsg1-0ubuntu5.6) ...
Setting up teckit (2.5.11+ds1-1) ...
Setting up libpdfbox-java (1:1.8.16-2) ...
Setting up libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.6) ...
Setting up preview-latex-style (12.2-1ubuntu1) ...
Setting up libcommons-parent-java (43-1) ...
Setting up dvisvgm (2.13.1-1) ...
Setting up libcommons-logging-java (1.2-2) ...
Setting up xfonts-utils (1:7.7+6build2) ...
Setting up libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.1) ...
Setting up texlive-binaries (2021.20210626.59705-1ubuntu0.1) ...
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin (xdvi.bin) in a
uto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex (bibtex) i
n auto mode
Setting up lmodern (2.004.5-6.1) ...
Setting up texlive-base (2021.20220204-1) ...
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN...
mktexlsr: Updating /var/lib/texmf/ls-R...
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4: /var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4: /var/lib/texmf/dvipdfmx/dvipdfmx-paper.c
fg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/tex-ini-files/p
dftexconfig.tex
Setting up tex-gyre (20180621-3.1) ...
Setting up texlive-plain-generic (2021.20220204-1) ...
Setting up texlive-latex-base (2021.20220204-1) ...
Setting up texlive-latex-recommended (2021.20220204-1) ...
```

```
Setting up texlive-pictures (2021.20220204-1) ...
Setting up texlive-fonts-recommended (2021.20220204-1) ...
Setting up tipa (2:1.3-21) ...
Setting up texlive (2021.20220204-1) ...
Setting up texlive-latex-extra (2021.20220204-1) ...
Setting up texlive-xetex (2021.20220204-1) ...
Setting up rake (13.0.6-2) ...
Setting up libruby3.0:amd64 (3.0.2-7ubuntu2.4) ...
Setting up ruby3.0 (3.0.2-7ubuntu2.4) ...
Setting up ruby (1:3.0~exp1) ...
Setting up ruby-rubygems (3.3.5-2) ...
Processing triggers for man-db (2.10.2-1) ...
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) ...
Processing triggers for libc-bin (2.35-0ubuntu3.4) ...
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link

Processing triggers for tex-common (6.17) ...
Running updmap-sys. This may take some time... done.
Running mktexlsr /var/lib/texmf ... done.
Building format(s) --all.
 This may take some time... done.
Collecting pypandoc
  Downloading pypandoc-1.13-py3-none-any.whl (21 kB)
Installing collected packages: pypandoc
Successfully installed pypandoc-1.13
```

In [38]:

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

In [39]:

```
!jupyter nbconvert --output-dir='/content' --to latex  '/content/drive/My Drive/Colab Notebooks/Lab1.ipynb'
```

```
[NbConvertApp] Converting notebook /content/drive/My Drive/Colab Notebooks/Lab1.ipynb to latex
[NbConvertApp] Support files will be in Lab1_files/
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Making directory /content/Lab1_files
[NbConvertApp] Writing 164583 bytes to /content/Lab1.tex
```

In [40]:

```
!buf_size=1000000 xelatex --interaction=nonstopmode 'Lab1.tex'
```

```
This is XeTeX, Version 3.141592653-2.6-0.999993 (TeX Live 2022/dev/Debian) (preloaded format=xelatex)
 restricted \write18 enabled.
```

```
entering extended mode
(./Lab1.tex
LaTeX2e <2021-11-15> patch level 1
L3 programming layer <2022-01-21>
(/usr/share/texlive/texmf-dist/tex/latex/base/article.cls
Document Class: article 2021/10/04 v1.4n Standard LaTeX document class
(/usr/share/texlive/texmf-dist/tex/latex/base/size11.clo))
(/usr/share/texlive/texmf-dist/tex/latex/tcolorbox/tcolorbox.sty
(/usr/share/texlive/texmf-dist/tex/latex/pgf/basiclayer/pgf.sty
(/usr/share/texlive/texmf-dist/tex/latex/pgf/utilities/pgfrcs.sty
(/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfutil-common.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfutil-common-lists.t
ex)) (/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfutil-latex.def
) (/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfrcs.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/pgf.revision.tex)))
(/usr/share/texlive/texmf-dist/tex/latex/pgf/basiclayer/pgfcore.sty
(/usr/share/texlive/texmf-dist/tex/latex/graphics/graphicx.sty
(/usr/share/texlive/texmf-dist/tex/latex/graphics/keyval.sty)
(/usr/share/texlive/texmf-dist/tex/latex/graphics/graphics.sty
(/usr/share/texlive/texmf-dist/tex/latex/graphics/trig.sty)
(/usr/share/texlive/texmf-dist/tex/latex/graphics-cfg/graphics.cfg)
(/usr/share/texlive/texmf-dist/tex/latex/graphics-def/xetex.def)))
(/usr/share/texlive/texmf-dist/tex/latex/pgf/systemlayer/pgfsys.sty
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsys.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfkeys.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/utilities/pgfkeysfiltered.code.t
ex)) (/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgf.cfg)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsys-xetex.def
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsys-dvipdfmx.def
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsys-common-pdf.de
f))))
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsyssoftpath.code.
tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/systemlayer/pgfsysprotocol.code.
tex)) (/usr/share/texlive/texmf-dist/tex/latex/xcolor/xcolor.sty
(/usr/share/texlive/texmf-dist/tex/latex/graphics-cfg/color.cfg))
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcore.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmath.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathcalc.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathutil.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathparser.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.code.tex
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.basic.code
.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.trigonomet
ric.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.random.cod
e.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.comparison
.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.base.code.
tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.round.code
.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.misc.code.
tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfunctions.integerari
thmetics.code.tex)))
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfmathfloat.code.tex))
(/usr/share/texlive/texmf-dist/tex/generic/pgf/math/pgfint.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorepoints.code.te
x)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorepathconstruct.
code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorepathusage.code
.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorescopes.code.te
x)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoregraphicstate.c
ode.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoretransformation
s.code.tex)
```

```
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorequick.code.tex
)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoreobjects.code.t
ex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorepathprocessing
.code.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorearrows.code.te
x)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoreshade.code.tex
)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoreimage.code.tex

(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoreexternal.code.
tex))
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorelayers.code.te
x)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcoretransparency.c
ode.tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorepatterns.code.
tex)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/basiclayer/pgfcorerdf.code.tex))
)
(/usr/share/texlive/texmf-dist/tex/generic/pgf/modules/pgfmoduleshapes.code.tex
) (/usr/share/texlive/texmf-dist/tex/generic/pgf/modules/pgfmoduleplot.code.tex
)
(/usr/share/texlive/texmf-dist/tex/latex/pgf/compatibility/pgfcomp-version-0-65
.sty)
(/usr/share/texlive/texmf-dist/tex/latex/pgf/compatibility/pgfcomp-version-1-18
.sty)) (/usr/share/texlive/texmf-dist/tex/latex/tools/verbatim.sty)
(/usr/share/texlive/texmf-dist/tex/latex/environ/environ.sty
(/usr/share/texlive/texmf-dist/tex/latex/trimspaces/trimspaces.sty))
(/usr/share/texlive/texmf-dist/tex/latex/etoolbox/etoolbox.sty)
(/usr/share/texlive/texmf-dist/tex/latex/tcolorbox/tcbbreakable.code.tex
Library (tcolorbox): 'tcbbreakable.code.tex' version '5.0.2'
(/usr/share/texlive/texmf-dist/tex/generic/oberdiek/pdfcol.sty
(/usr/share/texlive/texmf-dist/tex/generic/ltxcmds/ltxcmds.sty)
(/usr/share/texlive/texmf-dist/tex/generic/infwarerr/infwarerr.sty)
(/usr/share/texlive/texmf-dist/tex/generic/iftex/iftex.sty))))
(/usr/share/texlive/texmf-dist/tex/latex/parskip/parskip.sty
(/usr/share/texlive/texmf-dist/tex/latex/kvoptions/kvoptions.sty
(/usr/share/texlive/texmf-dist/tex/generic/kvsetkeys/kvsetkeys.sty)))
(/usr/share/texlive/texmf-dist/tex/latex/caption/caption.sty
(/usr/share/texlive/texmf-dist/tex/latex/caption/caption3.sty))
(/usr/share/texlive/texmf-dist/tex/latex/float/float.sty)
(/usr/share/texlive/texmf-dist/tex/latex/tools/enumerate.sty)
(/usr/share/texlive/texmf-dist/tex/latex/geometry/geometry.sty
(/usr/share/texlive/texmf-dist/tex/generic/iftex/ifvtex.sty))
(/usr/share/texlive/texmf-dist/tex/latex/amsmath/amsmath.sty
For additional information on amsmath, use the `?' option.
(/usr/share/texlive/texmf-dist/tex/latex/amsmath/amstext.sty
(/usr/share/texlive/texmf-dist/tex/latex/amsmath/amsgen.sty))
(/usr/share/texlive/texmf-dist/tex/latex/amsmath/amsbsy.sty)
(/usr/share/texlive/texmf-dist/tex/latex/amsmath/amsopn.sty))
(/usr/share/texlive/texmf-dist/tex/latex/amsfonts/amssymb.sty
(/usr/share/texlive/texmf-dist/tex/latex/amsfonts/amsfonts.sty))
(/usr/share/texlive/texmf-dist/tex/latex/base/textcomp.sty)
(/usr/share/texlive/texmf-dist/tex/latex/upquote/upquote.sty)
(/usr/share/texlive/texmf-dist/tex/latex/eurosym/eurosym.sty)
(/usr/share/texlive/texmf-dist/tex/latex/fontspec/fontspec.sty
(/usr/share/texlive/texmf-dist/tex/latex/l3packages/xparse/xparse.sty
(/usr/share/texlive/texmf-dist/tex/latex/l3kernel/expl3.sty
(/usr/share/texlive/texmf-dist/tex/latex/l3backend/l3backend-xetex.def
(|extractbb --version))))
(/usr/share/texlive/texmf-dist/tex/latex/fontspec/fontspec-xetex.sty
(/usr/share/texlive/texmf-dist/tex/latex/base/fontenc.sty)
(/usr/share/texlive/texmf-dist/tex/latex/fontspec/fontspec.cfg)))
(/usr/share/texlive/texmf-dist/tex/latex/unicode-math/unicode-math.sty
(/usr/share/texlive/texmf-dist/tex/latex/unicode-math/unicode-math-xetex.sty
(/usr/share/texlive/texmf-dist/tex/latex/l3packages/l3keys2e/l3keys2e.sty)
(/usr/share/texlive/texmf-dist/tex/latex/base/fix-cm.sty
(/usr/share/texlive/texmf-dist/tex/latex/base/ts1enc.def))
(/usr/share/texlive/texmf-dist/tex/latex/unicode-math/unicode-math-table.tex)))
```

```
(/usr/share/texlive/texmf-dist/tex/latex/fancyvrb/fancyvrb.sty)
(/usr/share/texlive/texmf-dist/tex/latex/grffile/grffile.sty)
(/usr/share/texlive/texmf-dist/tex/latex/adjustbox/adjustbox.sty
(/usr/share/texlive/texmf-dist/tex/latex/xkeyval/xkeyval.sty
(/usr/share/texlive/texmf-dist/tex/generic/xkeyval/xkeyval.tex
(/usr/share/texlive/texmf-dist/tex/generic/xkeyval/xkvutils.tex)))
(/usr/share/texlive/texmf-dist/tex/latex/adjustbox/adjcalc.sty)
(/usr/share/texlive/texmf-dist/tex/latex/adjustbox/trimclip.sty
(/usr/share/texlive/texmf-dist/tex/latex/collectbox/collectbox.sty)
(/usr/share/texlive/texmf-dist/tex/latex/adjustbox/tc-xetex.def))
(/usr/share/texlive/texmf-dist/tex/latex/ifoddpage/ifoddpage.sty)
(/usr/share/texlive/texmf-dist/tex/latex/varwidth/varwidth.sty))
(/usr/share/texlive/texmf-dist/tex/latex/hyperref/hyperref.sty
(/usr/share/texlive/texmf-dist/tex/generic/pdftexcmds/pdftexcmds.sty)
(/usr/share/texlive/texmf-dist/tex/generic/kvdefinekeys/kvdefinekeys.sty)
(/usr/share/texlive/texmf-dist/tex/generic/pdfescape/pdfescape.sty)
(/usr/share/texlive/texmf-dist/tex/latex/hycolor/hycolor.sty)
(/usr/share/texlive/texmf-dist/tex/latex/letltxmacro/letltxmacro.sty)
(/usr/share/texlive/texmf-dist/tex/latex/auxhook/auxhook.sty)
(/usr/share/texlive/texmf-dist/tex/latex/hyperref/pd1enc.def)
(/usr/share/texlive/texmf-dist/tex/latex/hyperref/hyperref-langpatches.def)
(/usr/share/texlive/texmf-dist/tex/generic/intcalc/intcalc.sty)
(/usr/share/texlive/texmf-dist/tex/generic/etexcmds/etexcmds.sty)
(/usr/share/texlive/texmf-dist/tex/latex/hyperref/puenc.def)
(/usr/share/texlive/texmf-dist/tex/latex/url/url.sty)
(/usr/share/texlive/texmf-dist/tex/generic/bitset/bitset.sty
(/usr/share/texlive/texmf-dist/tex/generic/bigintcalc/bigintcalc.sty))
(/usr/share/texlive/texmf-dist/tex/latex/base/atbegshi-ltx.sty))
(/usr/share/texlive/texmf-dist/tex/latex/hyperref/hxetex.def
(/usr/share/texlive/texmf-dist/tex/generic/stringenc/stringenc.sty)
(/usr/share/texlive/texmf-dist/tex/latex/rerunfilecheck/rerunfilecheck.sty
(/usr/share/texlive/texmf-dist/tex/latex/base/atveryend-ltx.sty)
(/usr/share/texlive/texmf-dist/tex/generic/uniquecounter/uniquecounter.sty)))
(/usr/share/texlive/texmf-dist/tex/latex/titling/titling.sty)
(/usr/share/texlive/texmf-dist/tex/latex/tools/longtable.sty)
(/usr/share/texlive/texmf-dist/tex/latex/booktabs/booktabs.sty)
(/usr/share/texlive/texmf-dist/tex/latex/tools/array.sty)
(/usr/share/texlive/texmf-dist/tex/latex/tools/calc.sty)
(/usr/share/texlive/texmf-dist/tex/latex/enumitem/enumitem.sty)
(/usr/share/texlive/texmf-dist/tex/generic/ulem/ulem.sty)
(/usr/share/texlive/texmf-dist/tex/latex/jknapltx/mathrsfs.sty)
No file Lab1.aux.
(/usr/share/texlive/texmf-dist/tex/latex/caption/ltcaption.sty)
*geometry* driver: auto-detecting
*geometry* detected driver: xetex
*geometry* verbose mode - [ preamble ] result:
* driver: xetex
* paper: <default>
* layout: <same size as paper>
* layoutoffset:(h,v)=(0.0pt,0.0pt)
* modes:
* h-part:(L,W,R)=(72.26999pt, 469.75502pt, 72.26999pt)
* v-part:(T,H,B)=(72.26999pt, 650.43001pt, 72.26999pt)
* \paperwidth=614.295pt
* \paperheight=794.96999pt
* \textwidth=469.75502pt
* \textheight=650.43001pt
* \oddsidemargin=0.0pt
* \evensidemargin=0.0pt
* \topmargin=-37.0pt
* \headheight=12.0pt
* \headsep=25.0pt
* \topskip=11.0pt
* \footskip=30.0pt
* \marginparwidth=59.0pt
* \marginparsep=10.0pt
* \columnsep=10.0pt
* \skip\footins=10.0pt plus 4.0pt minus 2.0pt
* \hoffset=0.0pt
* \voffset=0.0pt
* \mag=1000
* \@twocolumnfalse
```

```
* \@twosidefalse
* \@mparswitchfalse
* \@reversemarginfalse
* (1in=72.27pt=25.4mm, 1cm=28.453pt)

(/usr/share/texlive/texmf-dist/tex/latex/hyperref/nameref.sty
(/usr/share/texlive/texmf-dist/tex/latex/refcount/refcount.sty)
(/usr/share/texlive/texmf-dist/tex/generic/gettitlestring/gettitlestring.sty))

Package hyperref Warning: Rerun to get /PageLabels entry.

(/usr/share/texlive/texmf-dist/tex/latex/amsfonts/umsa.fd)
(/usr/share/texlive/texmf-dist/tex/latex/amsfonts/umsb.fd)
(/usr/share/texlive/texmf-dist/tex/latex/jknapltx/ursfs.fd)

LaTeX Warning: No \author given.

[1]

Package hyperref Warning: Difference (2) between bookmark levels is greater
(hyperref)                than one, level fixed on input line 462.

[2]
Underfull \hbox (badness 10000) in paragraph at lines 550--551

[3]

LaTeX Font Warning: Font shape `U/rsfs/m/n' in size <5.475> not available
(Font)              size <5> substituted on input line 629.

[4] [5]
Underfull \hbox (badness 10000) in paragraph at lines 701--702

[6] [7] [8]
Underfull \hbox (badness 10000) in paragraph at lines 1056--1057

[9] [10]
Underfull \hbox (badness 10000) in paragraph at lines 1224--1225

[11] [12]
Underfull \hbox (badness 10000) in paragraph at lines 1418--1419

[13]
Underfull \hbox (badness 10000) in paragraph at lines 1432--1433

[14] [15] [16]
Underfull \hbox (badness 10000) in paragraph at lines 1674--1675

[17] [18]
Underfull \hbox (badness 10000) in paragraph at lines 1794--1795

[19] [20]
Underfull \hbox (badness 10000) in paragraph at lines 1941--1942

[21]
Overfull \hbox (713.65057pt too wide) in paragraph at lines 2032--2032
[][]\TU/lmtt/m/n/10.95 assign(newspaper_radio[]=[]train[[][][][]newspaper[][][]
[]][]*[]train[[][][][]radio[][][][]],TV_radio[]=[]train[[][][][]TV[][][][][]]*[
]train[[][][][]radio[][][][]],newspaper_TV[]=[]train[[][][][]newspaper[][][][]]
[]*[]train[[][][][]TV[][][][]],newspaper_radio_TV[]=[]train[[][][][]newspaper[]
[][][]][]*[]train[[][][][]radio[][][][]][]*[]train[[][][][]TV[][][][]])|

Overfull \hbox (661.91183pt too wide) in paragraph at lines 2033--2033
[][]\TU/lmtt/m/n/10.95 assign(newspaper_radio[]=[]test[[][][][]newspaper[][][][
]][]*[]test[[][][][]radio[][][][]],TV_radio[]=[]test[[][][][]TV[][][][]]][]*[]te
st[[][][][]radio[][][][]],newspaper_TV[]=[]test[[][][][]newspaper[][][][]]][]*[]
test[[][][][]TV[][][][]],newspaper_radio_TV[]=[]test[[][][][]newspaper[][][][]]
[]*[]test[[][][][]radio[][][][]][]*[]test[[][][][]TV[][][][]])|
[22] [23]
Underfull \hbox (badness 10000) in paragraph at lines 2196--2197

[24]
```

```
Underfull \hbox (badness 10000) in paragraph at lines 2312--2313

[25] [26] [27]
Underfull \hbox (badness 10000) in paragraph at lines 2565--2566

[28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] (./Lab1.aux)

LaTeX Font Warning: Size substitutions with differences
(Font)              up to 0.475pt have occurred.


LaTeX Warning: Label(s) may have changed. Rerun to get cross-references right.


Package rerunfilecheck Warning: File `Lab1.out' has changed.
(rerunfilecheck)                Rerun to get outlines right
(rerunfilecheck)                or use package `bookmark'.

 )
(see the transcript file for additional information)
Output written on Lab1.pdf (38 pages).
Transcript written on Lab1.log.
```