Data Visualization

What is DV?

- Graphical representation of information and data

Automotive Radars

A review of signal processing techniques

Automotive radars, along with other sensors such as lidar, (which stands for "light detection and ranging"), ultrasound, and cameras, form the backbone of self-driving cars and advanced driver assistant systems (ADASs). These technological advancements are enabled by extremely complex systems with a long signal processing path from radars/sensors to the controller. Automotive radar systems are responsible for the detection of objects and obstacles, their position, and speed relative to the vehicle. The development of signal processing techniques along with progress in the millimeter-wave (mm-wave) semiconductor technology plays a key role in automotive radar systems. Various signal processing techniques have been developed to provide better resolution and estimation performance in all measurement dimensions: range, azimuth-elevation angles, and velocity of the targets surrounding the vehicles. This article summarizes various aspects of automotive radar signal processing techniques, including waveform design, possible radar architectures, estimation algorithms, implementation complexity-resolution trade off, and adaptive processing for complex environments, as well as unique problems associated with automotive radars such as pedestrian detection. We believe that this review article will combine the several contributions scattered in the literature to serve as a primary starting point to new researchers and to give a bird's-eye view to the existing research community.

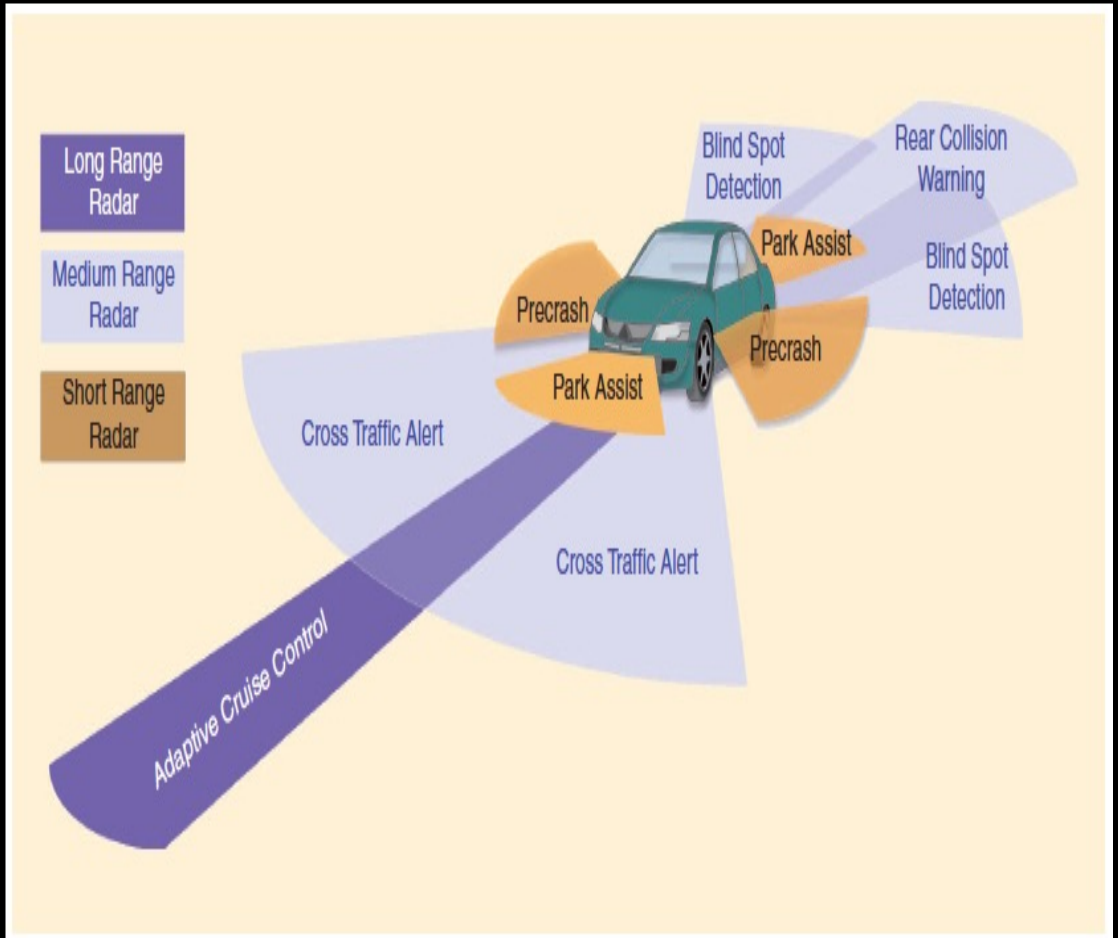


FIGURE 1. An ADAS consists of different range radars.

Textual communication

Visual communication

Introduction & Literature

Problem Formulation & Solution

Results

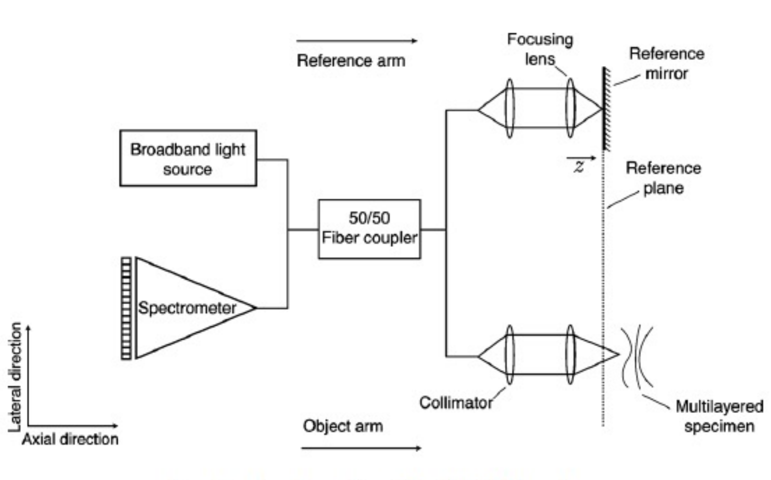


Fig. 1. A schematic of the FDOCT system.

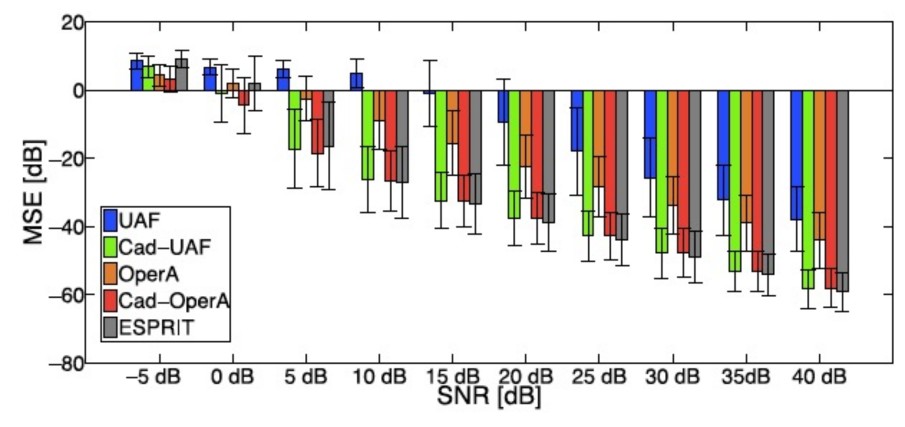
Algorithm 3: UDP packets retransmission

```
while G(V,E) has clique of size 3 do
    Find a clique {v_i, v_j, v_k} of size 3;
    XOR the UDP packets {v_i, v_j, v_k} and multicast to
      the clients;
    Remove {v_i, v_j, v_k} from G(V, E);
end
Compute a maximum matching of G(V, E);
while there is a pair {v_i, v_j} in the matching do
    XOR the UDP packets {v_i, v_j} and multicast to
      the clients;
    Remove {v_i, v_j} from G(V, E);
end
Send the remaining packets from G(V, E);
```

Table 2. Radar waveforms.

Waveform Type	Transmit Waveform s(t)	Detection Principle	Resolution	Comments
CW	$e^{j2\pi f_c t}$	Conjugate mixing	$\triangle f_d = 1/T$	No range information
Pulsed CW	$\Pi(T_p)\, e^{j2\pi f_c t}$	Correlation	$\triangle R = cT_p/2 \;\; \triangle f_d = 1/T_p$	Range-Doppler performance tradeoff
FMCW	$e^{j2\pi(f_c + 0.5Kt)t}, \quad K = \frac{B}{T_0}$	Conjugate mixing	$\triangle R = c/2B \;\; \triangle f_d = 1/PT_0$	Both range and Doppler information
SFCW	$e^{j2\pi f_n t}, \quad f_n = f_c + (n-1)\triangle f$	Inverse Fourier transform	$\triangle R = c/2B \;\; \triangle f_d = 1/PT_0$	$\triangle f$ decides maximum range
OFDM	$\sum_{n=0}^{N-1} I(n)\, e^{2\pi(f_c + n\triangle f)t}$	Frequency domain channel estimation	$\triangle R = c/N\triangle f \;\; \triangle f_d = 1/PT_N$	Suitable for vehicular communication

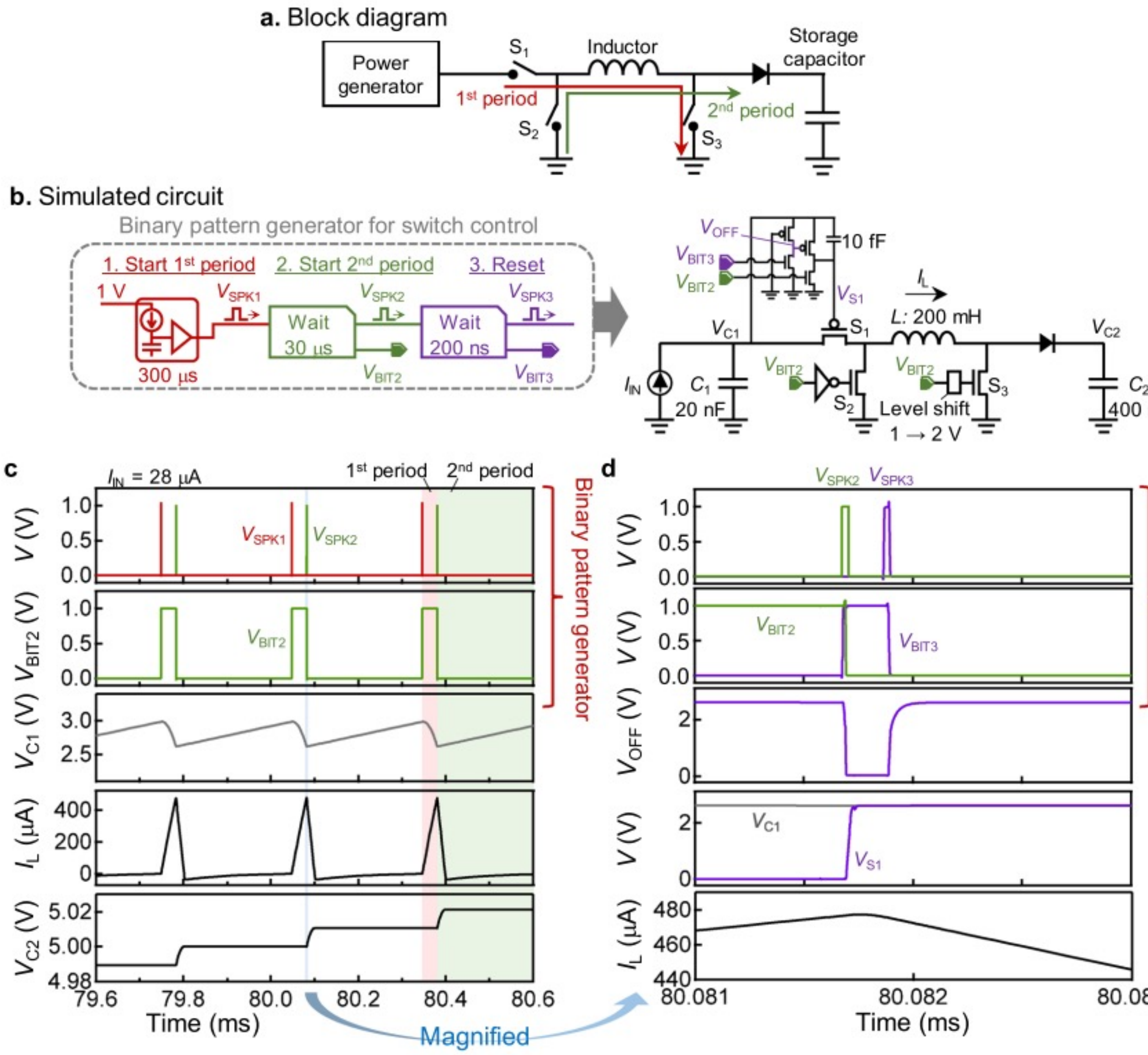
B denotes bandwidth of the radar. T is the amount of time for which data is captured.
N stands for a number of samples in CW and number of carriers in OFDM.
$\Pi(T_p)$ is rectangular pulse of duration T_p. P is number of FM/SF-CW or OFDM blocks of duration T_0 and T_N, respectively.
$I(n)$ is arbitrary sequence and $\triangle f$ is carrier/frequency separation in OFDM/SFCW.



Block Diagrams

- Describes a system, workflow, process, etc.

- Rules of thumb:
  - What to present?
    - A general problem
    - A set-up
    - The proposed solution
  - Details
  - Color combinations



Block Diagrams

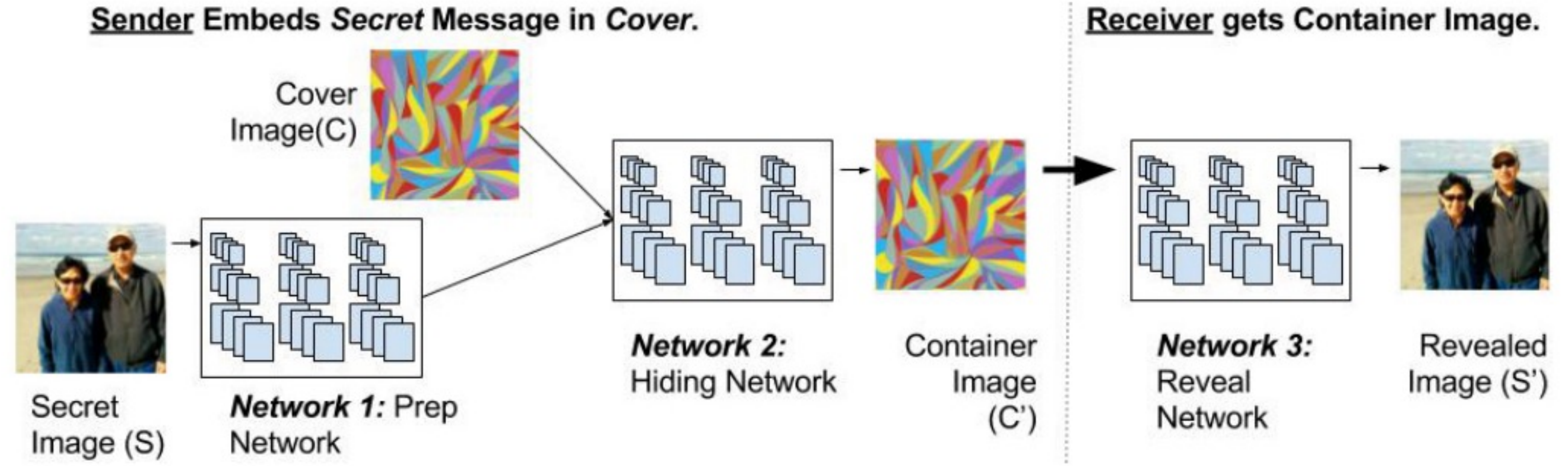
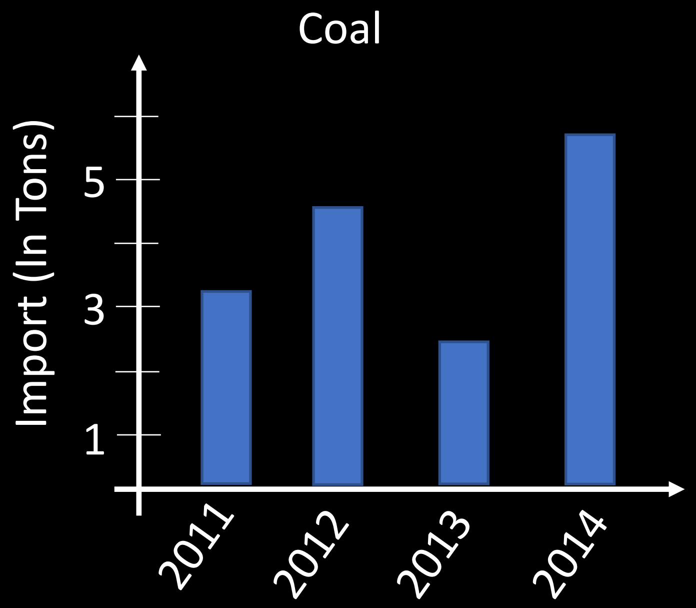
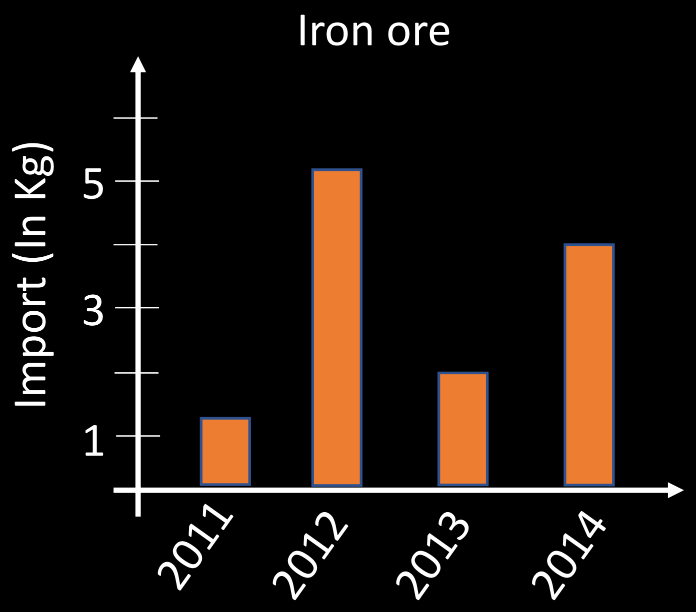


Figure 1: The three components of the full system. Left: Secret-Image preparation. Center: Hiding the image in the cover image. Right: Uncovering the hidden image with the reveal network; this is trained simultaneously, but is used by the receiver.





- Production was low in 2011, 2013, and was good in 2012, 2014

- Place detailed data/information in categories formatted
- Use when exact figures are important
- If the numbers are more important than the trend, use a table
- If the trend is more important than the numbers, use a graph
- Don't use both

Table 1: Imports and production over 2011-2014

Year	Coal (in Tons)	Iron ore (in Kg)	Production
2011	3.1	1.3	Low
2012	4.5	5.1	Good
2013	2.2	2.0	Low
2014	5.6	3.9	Good

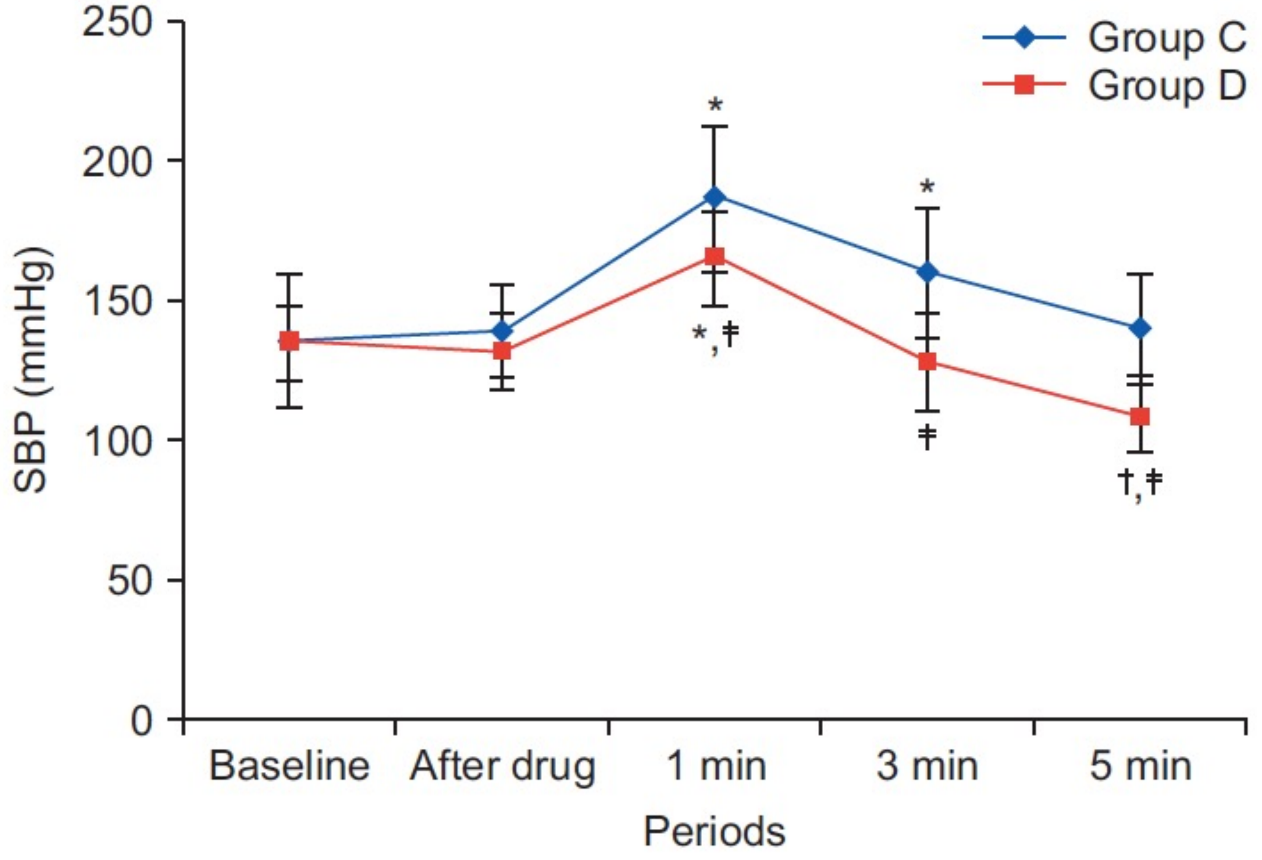


Fig. 1. Line graph with whiskers. Changes in systolic blood pressure (SBP) in the two groups. Group C: normal saline, Group D: dexmedetomidine. *P < 0.05 indicates a significant increase in each group, compared with the baseline values. †P < 0.05 indicates a significant decrease noted in Group D, compared with the baseline values. ‡P < 0.05 indicates a significant difference between the groups (Adapted from Korean J Anesthesiol 2017; 70: 39-45).

Three plots for three blood pressures

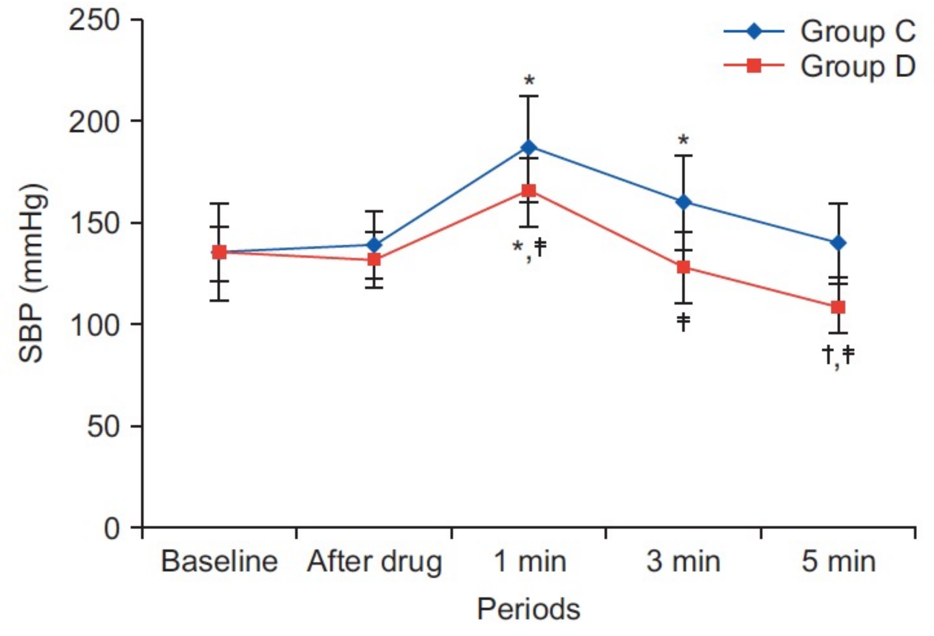


Fig. 1. Line graph with whiskers. Changes in systolic blood pressure (SBP)

- All information requires equal attention
- selectively look at information of interest

Table 1. Modified Table in Lee and Kim's Research (Adapted from Korean J Anesthesiol 2017; 70: 39-45)

Variable	Group	Baseline	After drug	1 min	3 min	5 min
SBP	C	135.1 ± 13.4	139.2 ± 17.1	$186.0 \pm 26.6^{*}$	$160.1 \pm 23.2^{*}$	140.7 ± 18.3
	D	135.4 ± 23.8	131.9 ± 13.5	$165.2 \pm 16.2^{*,\ddagger}$	$127.9 \pm 17.5^{\ddagger}$	$108.4 \pm 12.6^{\dagger,\ddagger}$
DBP	C	79.7 ± 9.8	79.4 ± 15.8	$104.8 \pm 14.9^{*}$	$87.9 \pm 15.5^{*}$	78.9 ± 11.6
	D	76.7 ± 8.3	78.4 ± 6.3	$97.0 \pm 14.5^{*}$	$74.1 \pm 8.3^{\ddagger}$	$66.5 \pm 7.2^{\dagger,\ddagger}$
MBP	C	100.3 ± 11.9	103.5 ± 16.8	$137.2 \pm 18.3^{*}$	$116.9 \pm 16.2^{*}$	103.9 ± 13.3
	D	97.7 ± 14.9	98.1 ± 8.7	$123.4 \pm 13.8^{*,\ddagger}$	$95.4 \pm 11.7^{\ddagger}$	$83.4 \pm 8.4^{\dagger,\ddagger}$

Values are expressed as mean ± SD. Group C: normal saline, Group D: dexmedetomidine. SBP: systolic blood pressure, DBP: diastolic blood pressure, MBP: mean blood pressure, HR: heart rate. $^{*}P < 0.05$ indicates a significant increase in each group, compared with the baseline values. $^{\dagger}P < 0.05$ indicates a significant decrease noted in Group D, compared with the baseline values. $^{\ddagger}P < 0.05$ indicates a significant difference between the groups.

Add highlighters to convey information in a better way

Table 2. Filter recovery error in dB on the test set for various CRs (bold indicates successful recovery with error below -50 dB).

CR [%]	M_z	G-MBD	GS-MBD	FS-MBD	LS-MBD	LS-MBD-L
50	99	**-54.05**	-44.93	-43.96	**-53.27**	-26.54
40.4	80	**-55.07**	-40.55	-26.52	**-52.80**	-
35.35	70	**-52.43**	-40.00	-22.76	**-51.50**	-
31.31	62	**-53.63**	-37.13	-21.86	**-54.71**	-
25.25	50	**-53.36**	-28.57	-8.40	**-51.41**	-
23.74	47	**-50.60**	-26.11	-6.84	**-50.35**	-
22.72	45	**-52.98**	-23.17	-6.14	-43.61	-
20.20	40	-47.39	-14.75	-5.13	-17.07	-

Add highlighters to convey information in a better way

Table 2. Difference between a Regular Table and a Heat Map

Example of a regular table				Example of a heat map			
SBP	DBP	MBP	HR	SBP	DBP	MBP	HR
128	66	87	87	128	66	87	87
125	43	70	85	125	43	70	85
114	52	68	103	114	52	68	103
111	44	66	79	111	44	66	79
139	61	81	90	139	61	81	90
103	44	61	96	103	44	61	96
94	47	61	83	94	47	61	83

All numbers were created by the author. SBP: systolic blood pressure, DBP: diastolic blood pressure, MBP: mean blood pressure, HR: heart rate.

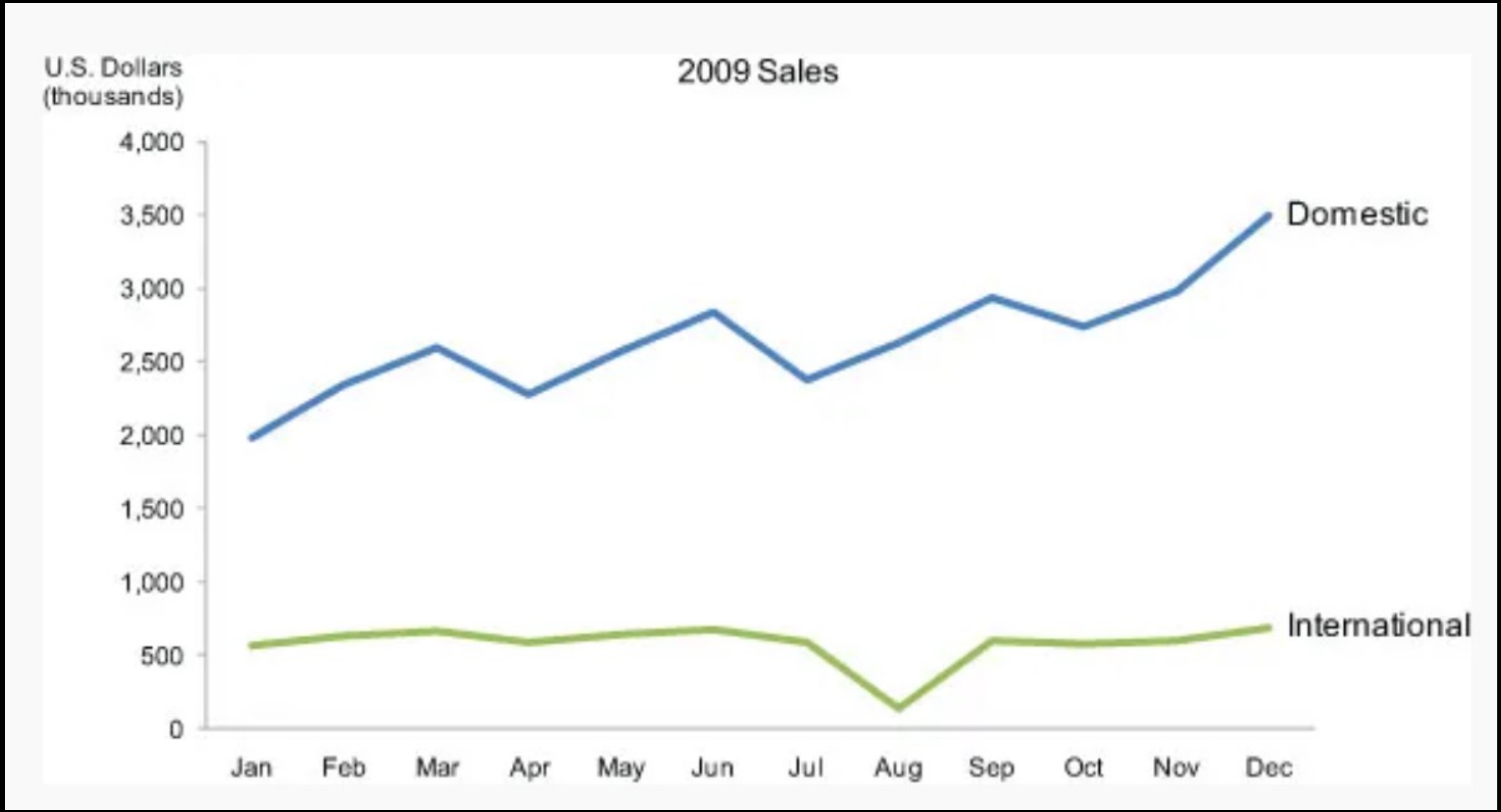
2009 Sales (thousands of U.S. $)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Domestic	1,983	2,343	2,593	2,283	2,574	2,838	2,382	2,634	2,938	2,739	2,983	3,493	31,783
International	574	636	673	593	644	679	593	139	599	583	602	690	7,005
Total	2,557	2,979	3,266	2,876	3,218	3,517	2,975	2,773	3,537	3,322	3,585	4,183	38,788

Source: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/data-visualization-for-human-perception

2009 Sales (thousands of U.S. $)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Domestic	1,983	2,343	2,593	2,283	2,574	2,838	2,382	2,634	2,938	2,739	2,983	3,493	31,783
International	574	636	673	593	644	679	593	139	599	583	602	690	7,005
Total	2,557	2,979	3,266	2,876	3,218	3,517	2,975	2,773	3,537	3,322	3,585	4,183	38,788



Source: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/data-visualization-for-human-perception

2009 Sales (thousands of U.S. $)

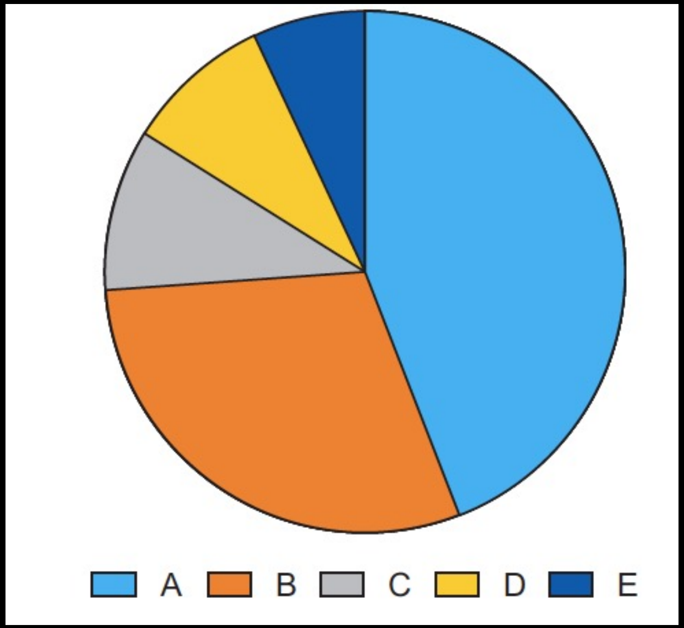
Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Domestic	1,983	2,343	2,593	2,283	2,574	2,838	2,382	2,634	2,938	2,739	2,983	3,493	31,783
International	574	636	673	593	644	679	593	139	599	583	602	690	7,005
Total	2,557	2,979	3,266	2,876	3,218	3,517	2,975	2,773	3,537	3,322	3,585	4,183	38,788

- Domestic sales were considerably and consistently higher than international.
- Domestic sales trended upward over the year as a whole.
- International sales, in contrast, remained relatively flat, with one glaring exception: they decreased sharply in August.
- Domestic sales exhibited a cyclical pattern - up, up, down - that repeated itself on a quarterly basis, always reaching the peak in the last month of the quarter and then declining dramatically in the first month of the next.

Source: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/data-visualization-for-human-perception

Charts and Graphs

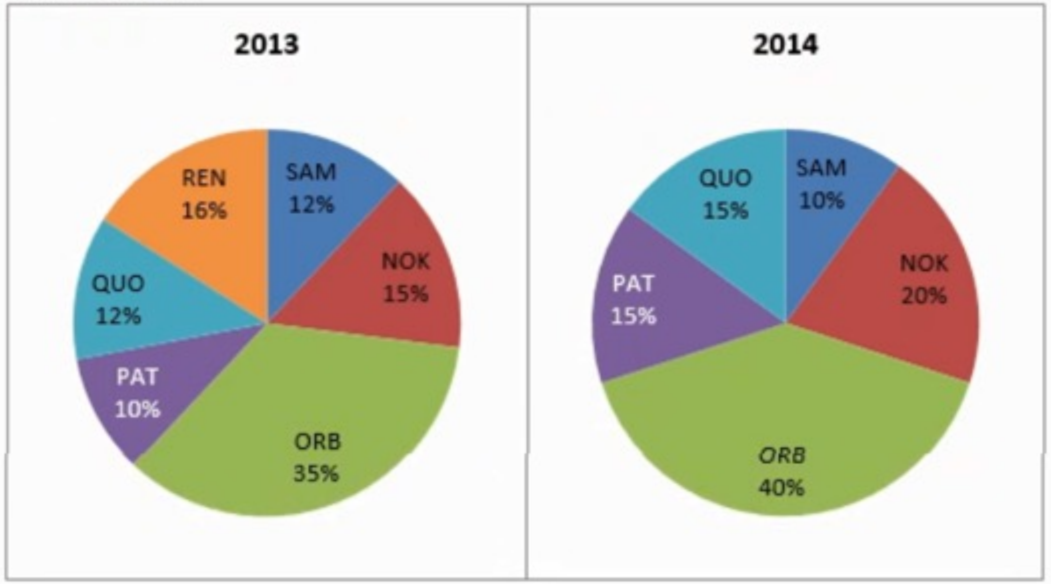
Pie Charts



- The picture is simple and easy-to-understand
- Data can be represented visually as a fractional part of a whole
- It helps in providing an effective communication tool for the even uninformed audience
- Provides a data comparison for the audience at a glance to give an immediate analysis
- No need to examine underlying numbers themselves

Pie Charts

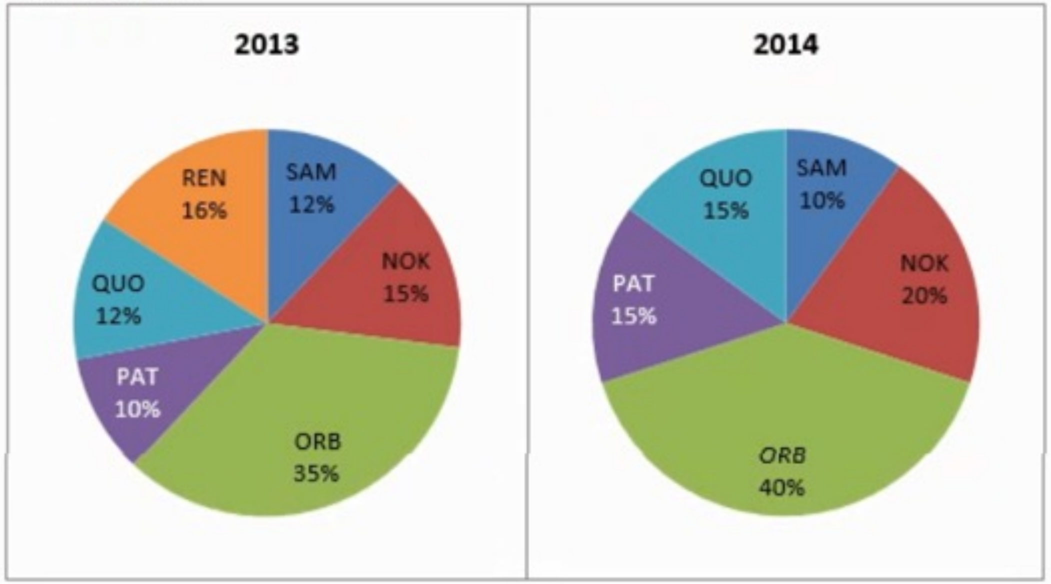
The pie-charts show the percentage break-up of revenue of all the players in the software market for the years 2013 and 2014. The share of REN was left out by mistake while constructing the pie-chart for 2014. It was found that REN commanded 20% share of the market in 2014.



Reference: Enphase 2020 Placement Paper

Pie Charts

The pie-charts show the percentage break-up of revenue of all the players in the software market for the years 2013 and 2014. The share of REN was left out by mistake while constructing the pie-chart for 2014. It was found that REN commanded 20% share of the market in 2014.

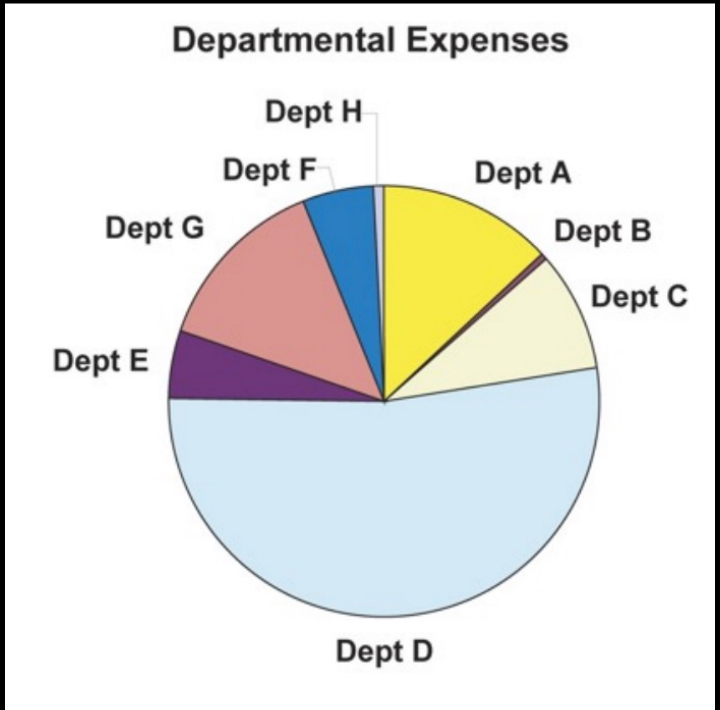


Reference: Enphase 2020 Placement Paper

- It becomes less effective if there are too many pieces of data to use
- The information is present in terms of percentages

Pie Charts

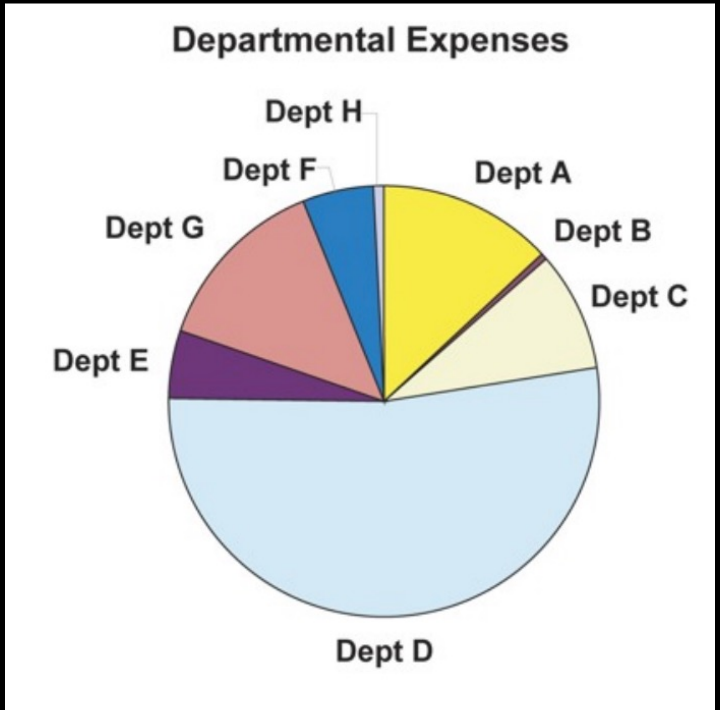
Goal: to show how Dept G is doing

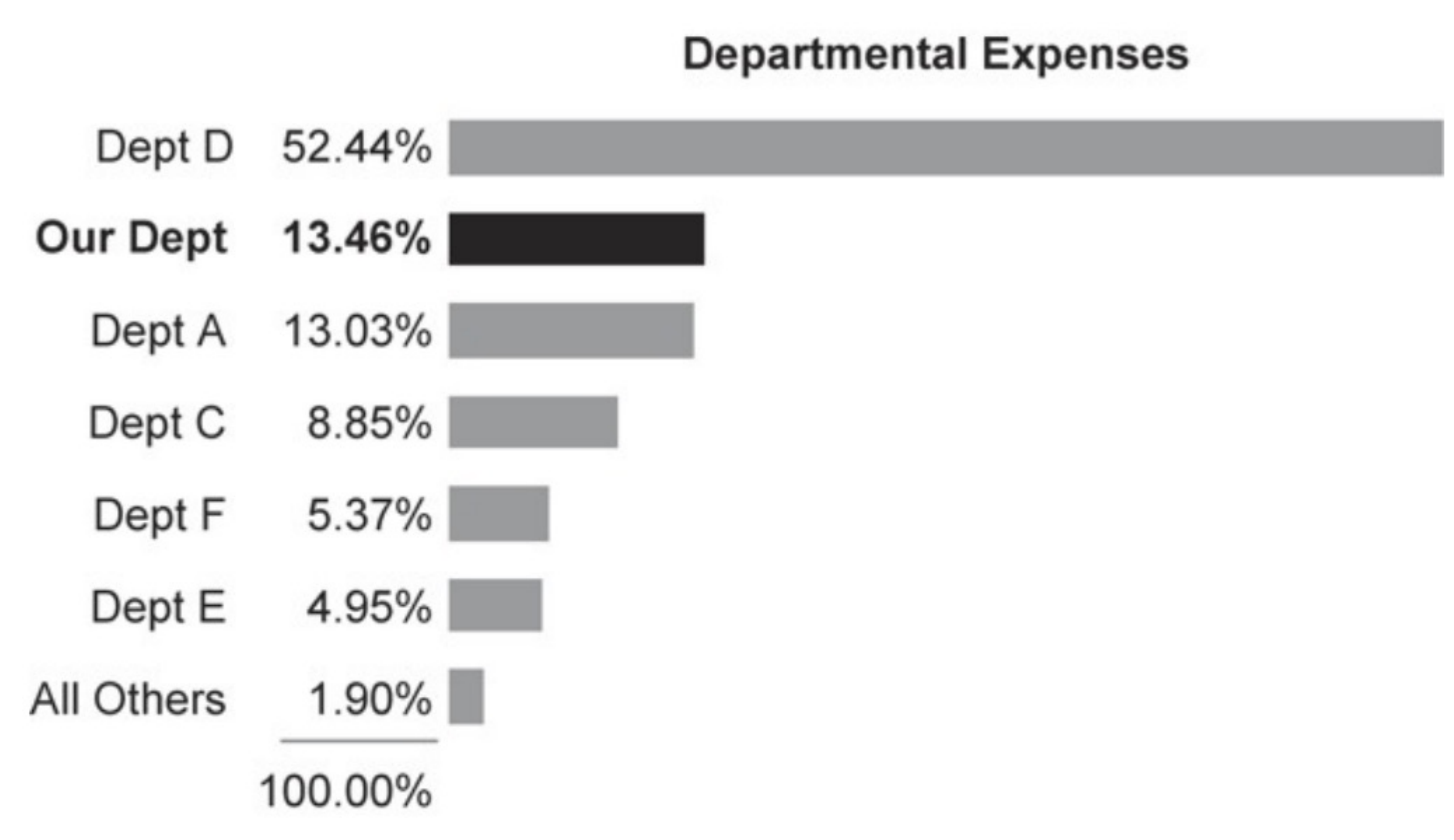


Reference: https://nces.ed.gov/forum/pdf/NCES_table_design.pdf

Pie Charts

Goal: to show how Dept G is doing



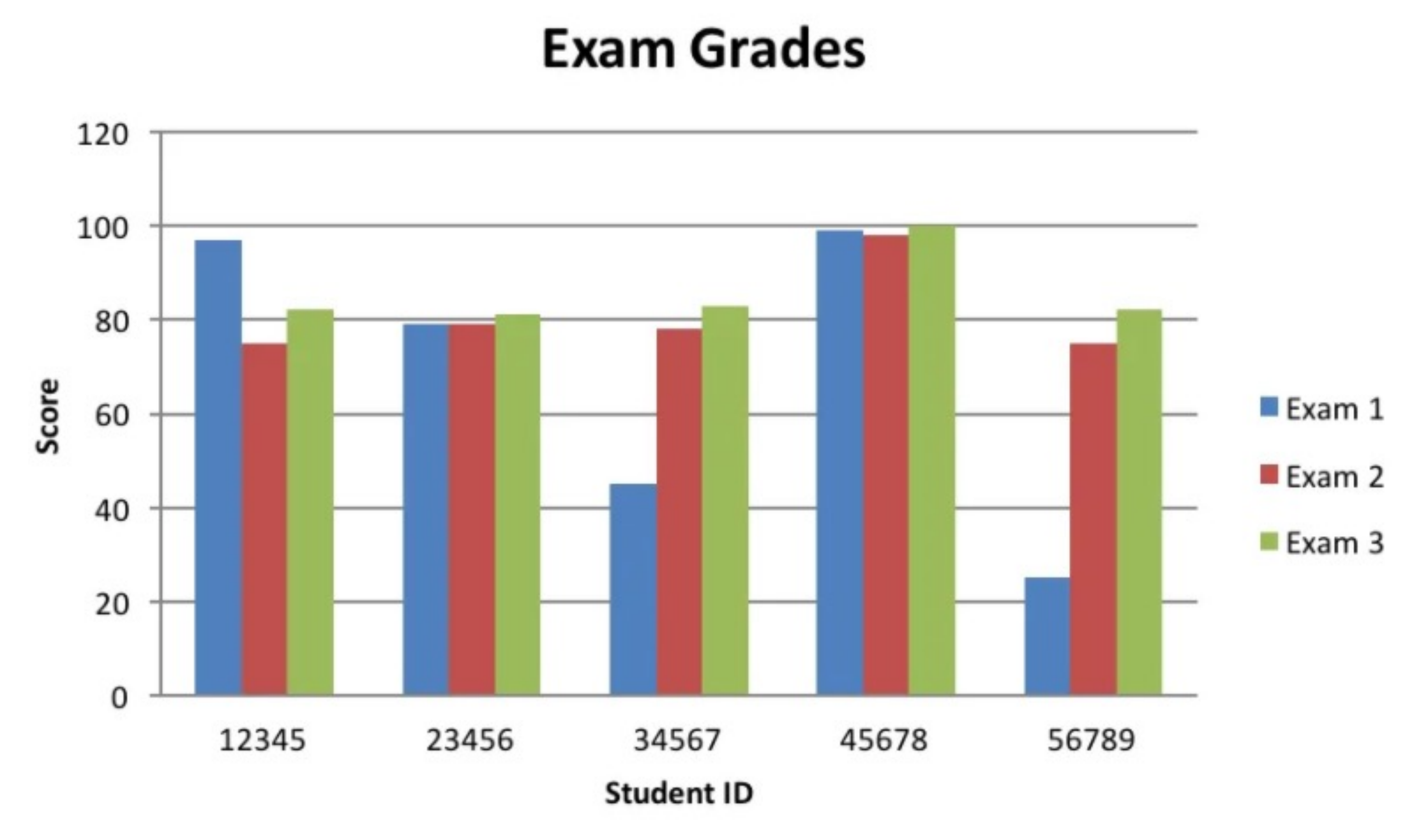


Reference: https://nces.ed.gov/forum/pdf/NCES_table_design.pdf

Bar Plots

Indicate and compare values in a discrete category

Compare multiple data sets

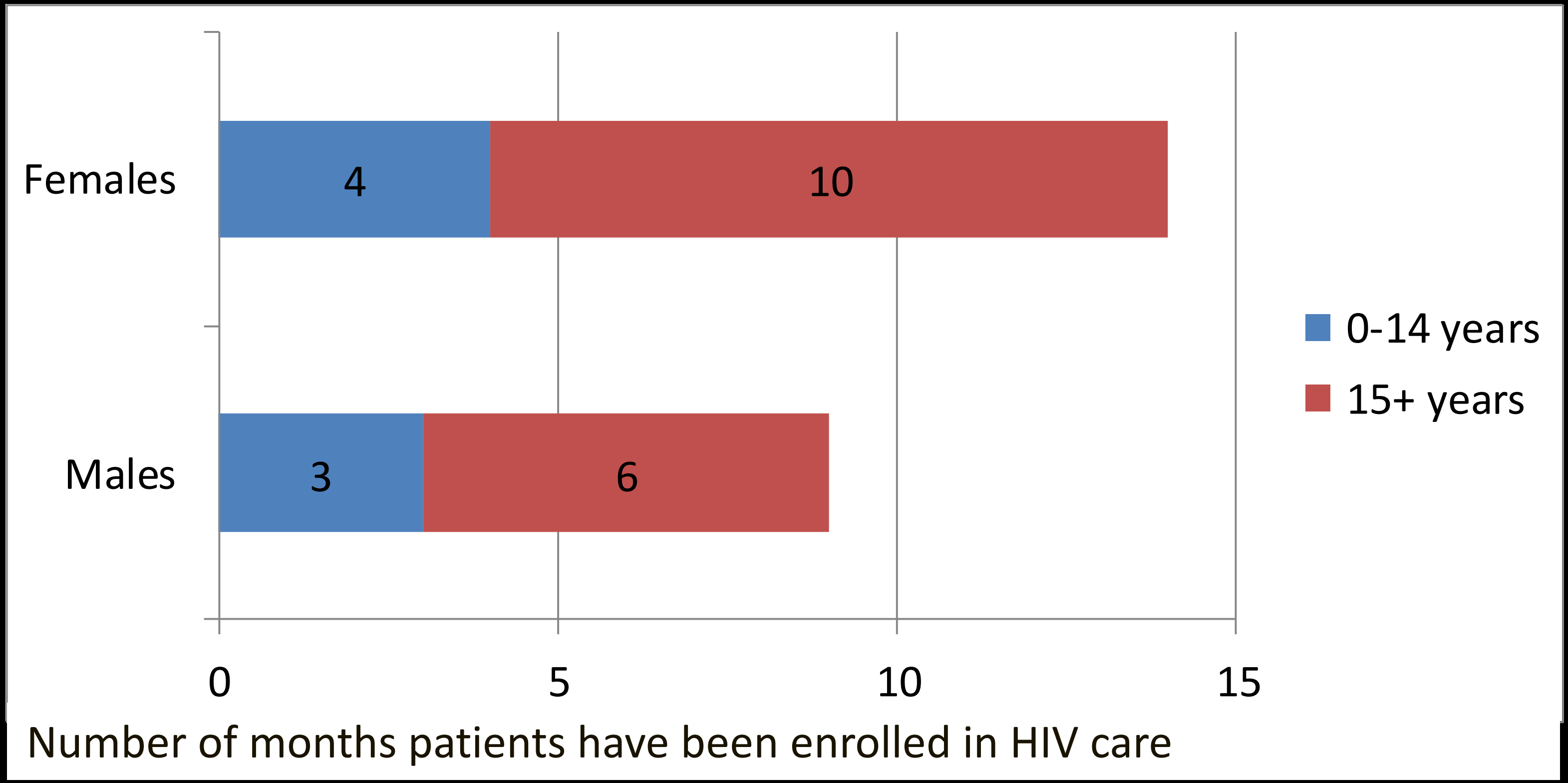


Source: https://writingcommons.org/article/data-visualizations

Stacked Bar Chart

Represent components of whole & compare wholes

Number of Months Female and Male Patients Have Been Enrolled in HIV Care, by Age Group

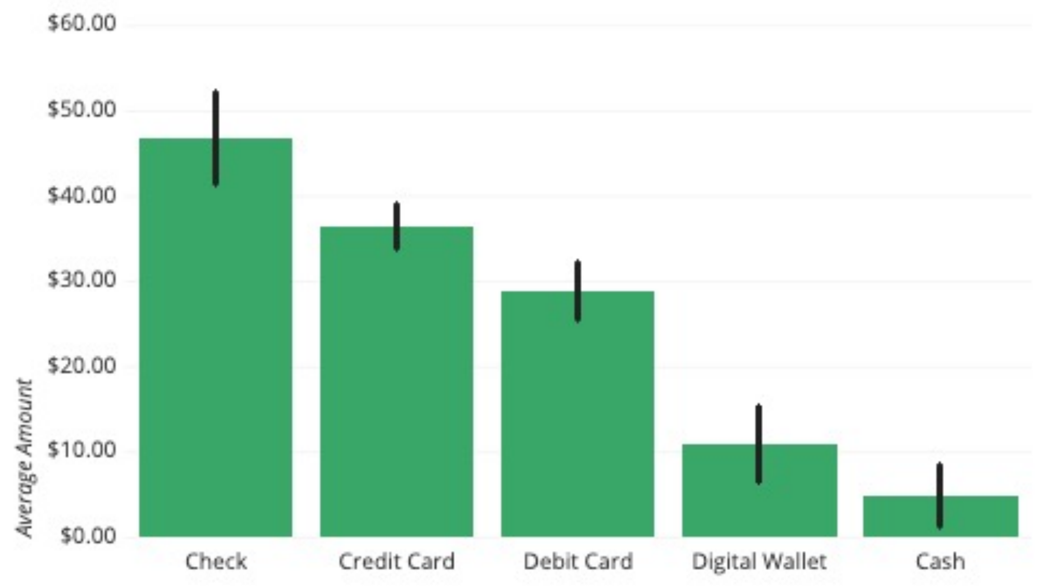


Data source: AIDSRelief program records January 2009 - 20011

Include values

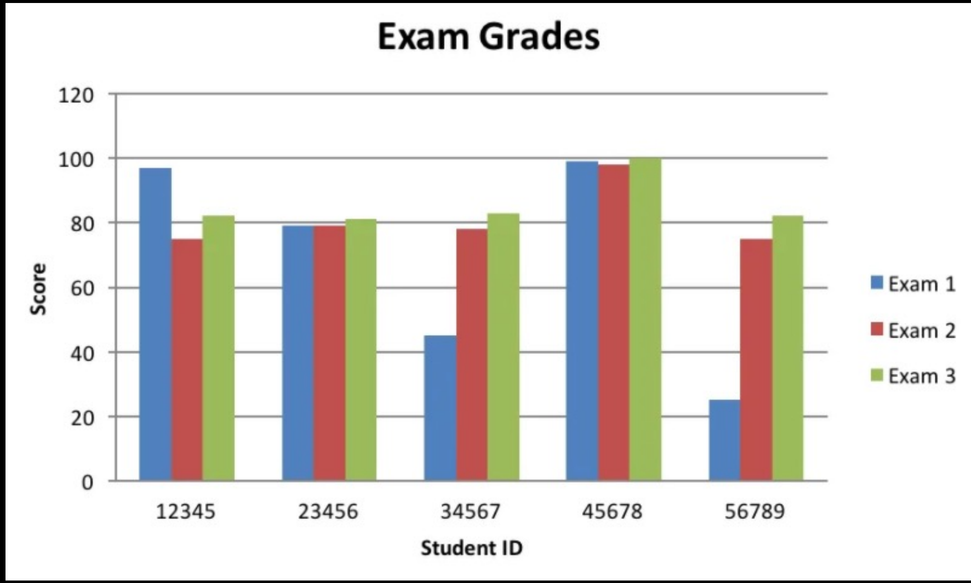
Source: https://chartio.com/learn/charts/bar-chart-complete-guide/

Include deviation

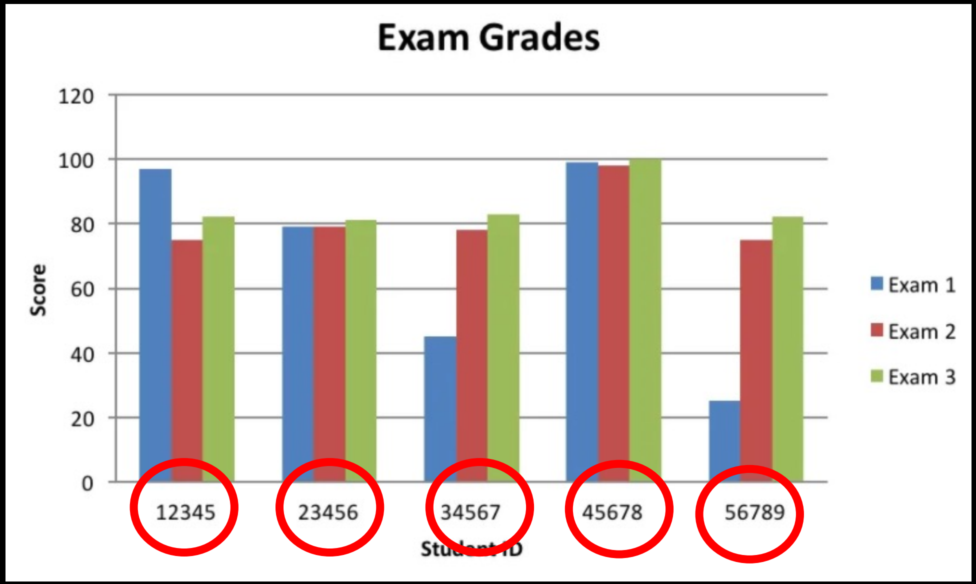


Error bars indicate the standard deviation for transaction amounts for each payment type. The variability is lower for credit and debit cards compared to the others.

Source: https://chartio.com/learn/charts/bar-chart-complete-guide/



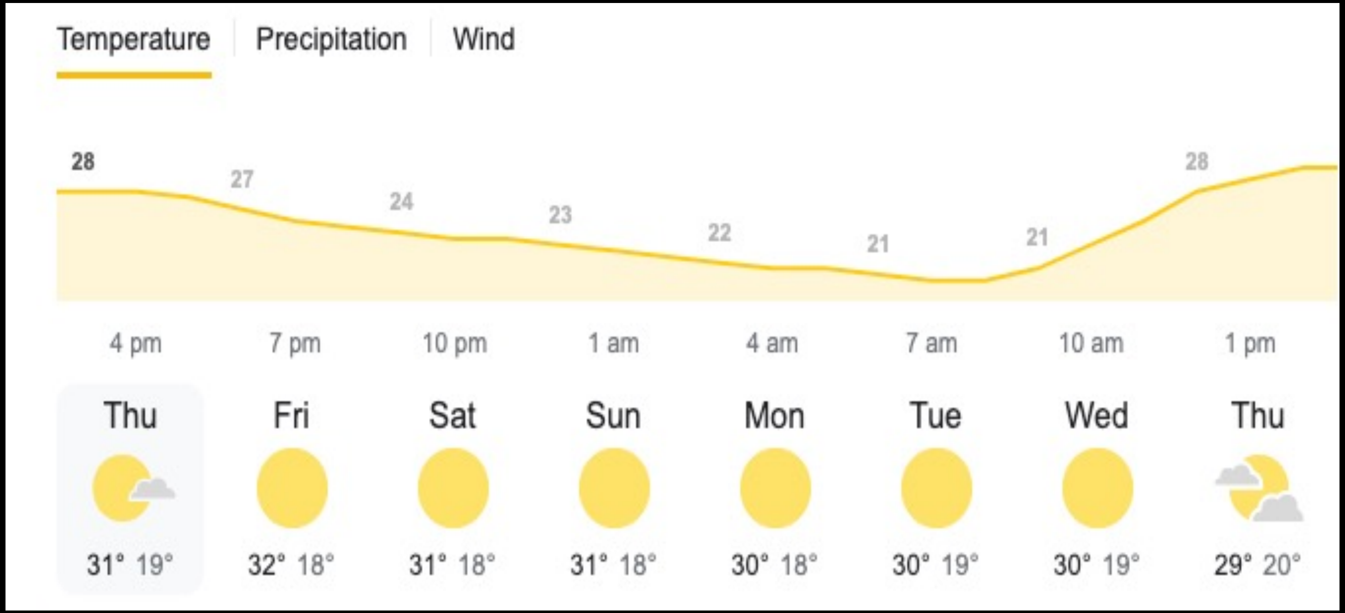
Source: https://writingcommons.org/article/data-visualizations



Discrete quantities

Source: https://writingcommons.org/article/data-visualizations

Line Graphs

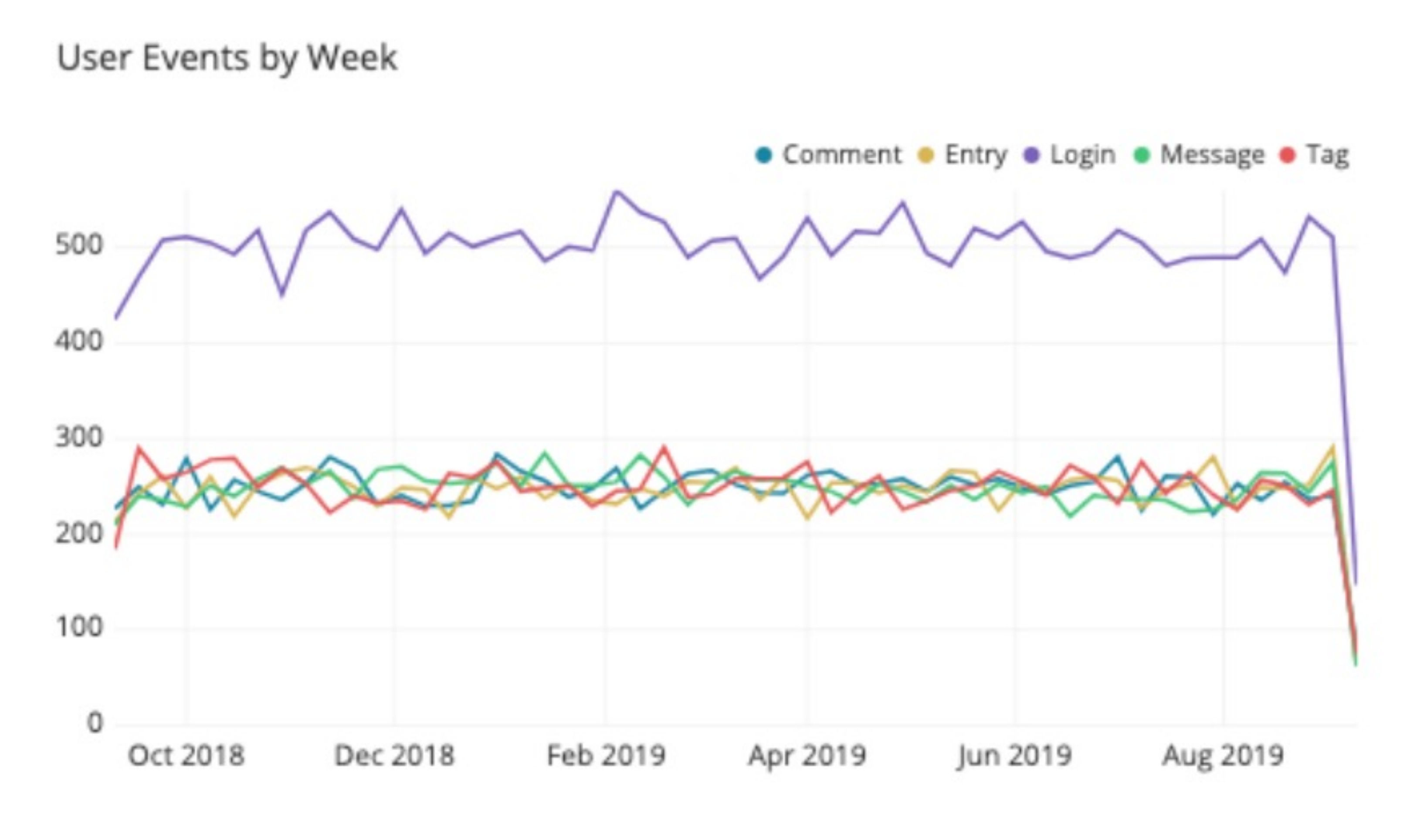


x-axis is a continuous variable

Source: https://writingcommons.org/article/data-visualizations

Line Graphs

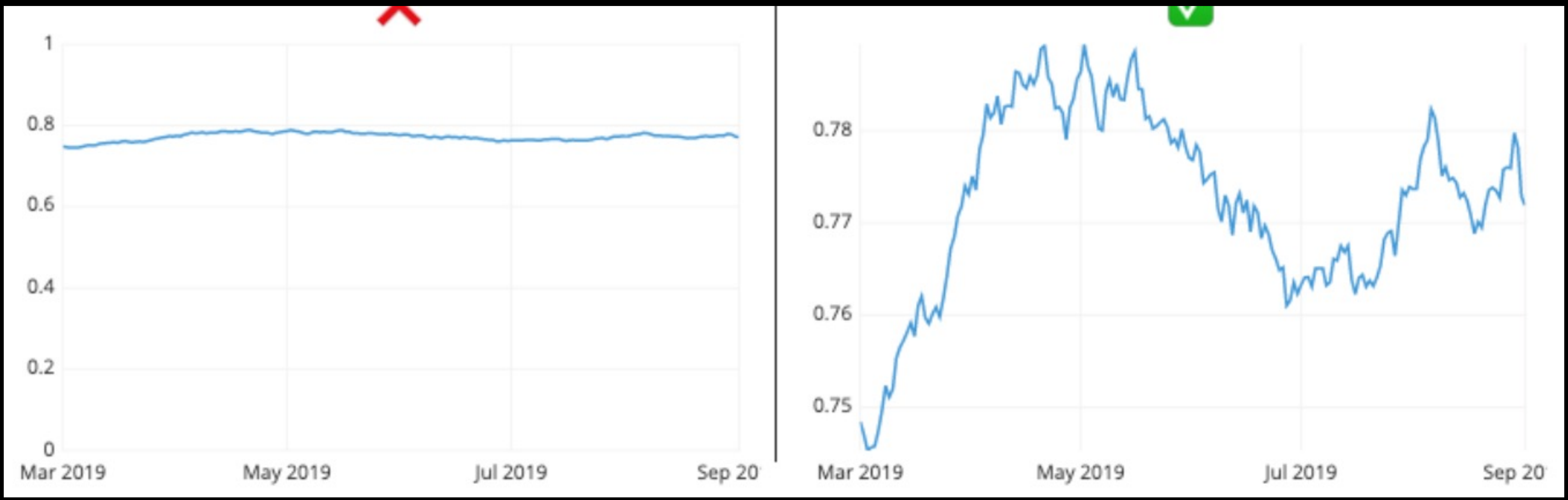
Don’t use too many of them



Source: https://chartio.com/learn/charts/line-chart-complete-guide/

Line Graphs

Zero value-baseline?



Source: https://chartio.com/learn/charts/line-chart-complete-guide/

Line Graphs

Zero value-baseline?

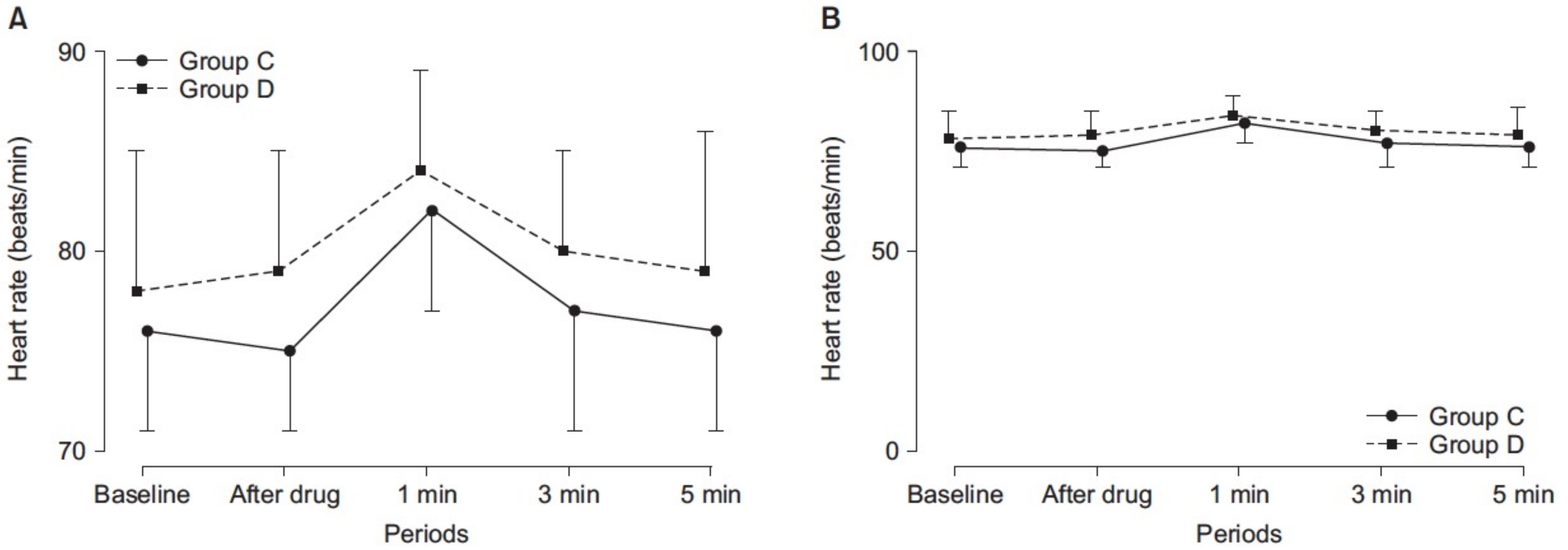
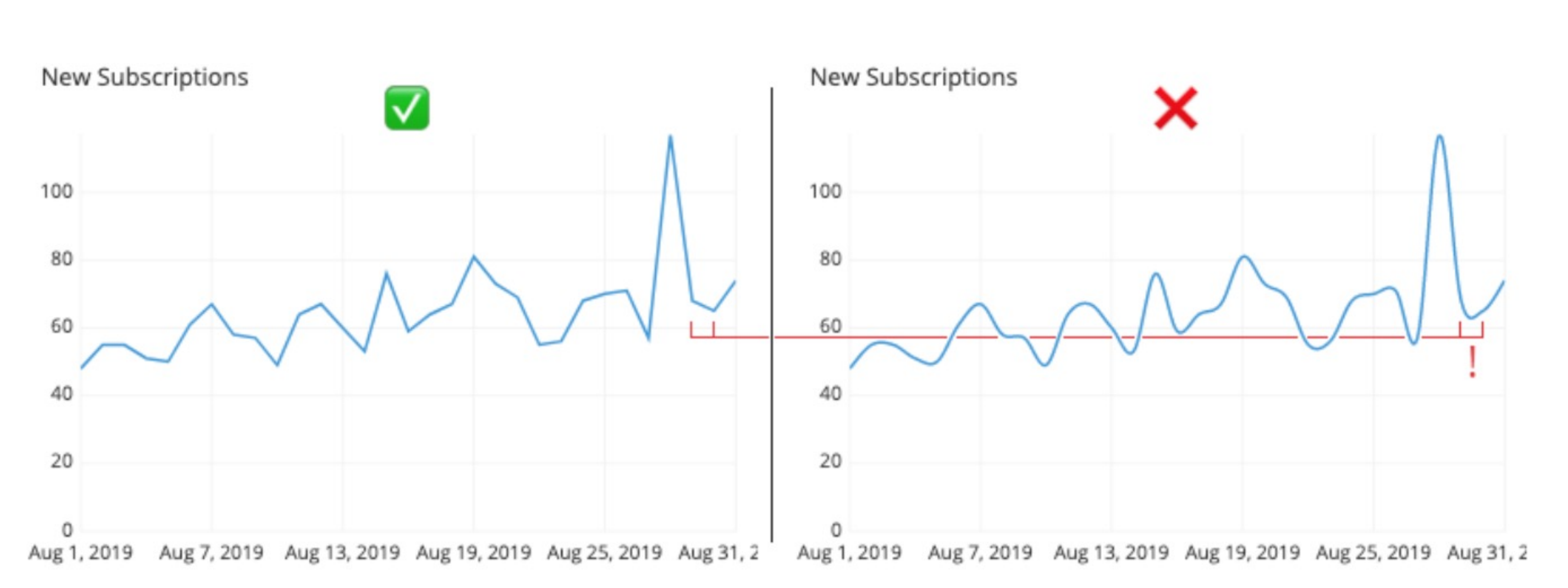


Fig. 10. An example of misleading graphs. Both plots use the same data set. (A) The readers might be thinking that the heart rates at 1 min are higher than others. (B) The heart rates are very stable during the study. The readers should check the scale of the y-axis and baseline values when they look at the graphs.

Source: https://chartio.com/learn/charts/line-chart-complete-guide/

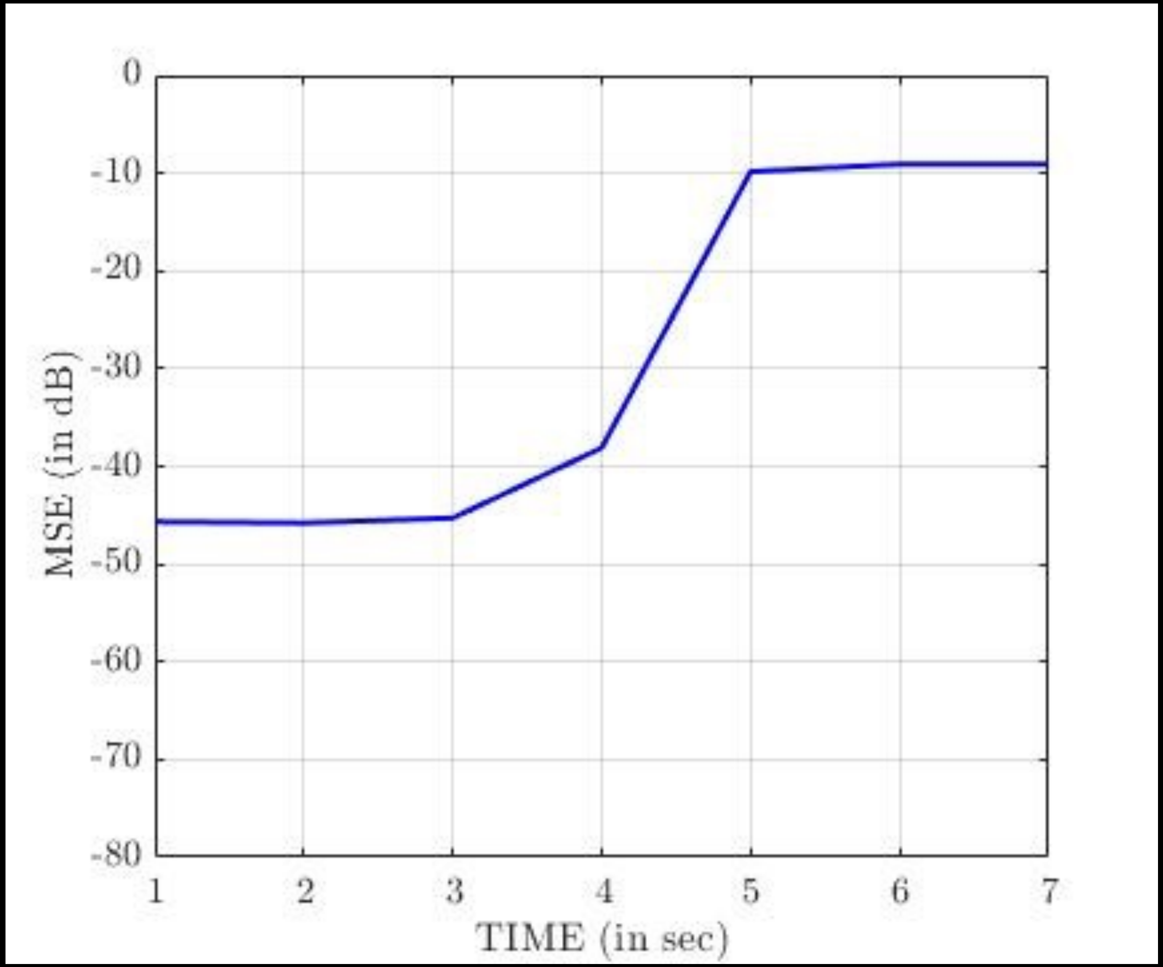
Line Graphs

Don’t use smoothing

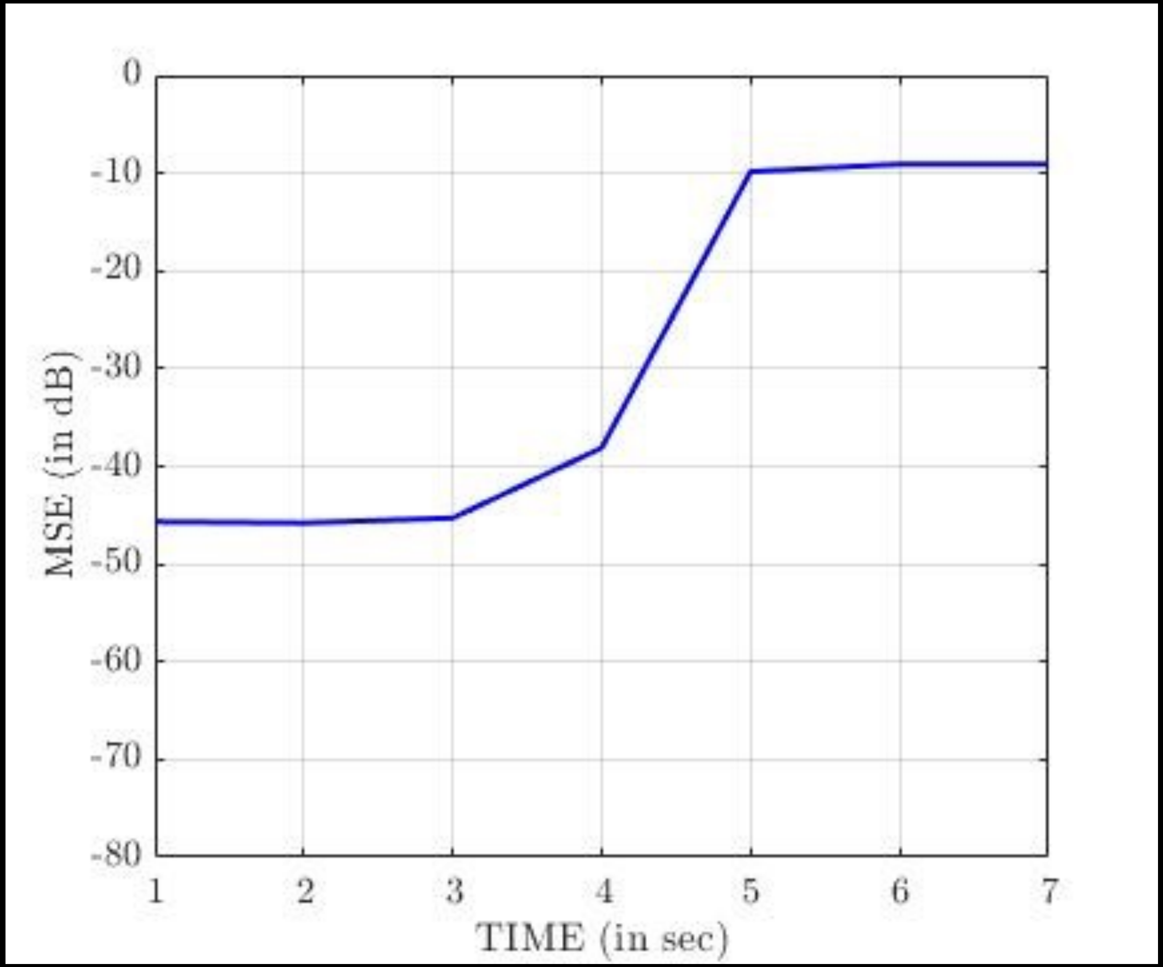


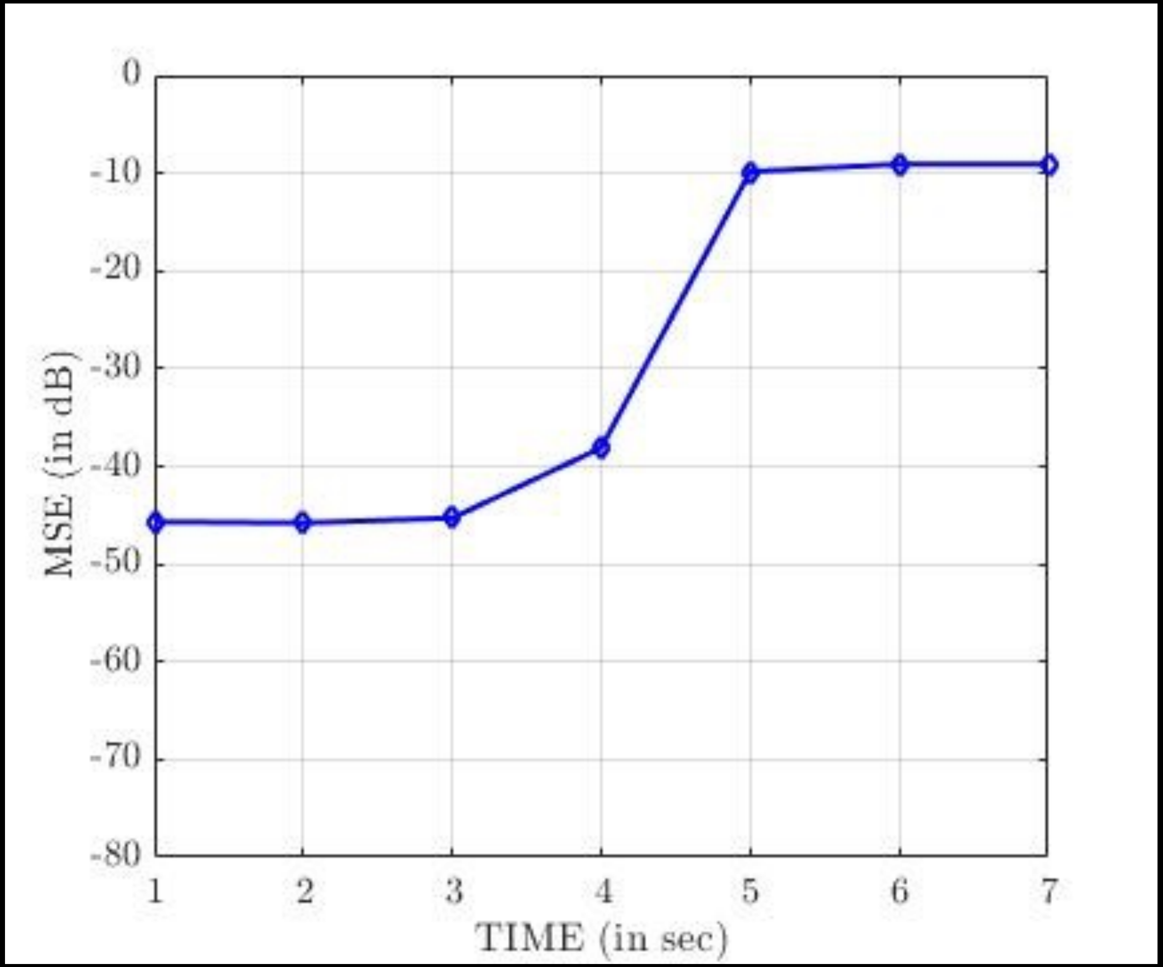
Source: https://chartio.com/learn/charts/line-chart-complete-guide/

Markers in Line Graphs

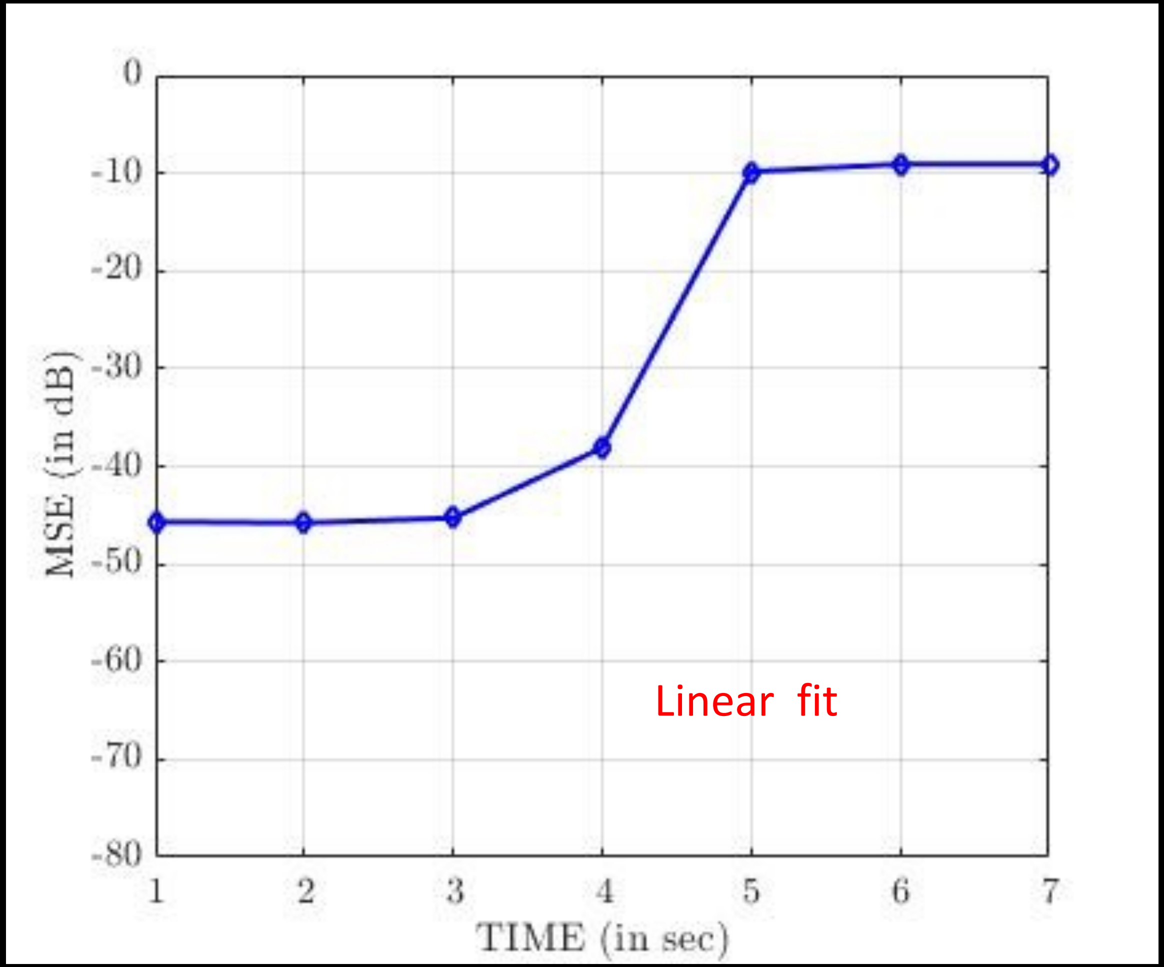


Markers in Line Graphs





Interpolation and fitting



Interpolation and fitting

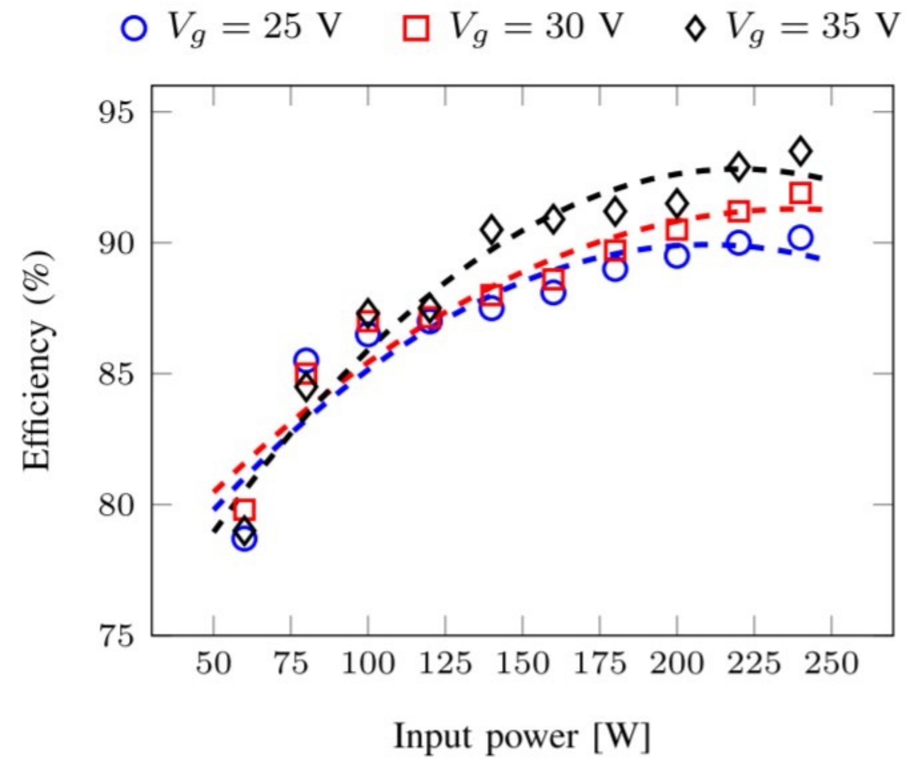
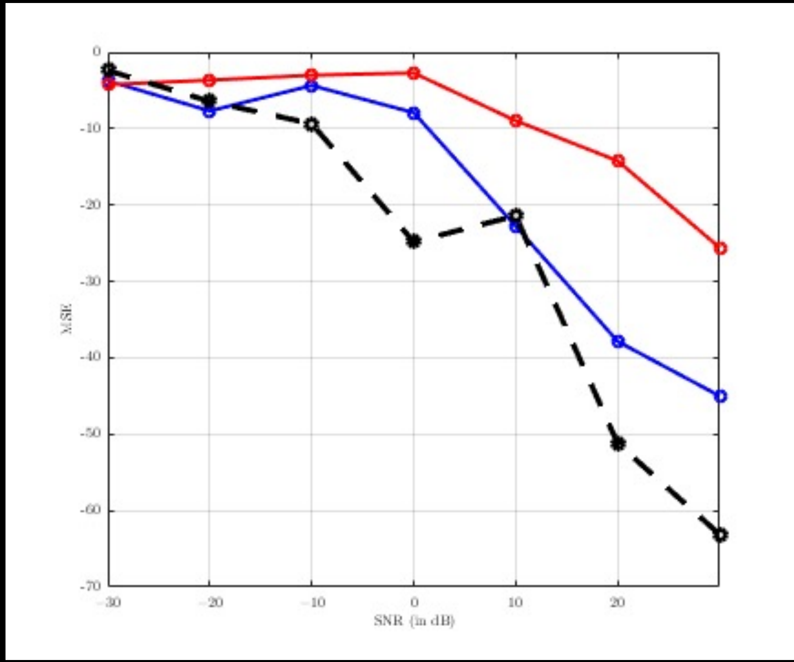
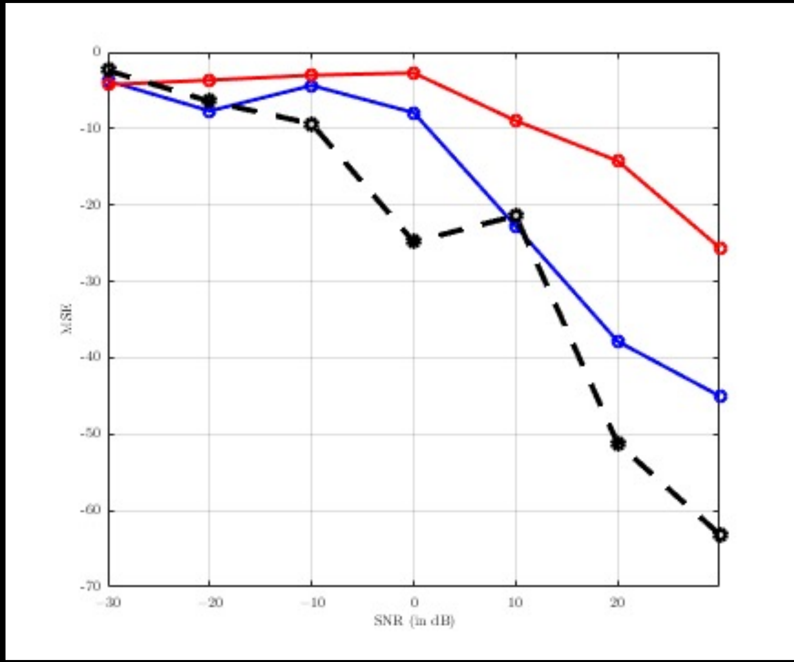


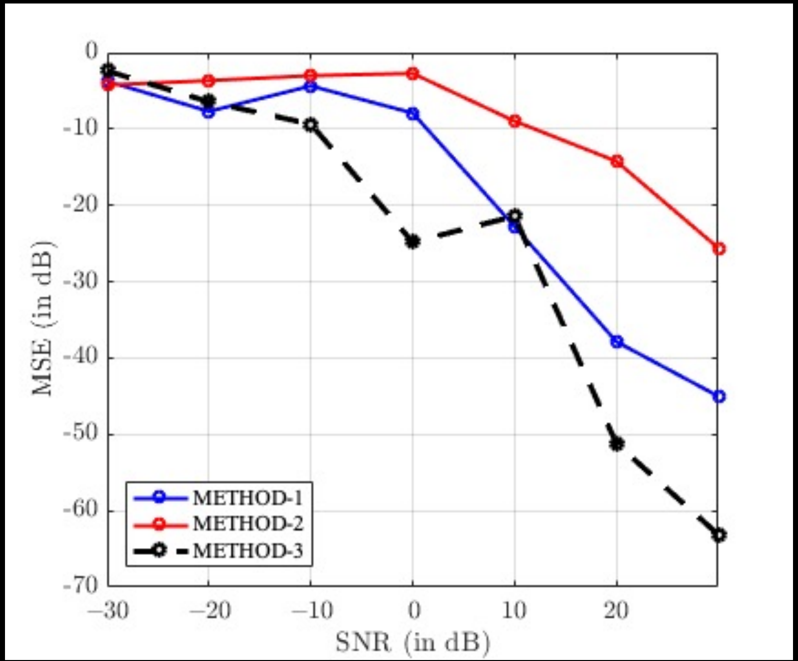
Fig. 26. Measured efficiency of the experimental prototype under different input voltage and load conditions. The dotted curves are corresponding quadratic best-fit curves.

Chakraborty and Chattopadhyay, "A Dual-Active-Bridge-Based Novel Single-Stage Low Device Count DC–AC Converter," *IEEE Trans. on Power Electron.*, 34 (3), Mar. 2019.



Comparing Method-1, Mehtod-2, and Method-3

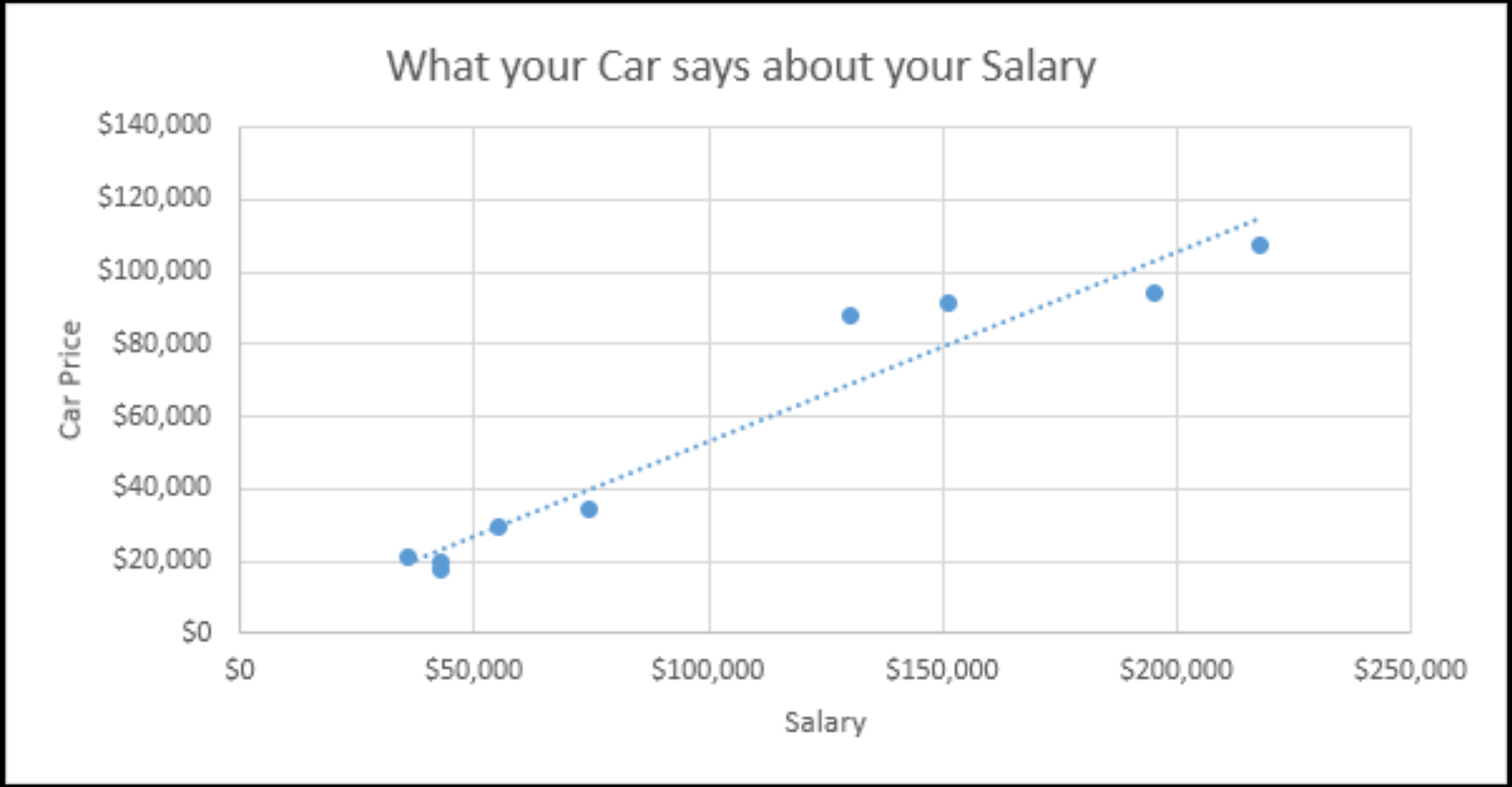




Comparing Method-1, Mehtod-2, and Method-3

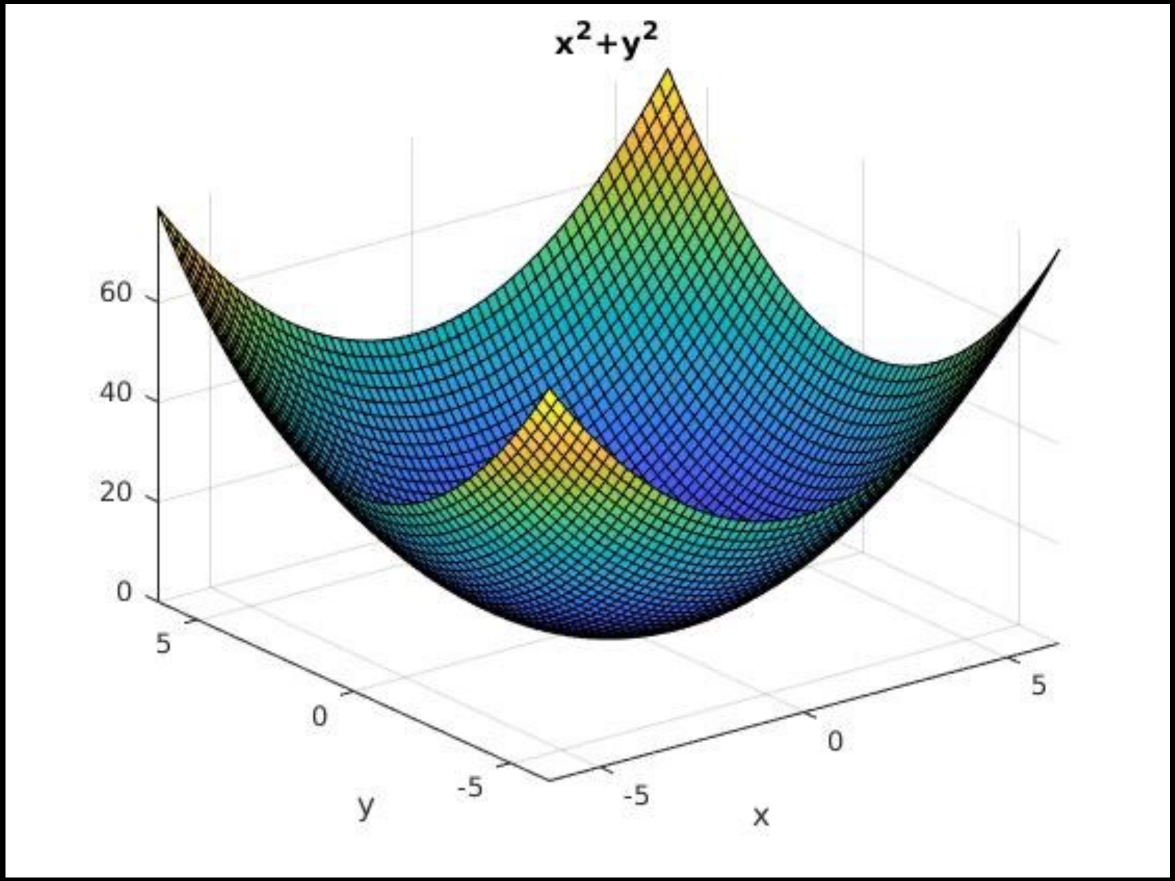
Scatter Plots

- Investigate an association between two variables

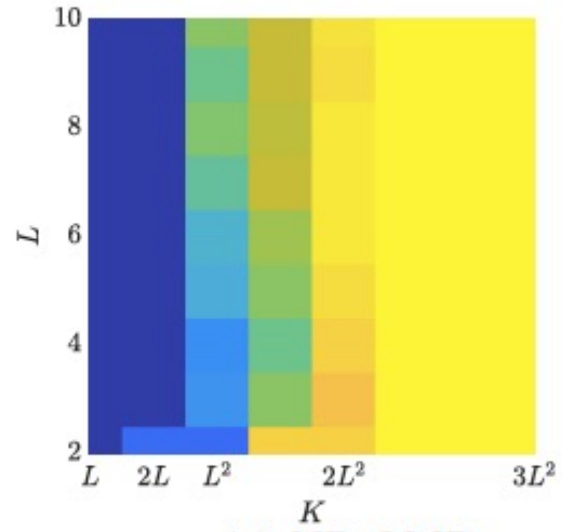


3D Plots

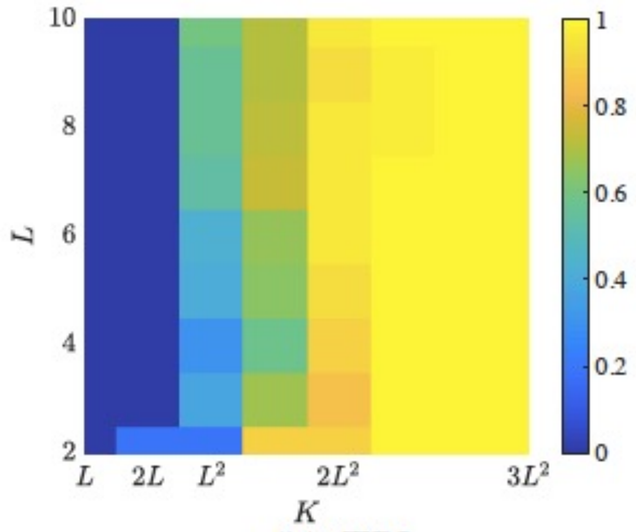
- Two continuous-valued independent variables



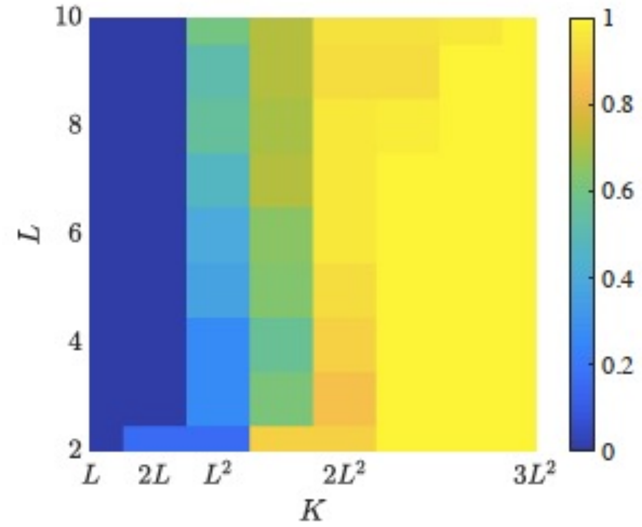
3D Plots



(a) NB-OMP

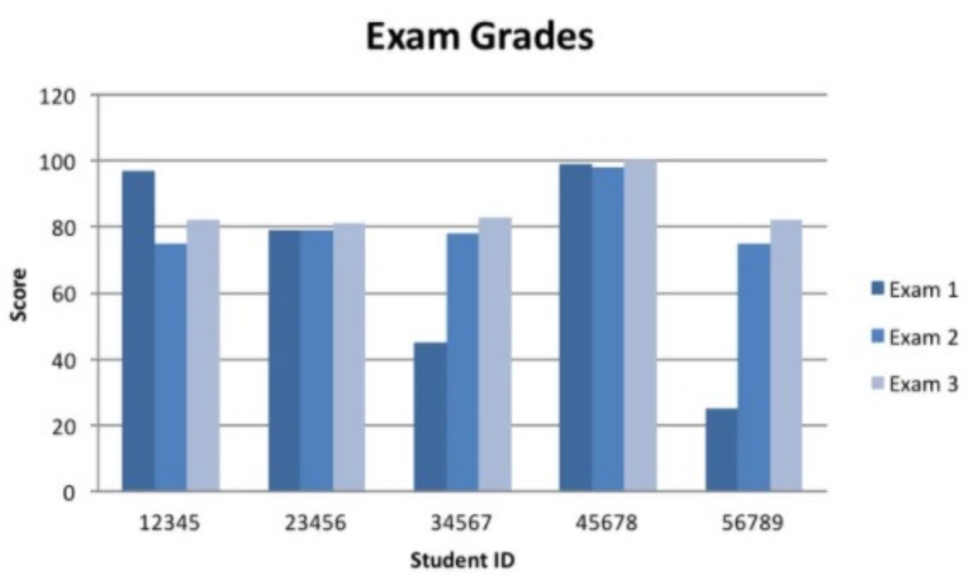


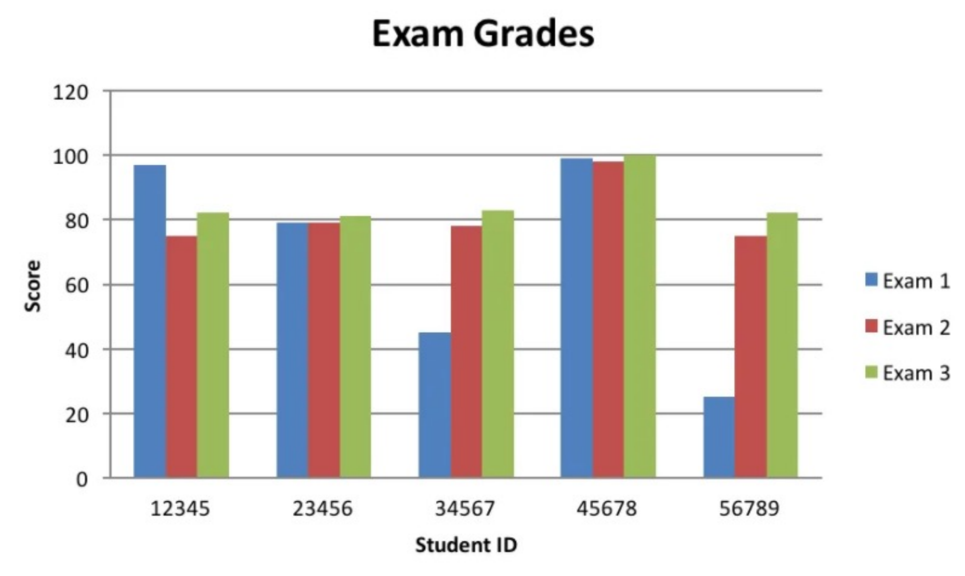
(b) TPI



(c) BDC

Use contrasting colors





Be consistent with the colors

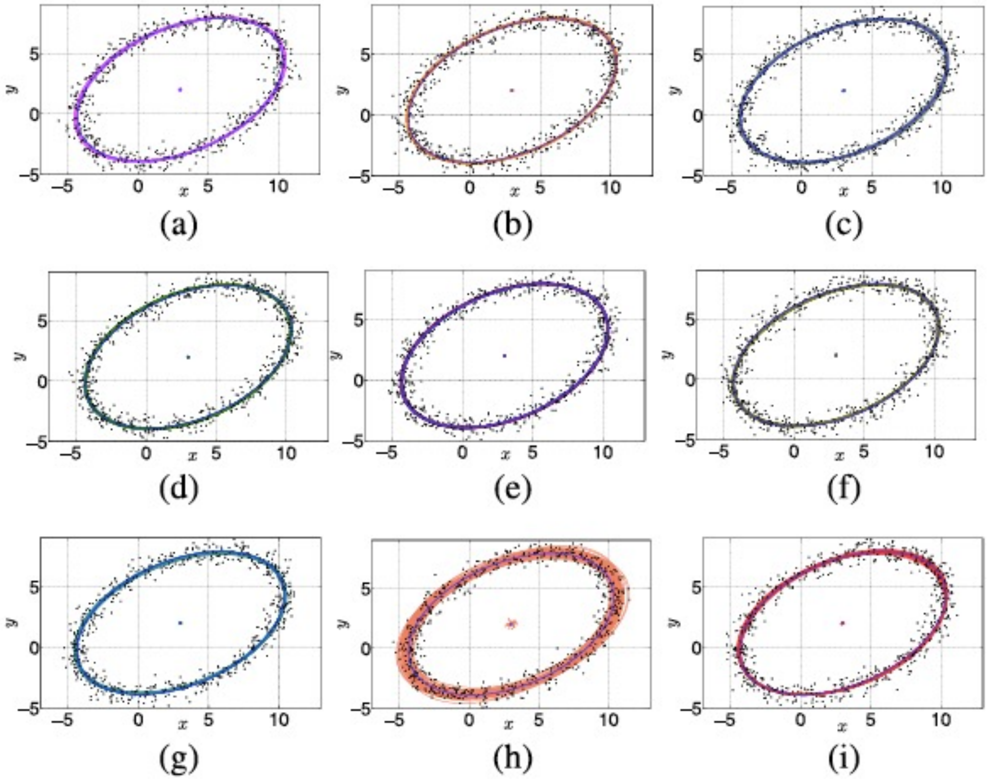


Fig. 3. A visual comparison of ellipse fitting methods; $N = 629$ uniform samples with $T = 0.01$. The ground-truth ellipse (in blue) parameters are $x_0 = 3$, $y_0 = 2$, $a = 8$, $b = 5$, and $\theta = 30^o$. The data is corrupted by AWGN with $\sigma = 0.5$. A noisy realization (in black) and 50 estimated ellipses are shown. We observe that all the methods give estimates close to the ground truth. (a) Bookstein. (b) Gander. (c) Taubin. (d) Fitzgibbon. (e) Halíř. (f) Szpak. (g) Dilip. (h) Hough. (i) EFFRIP.

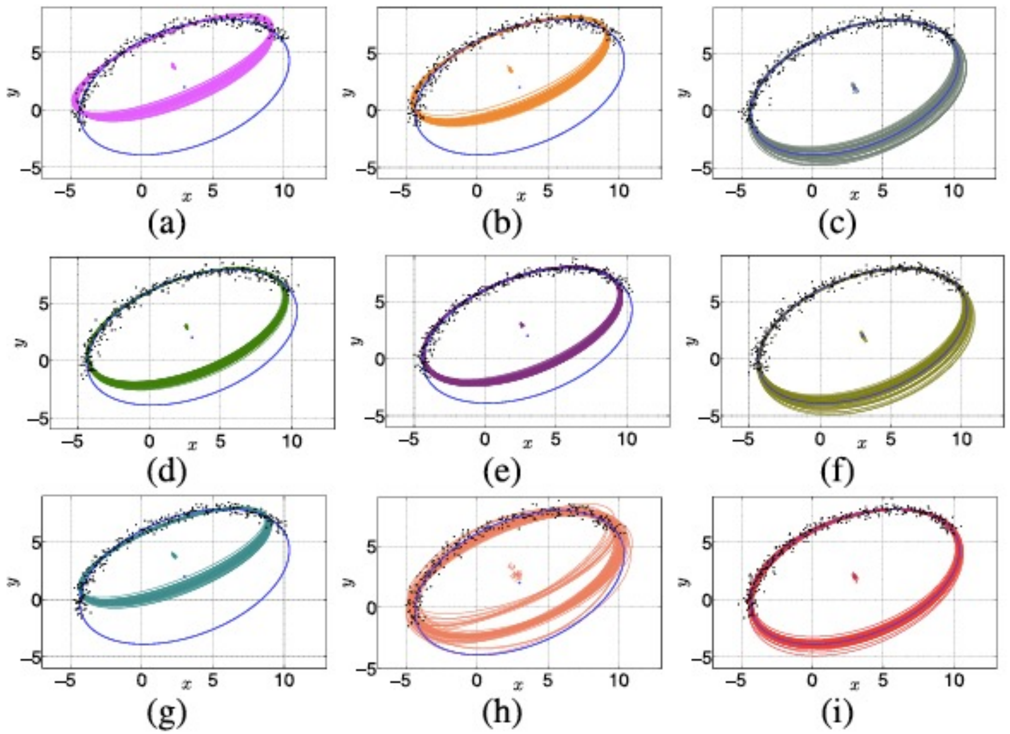


Fig. 5. A visual comparison of ellipse fitting methods from $N = 300$ uniform samples with $T = 0.01$ in the presence of noise ($\sigma = 0.3$). The ground-truth ellipse parameters are $x_0 = 3$, $y_0 = 2$, $a = 8$, $b = 5$, and $\theta = 30^o$ it is shown in blue. A noisy realization (in black) and 50 estimated ellipses are shown. Taubin's, Szpak's and EFFRIP methods estimate ellipses closer to the ground-truth ellipse. (a) Bookstein. (b) Gander. (c) Taubin. (d) Fitzgibbon. (e) Halíř. (f) Szpak. (g) Dilip. (h) Hough. (i) EFFRIP.

Be consistent with the colors

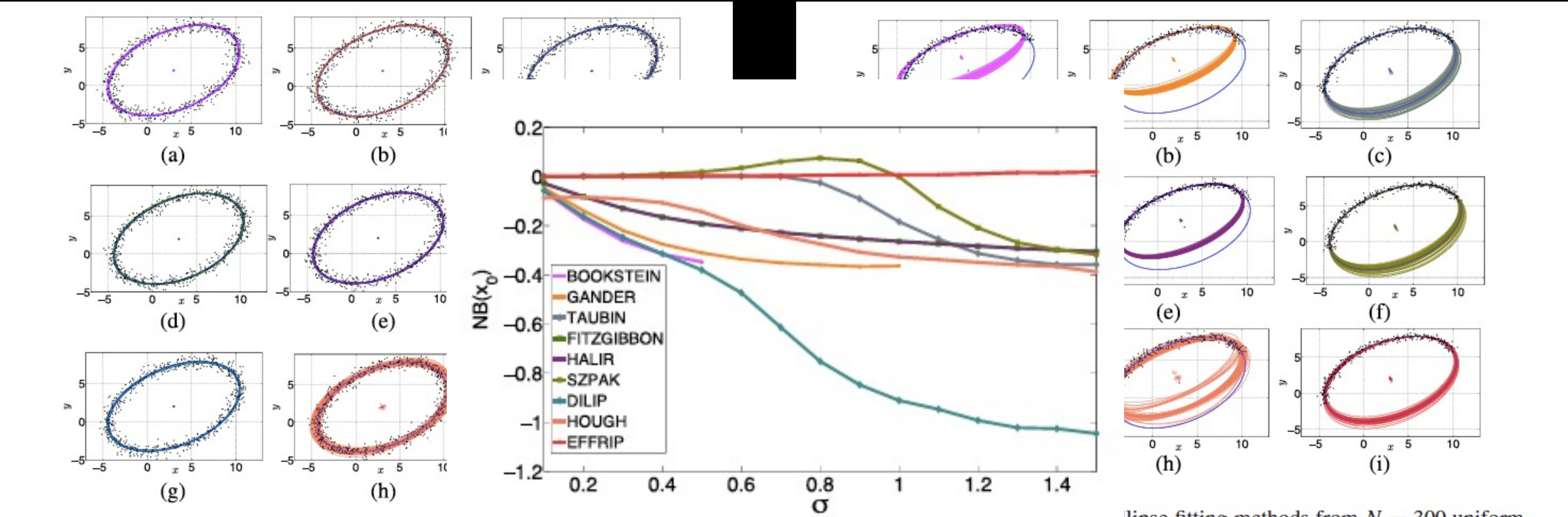


Fig. 3. A visual comparison of ellipse fitting methods; $N = 629$ uniform samples with $T = 0.01$. The ground-truth ellipse (in blue) parameters are $x_0 = 3$, $y_0 = 2$, $a = 8$, $b = 5$, and $\theta = 30^o$. The data is corrupted by AWGN with $\sigma = 0.5$. A noisy realization (in black) and 50 estimated ellipses are shown. We observe that all the methods give estimates close to the ground truth. (a) Bookstein. (b) Gander. (c) Taubin. (d) Fitzgibbon. (e) Halíř. (f) Szpak. (g) Dilip. (h) Hough. (i) EFFRIP.

llipse fitting methods from $N = 300$ uniform samples with $T = 0.01$ in the presence of noise ($\sigma = 0.3$). The ground-truth ellipse parameters are $x_0 = 3$, $y_0 = 2$, $a = 8$, $b = 5$, and $\theta = 30^o$ it is shown in blue. A noisy realization (in black) and 50 estimated ellipses are shown. Taubin's, Szpak's and EFFRIP methods estimate ellipses closer to the ground-truth ellipse. (a) Bookstein. (b) Gander. (c) Taubin. (d) Fitzgibbon. (e) Halíř. (f) Szpak. (g) Dilip. (h) Hough. (i) EFFRIP.


object to mirror
irror_mod.mirror_object
peration == "MIRROR_X":
irror_mod.use_x = True
irror_mod.use_y = False
irror_mod.use_z = False
operation == "MIRROR_Y":
irror_mod.use_x = False
irror_mod.use_y = True
irror_mod.use_z = False
operation == "MIRROR_Z":
irror_mod.use_x = False
irror_mod.use_y = False
irror_mod.use_z = True
election at the end -add
_ob.select= 1
er_ob.select=1
ntext.scene.objects.acti
("Selected" + str(modifie
irror_ob.select = 0
bpy.context.selected_ob
ata.objects[one.name].se
int("please select exactl
OPERATOR CLASSES
types.Operator):
X mirror to the selected
ject.mirror_mirror_x"
rror X"

Algorithms

- An algorithm is a *set of steps* to solve a problem
- Independent of programming or coding language

We are NOT discussing about algorithms used in CS courses

- An algorithm is a *set of steps* to solve a problem

$$\min_{x \in S} f(x)$$

- An algorithm is a *set of steps* to solve a problem

$$\min_{x \in S} f(x)$$

At k-th iteration:

$$x_k = x_{k-1} - \alpha \nabla f_{k-1}(x)$$
$$x_k = S(x_k)$$

- An algorithm is a *set of steps* to solve a problem

$$\min_{x \in S} f(x)$$

1. Output:
2. Input:
3. Initialization
4. Steps
When to stop

At k-th iteration:

$$x_k = x_{k-1} - \alpha \nabla f_{k-1}(x)$$
$$x_k = S(x_k)$$

- An algorithm is a *set of steps* to solve a problem

$$\min_{x \in S} f(x)$$

1. Output:
2. Input:
3. Initialization
4. Steps
When to stop

1. Output: optimum solution
2. Input: Gradient function
3. Initialization: x_0
4. Steps: A. B.
When to stop

At k-th iteration:

$$x_k = x_{k-1} - \alpha \nabla f_{k-1}(x)$$
$$x_k = S(x_k)$$

- An algorithm is a *set of steps* to solve a problem

Algorithm 1 BDC for solving (15).

Output: $\mathbf{s}$ and $\mathbf{X}$

Input: $\mathbf{Y}$, $\bar{\mathbf{A}}$ L, and the initial estimate $\mathbf{s}^{(0)}$

1: Let $i \leftarrow 1$
2: **repeat**
3: Estimate $\mathbf{X}^{(i)}$ by applying OMP to $\mathrm{diag}(\mathbf{s}^{(i-1)})^{-1}\mathbf{Y}$ columnwise
4: $\mathbf{s}^{(i)} \leftarrow \mathrm{argmin}_{\mathbf{s}} \|\mathbf{Y} - \mathrm{diag}(\mathbf{s})\bar{\mathbf{A}}\mathbf{X}^{(i)}\|_2^2$
5: $i \leftarrow i + 1$
6: **until** convergence criterion is reached

- Should be self contained

Algorithm 2 Joint Subsampling and Recovery Algorithm

Inputs: Data $\mathcal{D}$ and full sample indices $\mathcal{N}$

Initialize: $\mathcal{K}^{(0)} = \emptyset$

for $k = 1$ to K **do**

[S1] **for all** $i \in \mathcal{N} \backslash \mathcal{K}^{(k-1)}$ **do**

(a) For a binary-valued vector $\mathbf{c}_i \in \{0,1\}^{|\mathcal{N}|}$, set $\mathrm{supp}\{\mathbf{c}_i\} = \mathcal{K}^{(k-1)} \cup \{i\}$

(b) $\boldsymbol{\theta}_i^{(k)} = \arg\min_{\boldsymbol{\theta}} \frac{1}{Q} \sum_{q=1}^{Q} \|\mathbf{x}_q - r_{\boldsymbol{\theta}}\left(\mathrm{diag}(\mathbf{c}_i)\mathbf{f}_q\right)\|_2^2$ where $r_{\boldsymbol{\theta}}$ is a LISTA-based reconstruction.

(c) $\mathbf{x}_{q,i} = r_{\boldsymbol{\theta}_i^{(k)}}\left(\mathrm{diag}(\mathbf{c}_i)\mathbf{f}_q\right)$ for $q = 1, \cdots, Q$

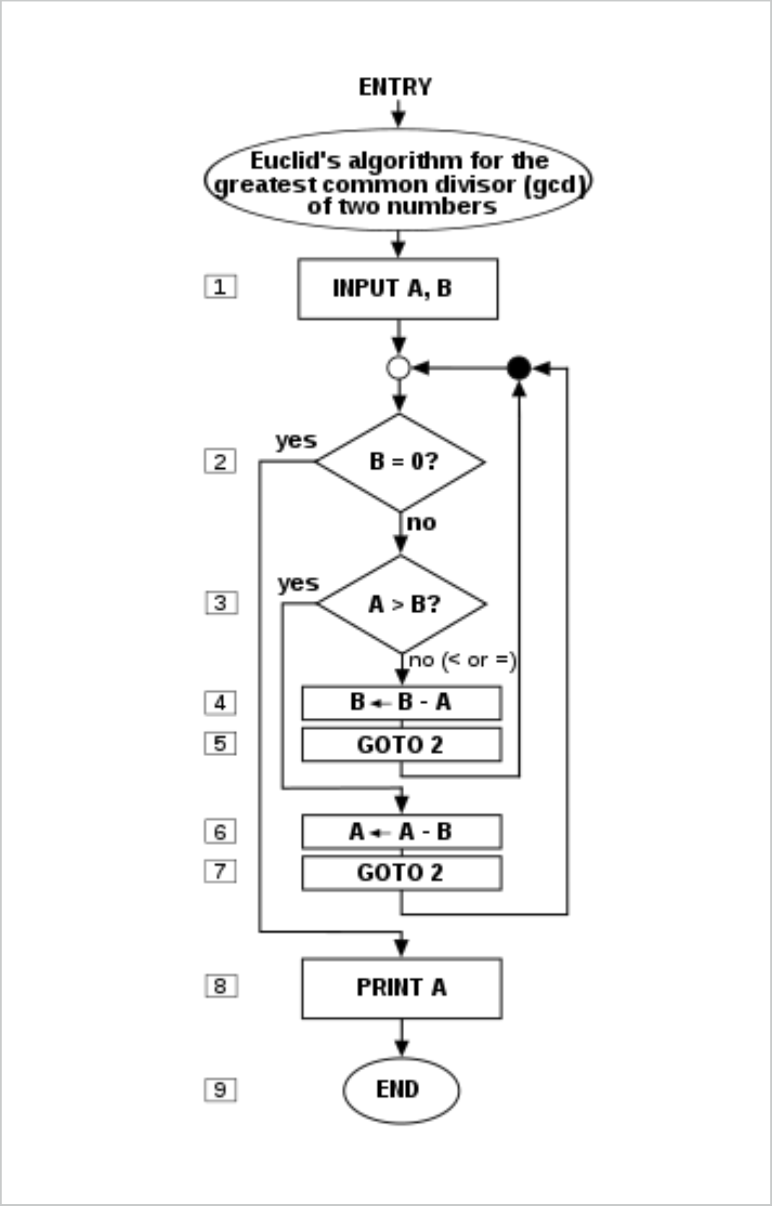
end for

[S2] $i_*^{(k)} = \underset{i \in \mathcal{N} \backslash \mathcal{K}^{(k-1)}}{\arg\min} \quad \frac{1}{Q} \sum_{q=1}^{Q} \|\mathbf{x}_q - \mathbf{x}_{q,\mathcal{K}\backslash\{i\}}\|_2^2$

[S3] $\mathcal{K}^{(k)} = \mathcal{K}^{(k-1)} \cup \{i_*^{(k)}\}$

end for

Output: Optimal sampling set $\mathcal{K}^K \subseteq \mathcal{N}$ with $|\mathcal{K}^K| = K$ and corresponding reconstruction parameters $\boldsymbol{\theta}_{i_*^{(k)}}$



- Flowcharts are alternative representations

Dos and Don'ts

- Don’t copy paste figures (block diagrams and results) from any other paper
- In a technical presentation you can use graphics from other sources with proper citation
- Technical writing: Visual communication is not a replacement of text
- Technical presentation: Advisable to use visuals instead of text