PROGRAMMING WITH R
ANALYTICAL QUESTIONS
EXPLORATORY DATA ANALYSIS
DATA REPRESENTATION
VECTORS
DATA FRAMES
LOAD DATA
TIDY DATA
STRINGS
TRANSFORM DATA
UNSTRUCTURED DATA
MACHINE LEARNING
VISUALIZE DATA
COMMUNICATE DATA

PROGRAMMING WITH R

variables

control structures

loops

functions

libraries

ANALYTICAL QUESTIONS

BACK

did you summarize the data?

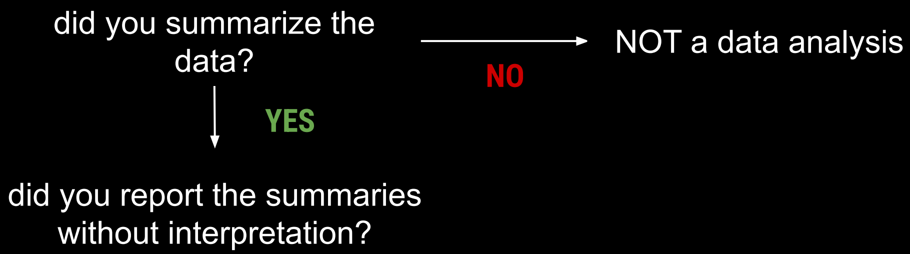
Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.

did you summarize the data?

NO

NOT a data analysis

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

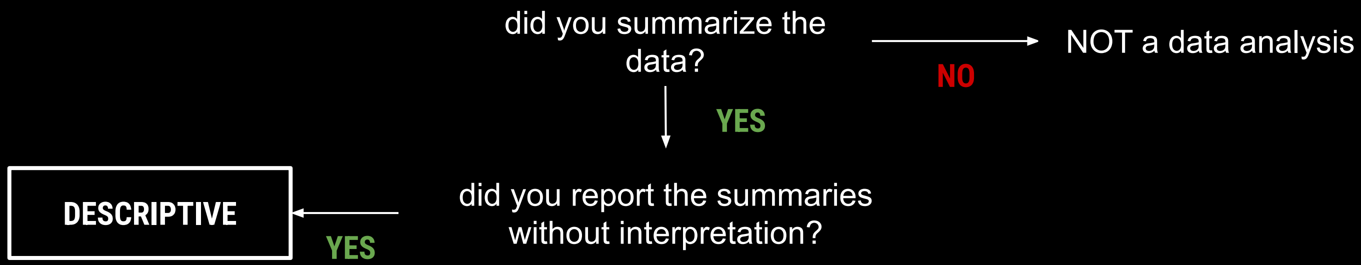
NO

NOT a data analysis

YES

did you report the summaries without interpretation?

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

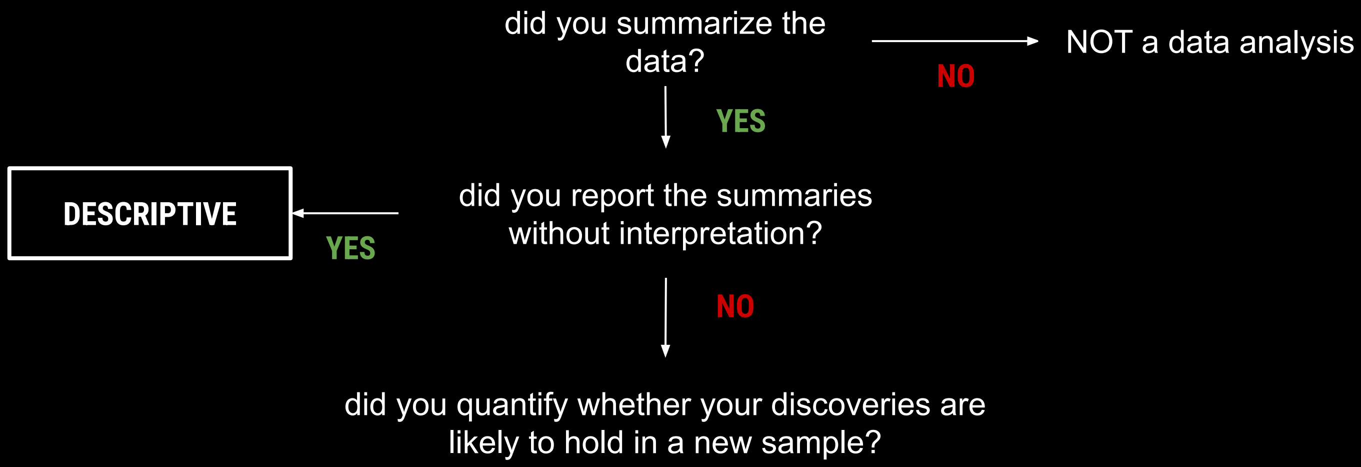
YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

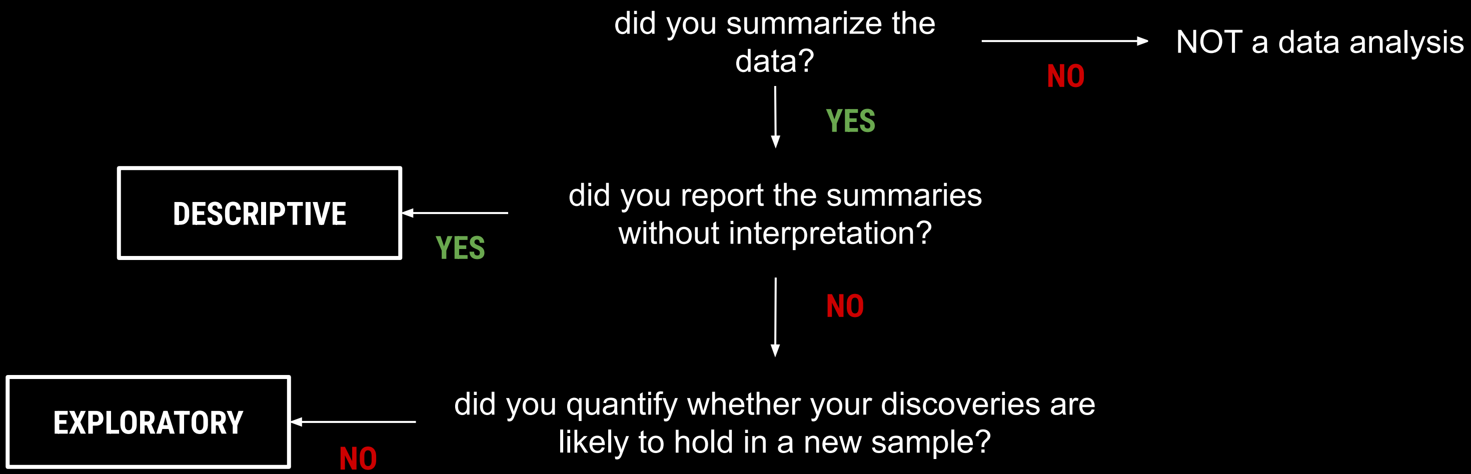
YES

DESCRIPTIVE

NO

did you quantify whether your discoveries are likely to hold in a new sample?

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

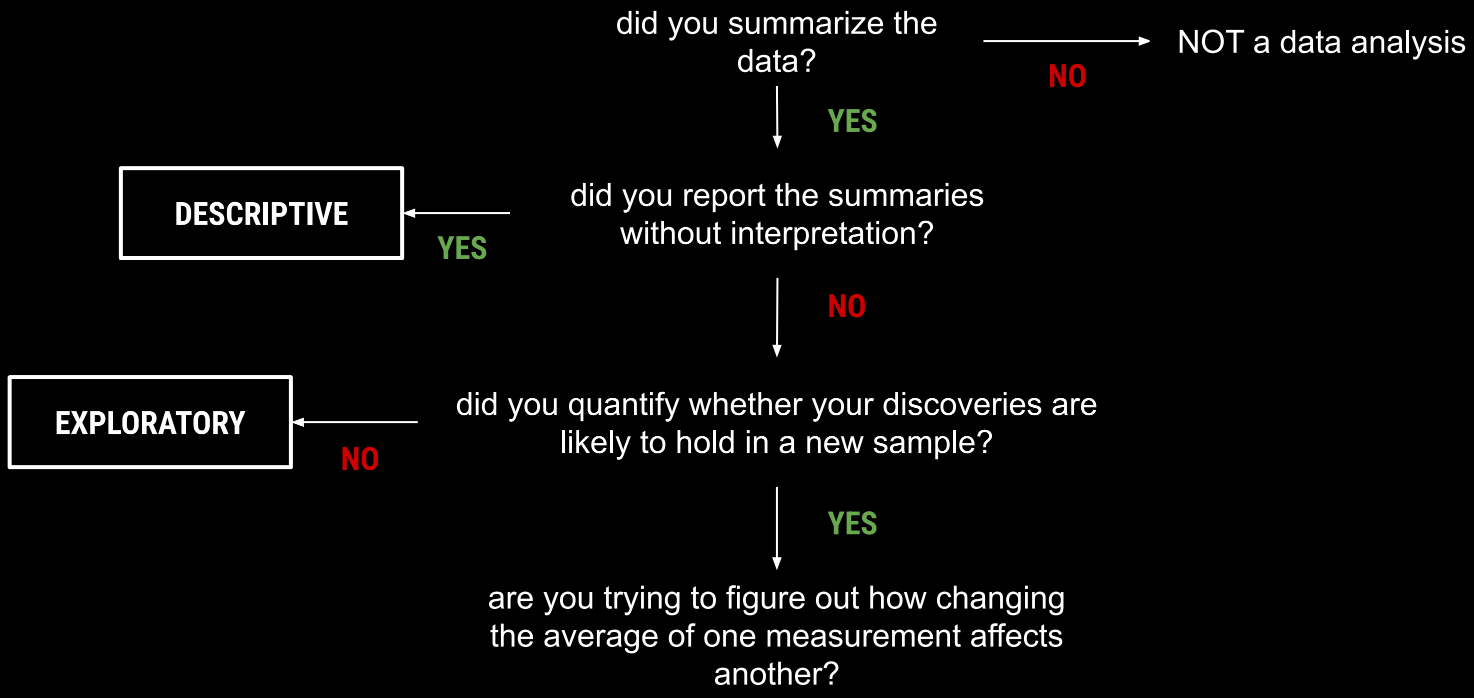
NO

did you quantify whether your discoveries are likely to hold in a new sample?

NO

EXPLORATORY

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

NO

did you quantify whether your discoveries are likely to hold in a new sample?

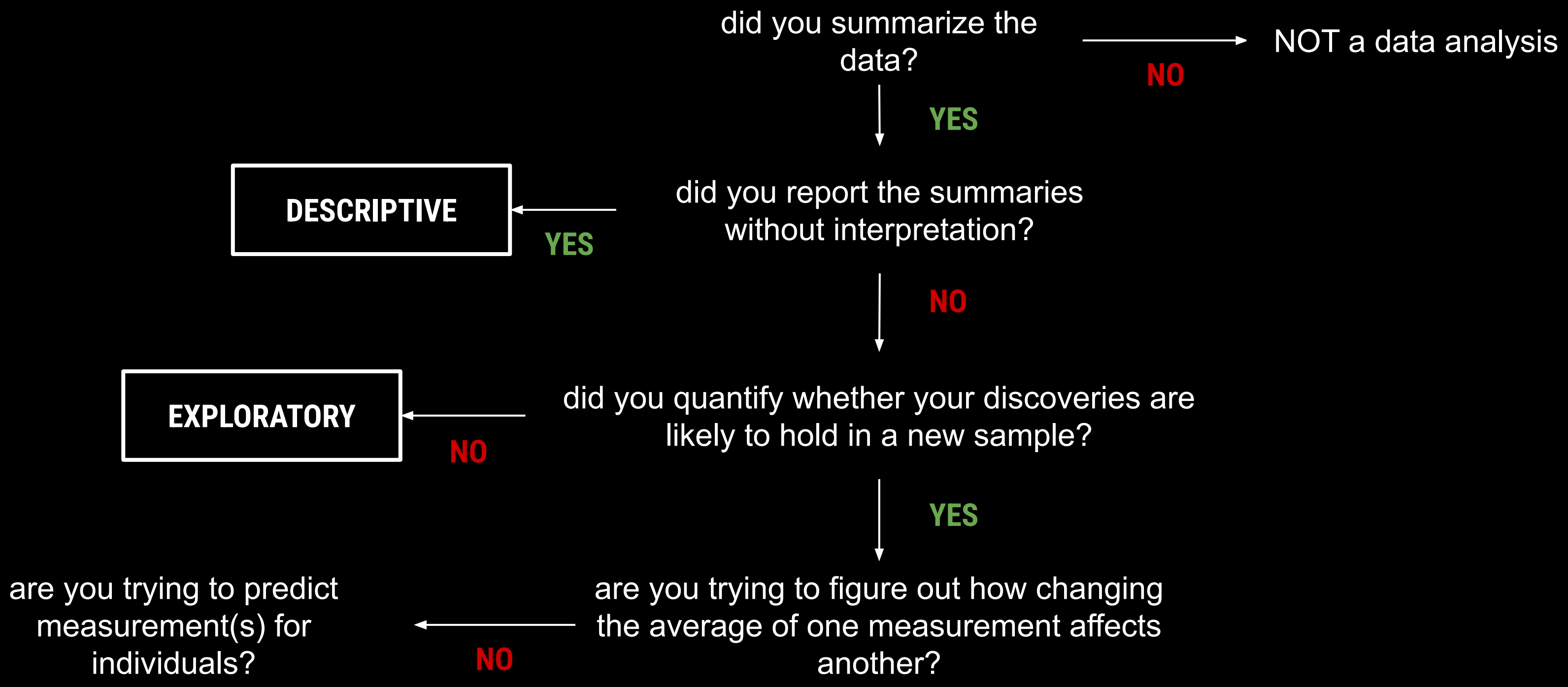
NO

EXPLORATORY

YES

are you trying to figure out how changing the average of one measurement affects another?

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

NO

did you quantify whether your discoveries are likely to hold in a new sample?

NO

EXPLORATORY

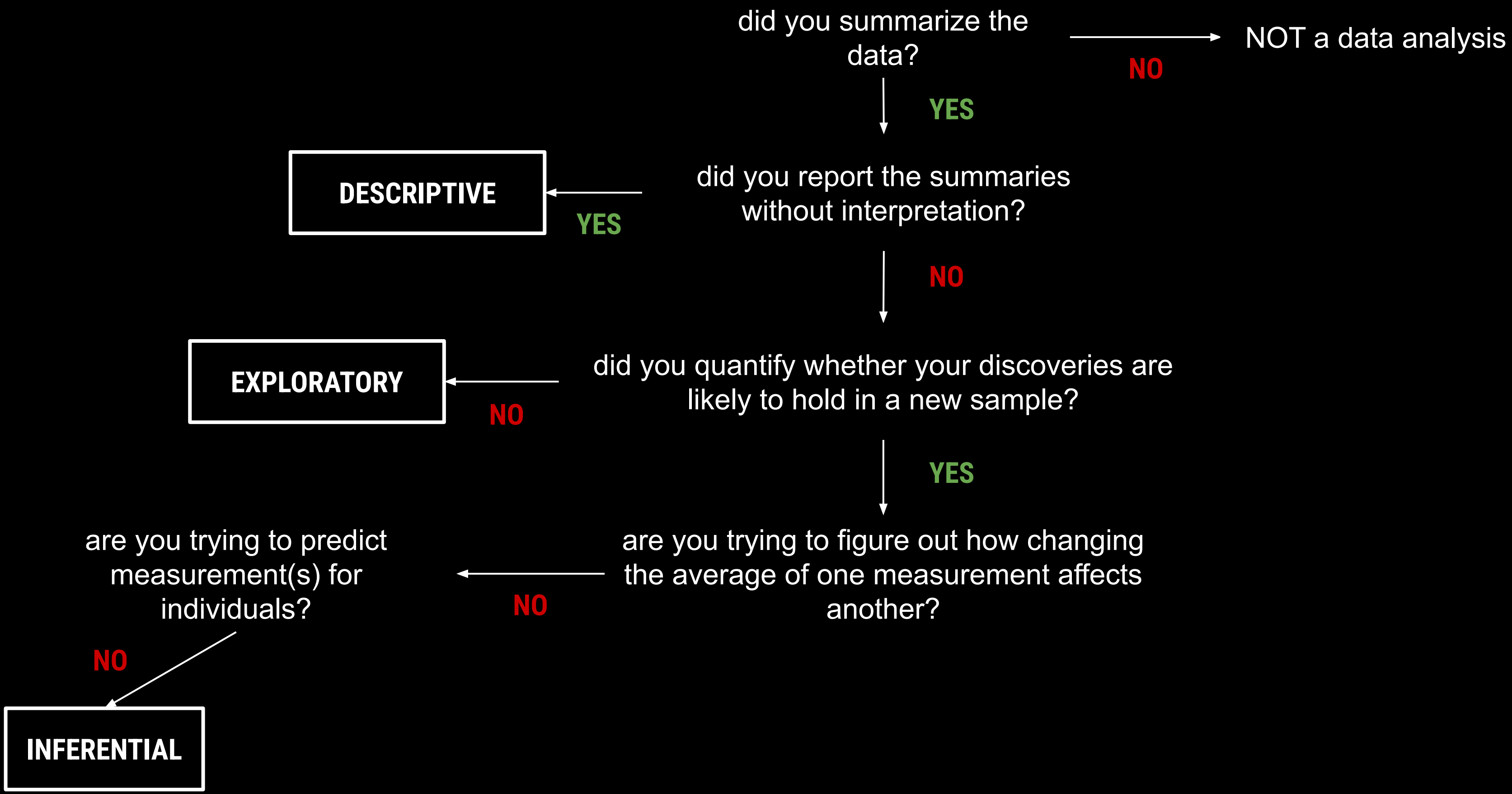
YES

are you trying to figure out how changing the average of one measurement affects another?

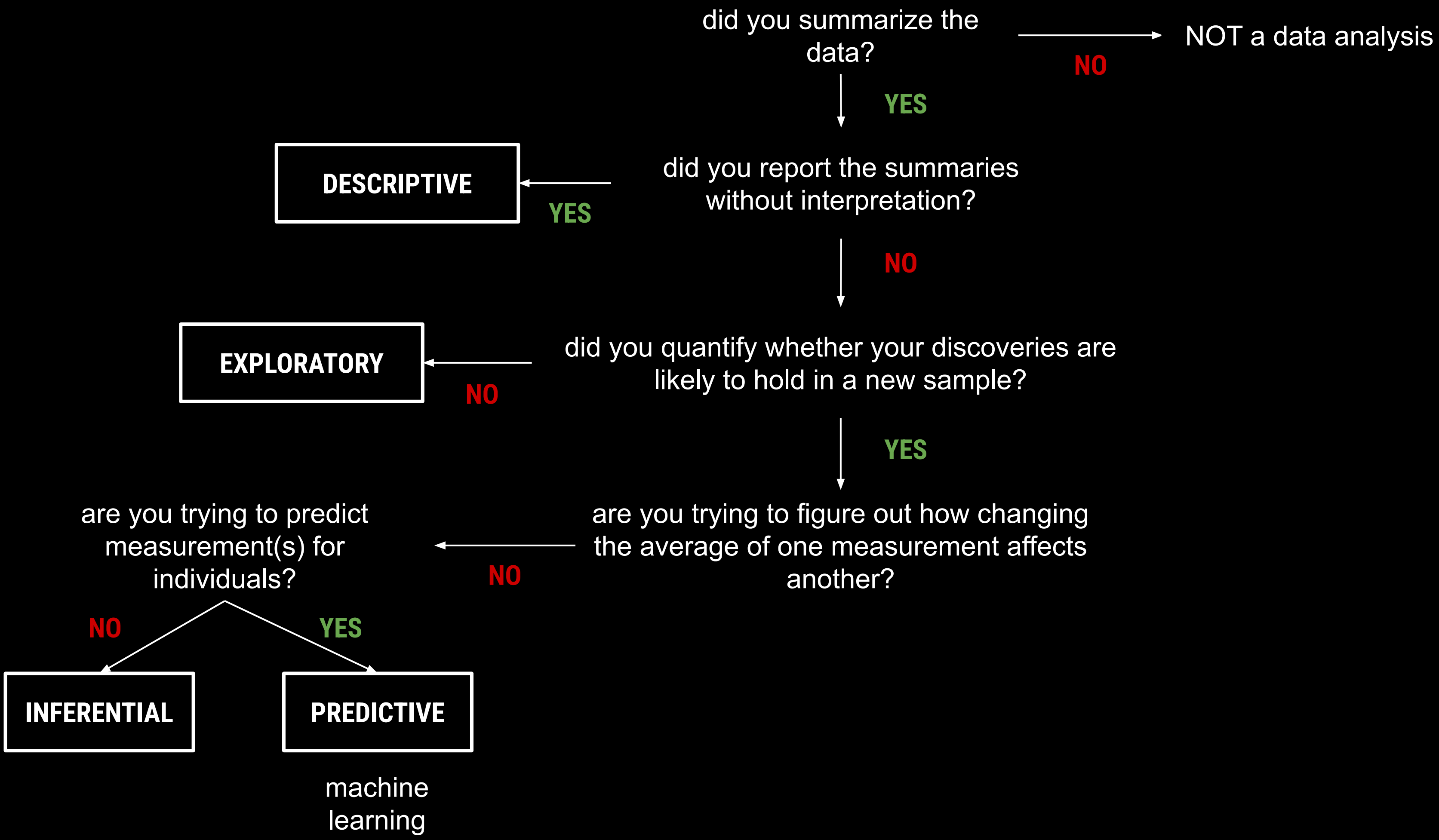
NO

are you trying to predict measurement(s) for individuals?

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.


did you summarize the data?
NO
NOT a data analysis
YES
did you report the summaries without interpretation?
YES
DESCRIPTIVE
NO
did you quantify whether your discoveries are likely to hold in a new sample?
NO
EXPLORATORY
YES
are you trying to figure out how changing the average of one measurement affects another?
NO
are you trying to predict measurement(s) for individuals?
NO
INFERENTIAL

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO → NOT a data analysis

YES ↓

did you report the summaries without interpretation?

YES → DESCRIPTIVE

NO ↓

did you quantify whether your discoveries are likely to hold in a new sample?

NO → EXPLORATORY

YES ↓

are you trying to figure out how changing the average of one measurement affects another?

NO ↓

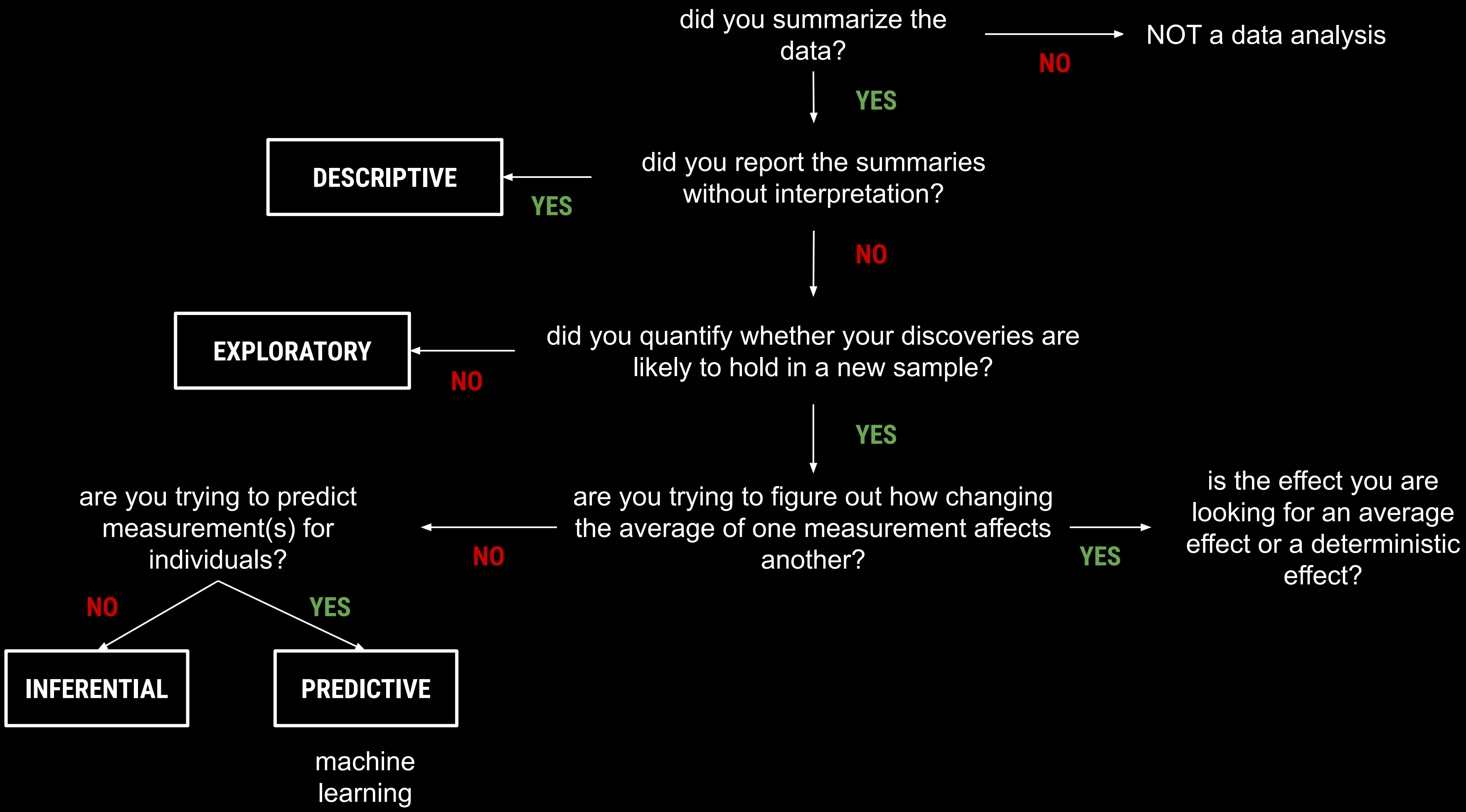
are you trying to predict measurement(s) for individuals?

NO → INFERENTIAL

YES → PREDICTIVE

machine learning

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

NO

did you quantify whether your discoveries are likely to hold in a new sample?

NO

EXPLORATORY

YES

are you trying to figure out how changing the average of one measurement affects another?

YES

is the effect you are looking for an average effect or a deterministic effect?

NO

are you trying to predict measurement(s) for individuals?

NO

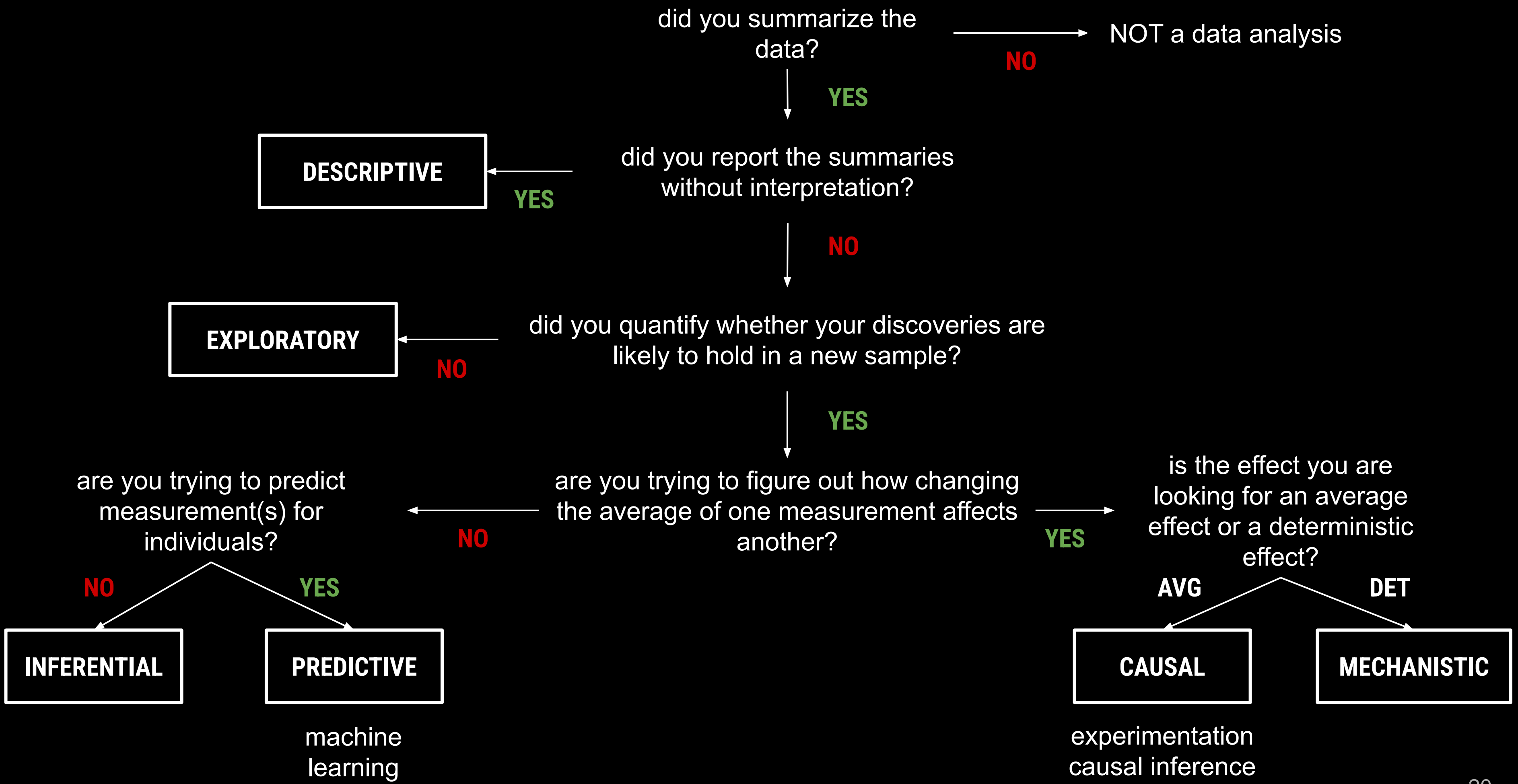
INFERENTIAL

YES

PREDICTIVE

machine learning

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



did you summarize the data?

NO

NOT a data analysis

YES

did you report the summaries without interpretation?

YES

DESCRIPTIVE

NO

did you quantify whether your discoveries are likely to hold in a new sample?

NO

EXPLORATORY

YES

are you trying to figure out how changing the average of one measurement affects another?

NO

are you trying to predict measurement(s) for individuals?

NO

INFERENTIAL

YES

PREDICTIVE

machine learning

YES

is the effect you are looking for an average effect or a deterministic effect?

AVG

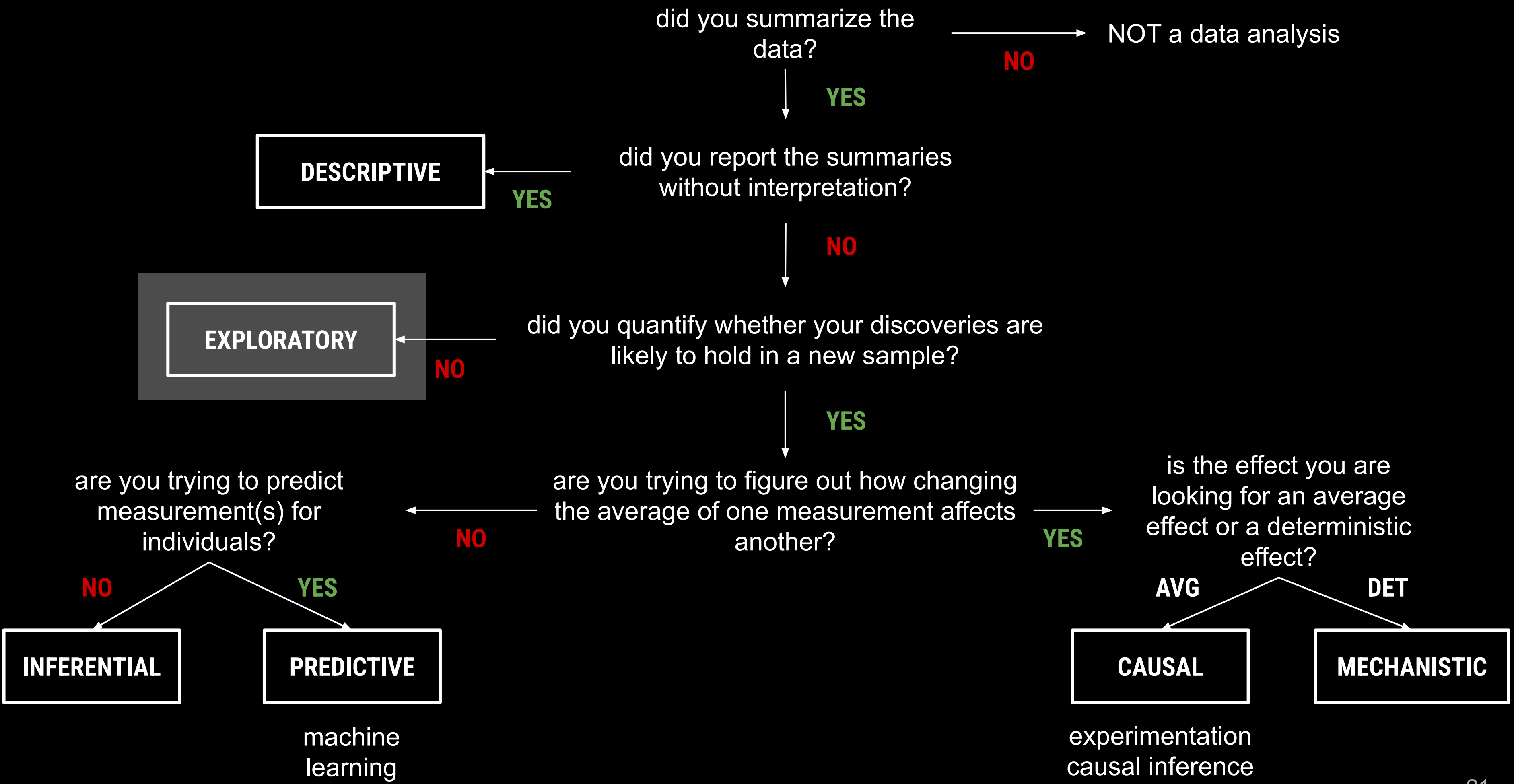
CAUSAL

experimentation causal inference

DET

MECHANISTIC

Source: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.



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NO

NOT a data analysis

YES

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EXPLORATORY

YES

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INFERENTIAL

YES

PREDICTIVE

machine learning

YES

is the effect you are looking for an average effect or a deterministic effect?

AVG

CAUSAL

experimentation causal inference

DET

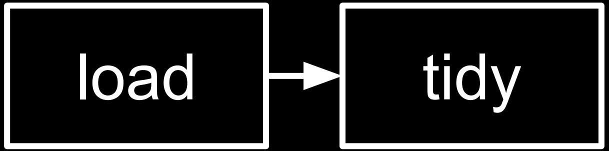
MECHANISTIC

Quelle: Jeffery T. Leek, Roger D. Peng: What is the question? Science 20.03.2015: 1314-1315.

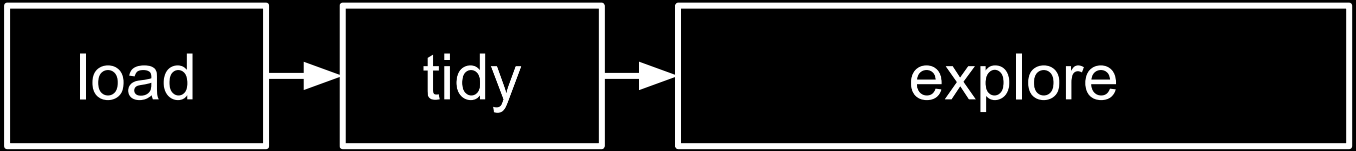
EXPLORATORY DATA ANALYSIS

load

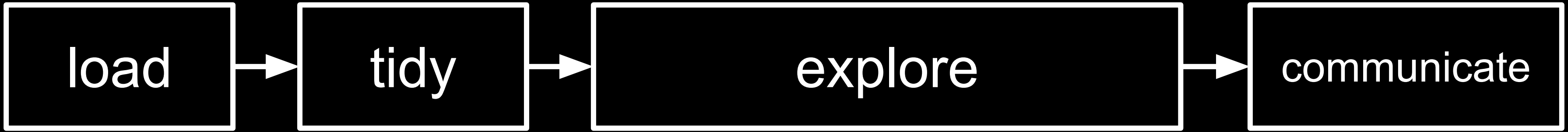
Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O’Reilly Media, Inc, 2023.



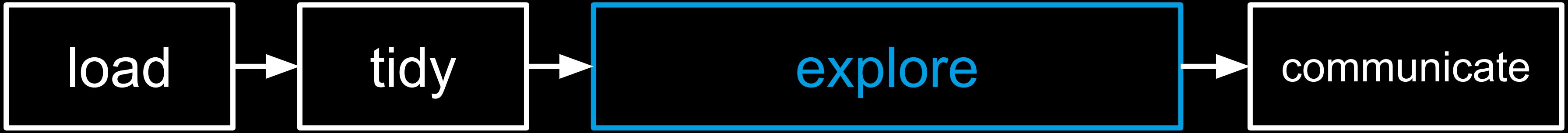
Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O'Reilly Media, Inc, 2023.



Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O’Reilly Media, Inc, 2023.



Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O’Reilly Media, Inc, 2023.



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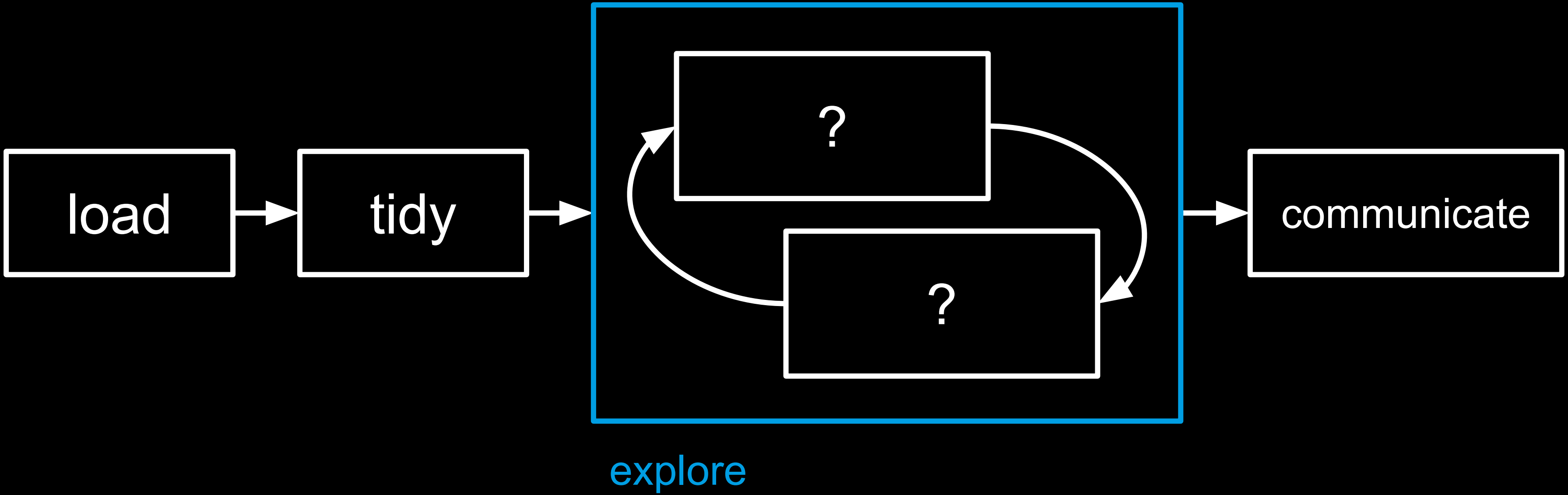

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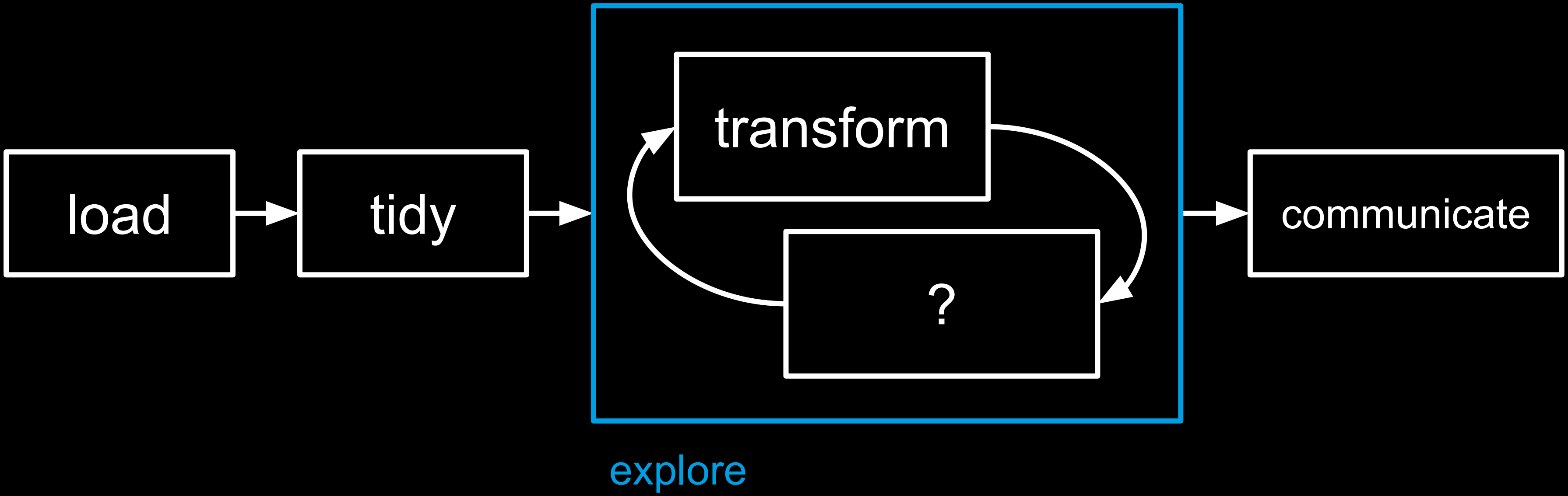

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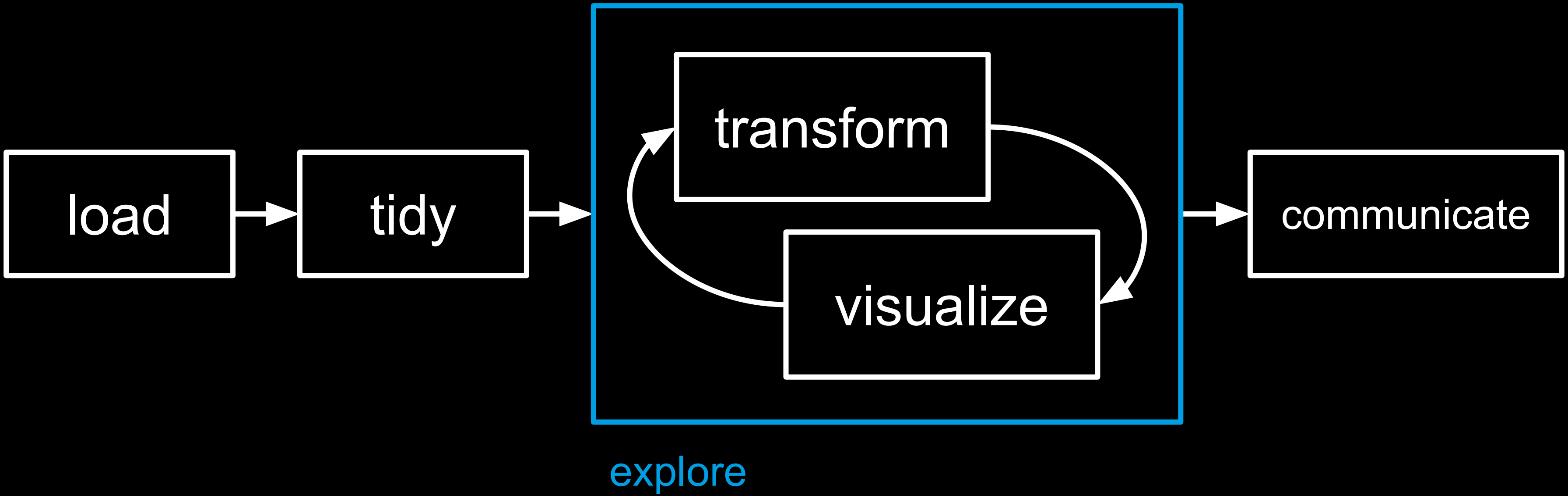
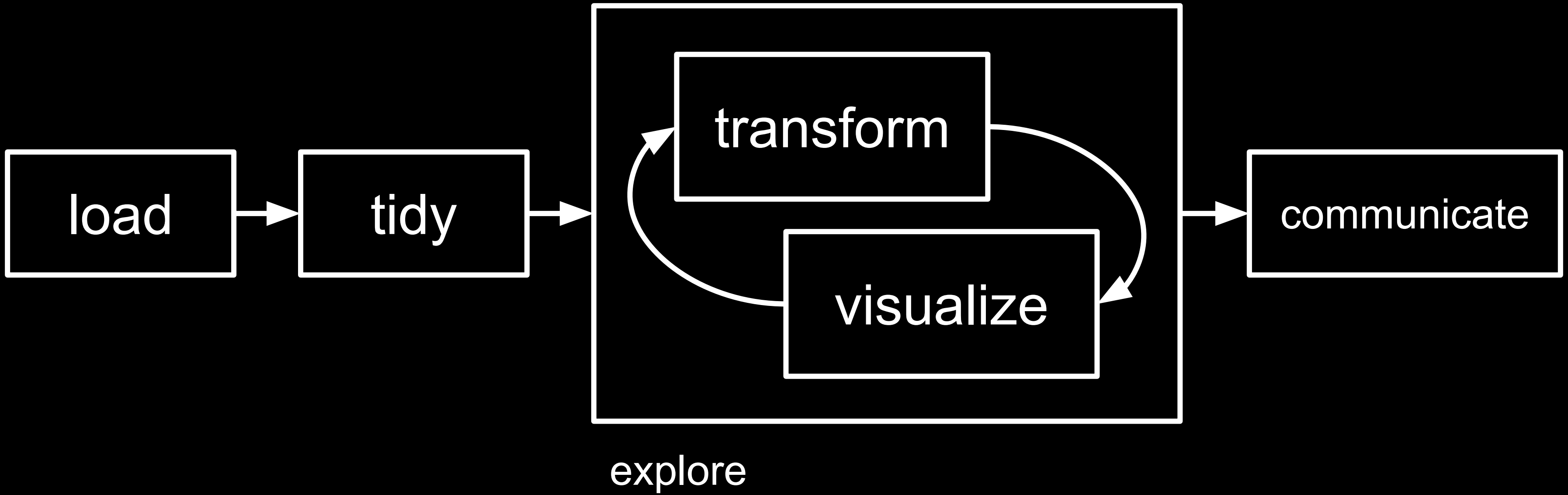


Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O'Reilly Media, Inc, 2023.



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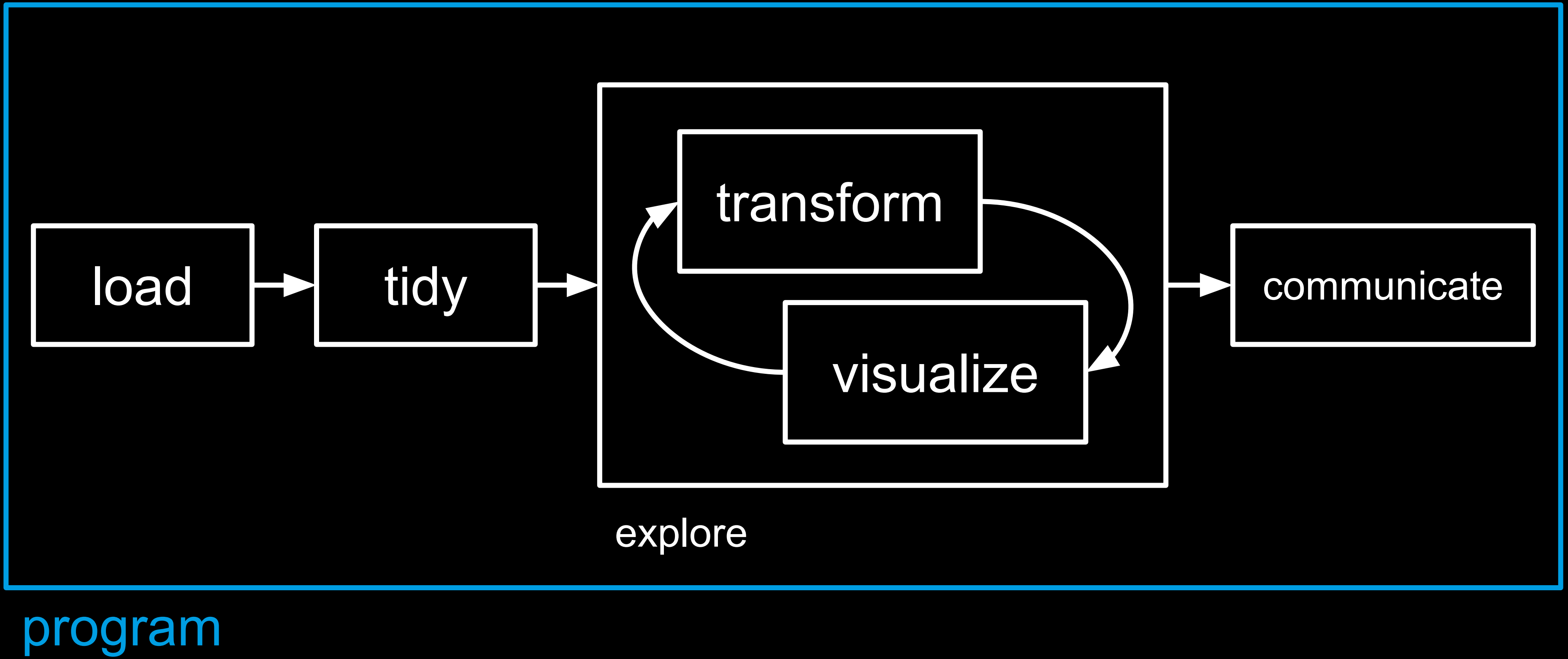
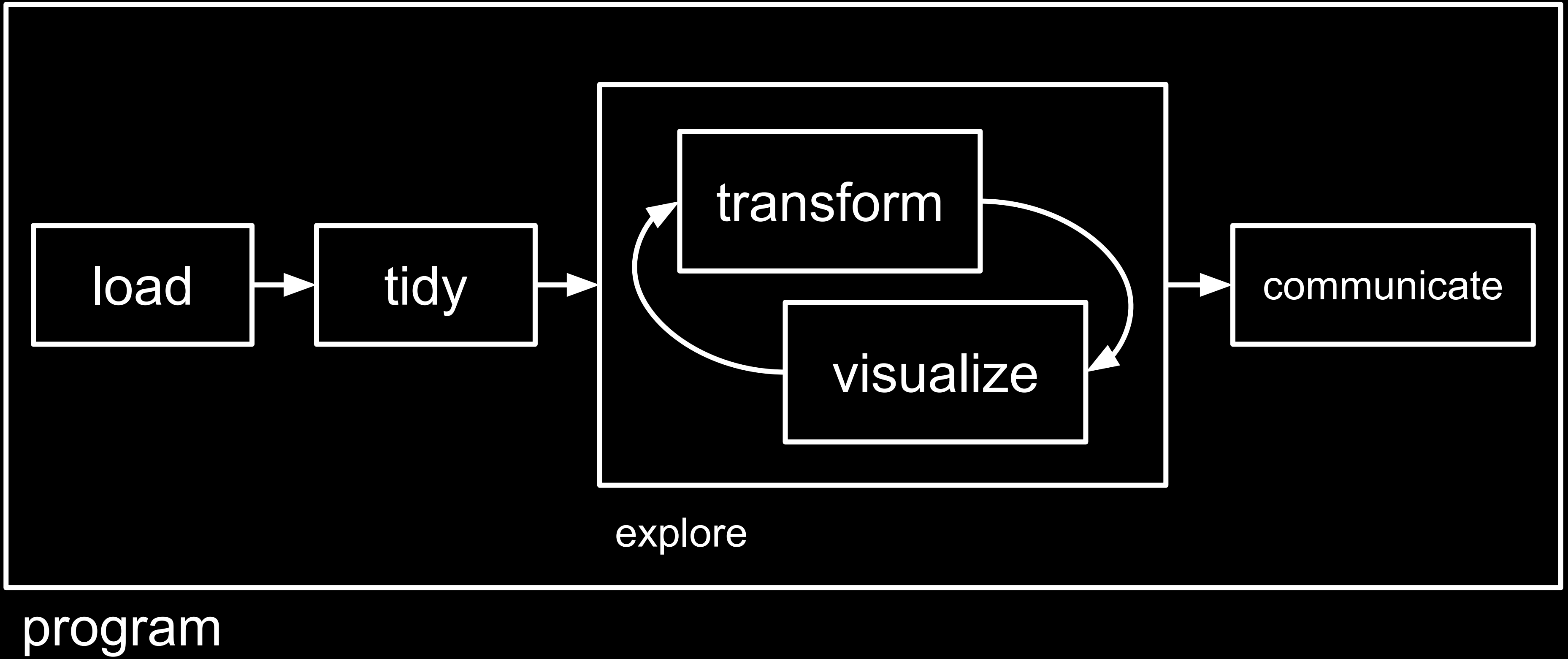


Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform,
Visualize, and Model Data. 2nd edition, O’Reilly Media, Inc, 2023.

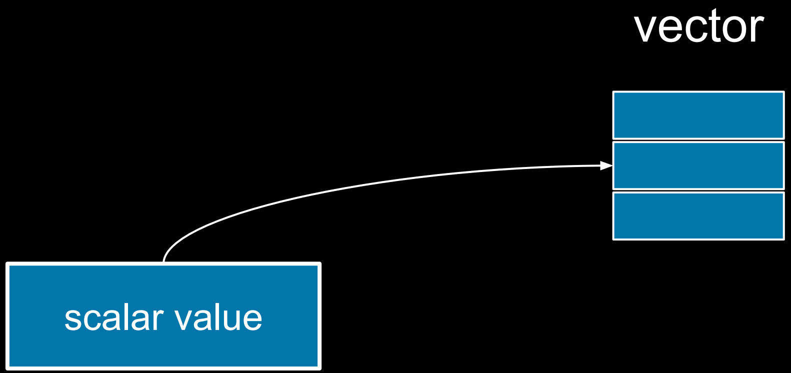


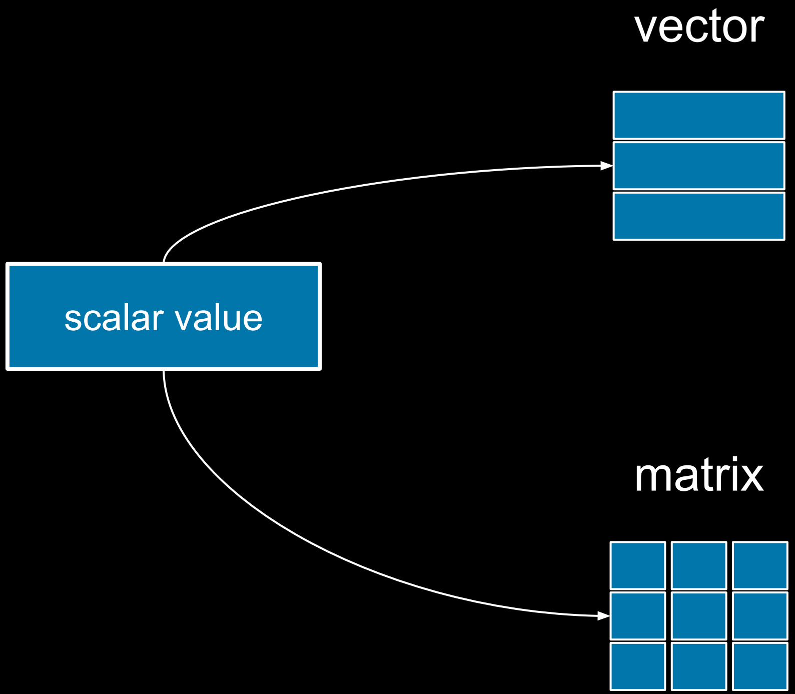
Following Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O'Reilly Media, Inc, 2023.

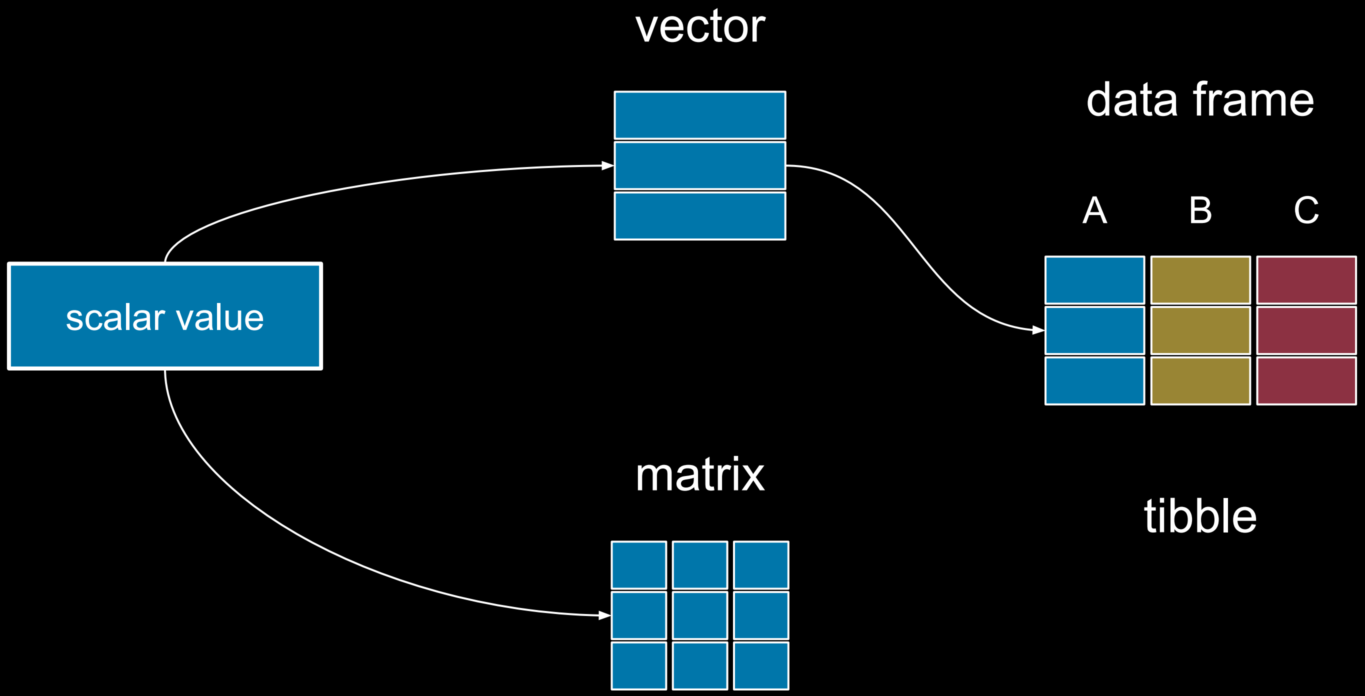
DATA REPRESENTATION

BACK

scalar value


vector
scalar value


vector
scalar value
matrix



scalar value

vector

matrix

data frame

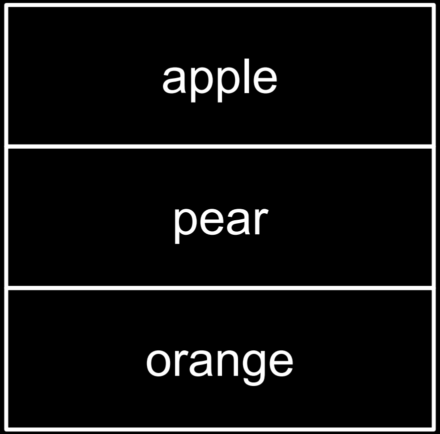
A

B

C

tibble

VECTORS



apple

pear

orange

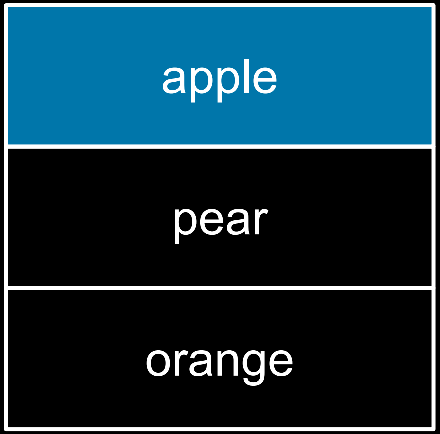
list of values with
the same storage mode

list of values with
the same storage mode

character
double
integer
logical

```
v <- c("apple", "pear", "orange")
```

`v[1]`

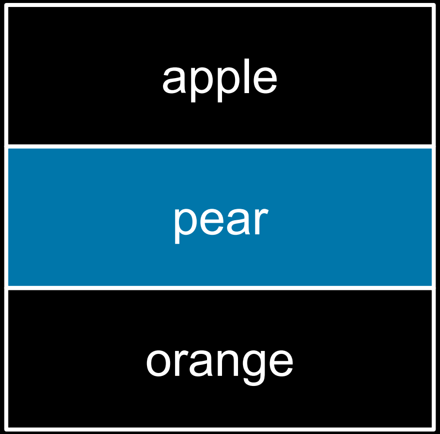


apple

pear

orange

```
v[2]
```

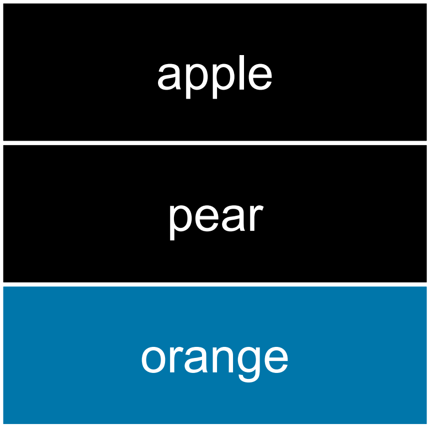


apple

pear

orange

```
v[3]
```



apple

pear

orange

```
weight <- c(91, 75.5, 61, 88.5, 120)
```

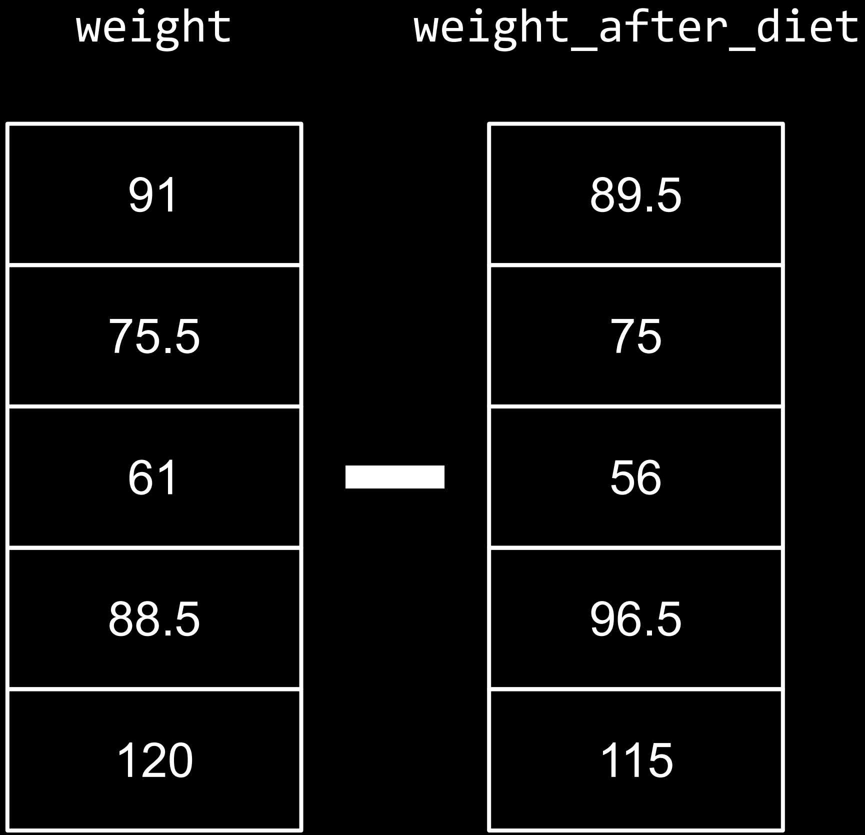
```r
weight <- c(91, 75.5, 61, 88.5, 120)
mean(weight)
```

sum
mean
median
sd
var
min
max

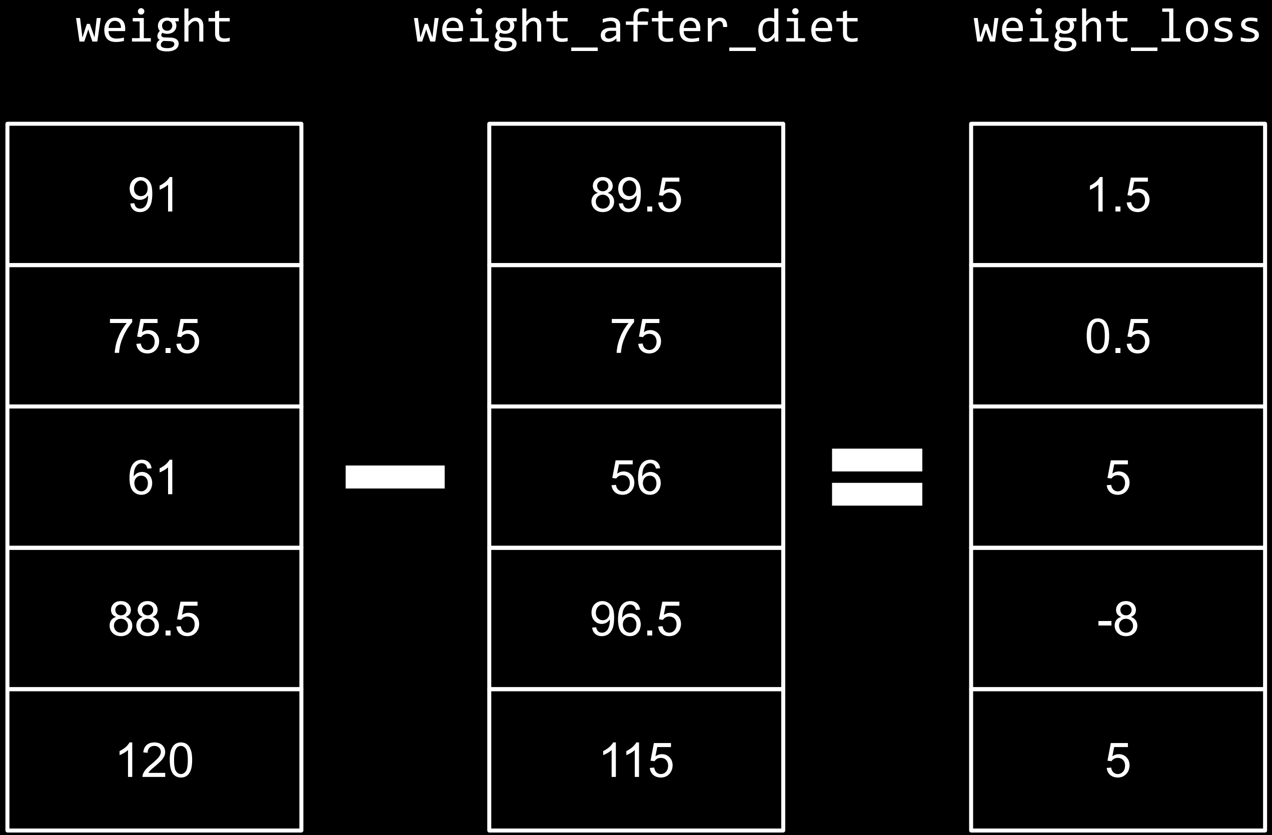
length
sort
cumsum
prod
quantile
abs
range

91
75.5
61
88.5
120

```
weight_after_diet <-
   c(89.5, 75, 56, 96.5, 115)
```



weight		weight_after_diet
91		89.5
75.5		75
61	−	56
88.5		96.5
120		115



weight		weight_after_diet		weight_loss
91		89.5		1.5
75.5		75		0.5
61	−	56	=	5
88.5		96.5		-8
120		115		5

```
weight_loss <-
   weight - weight_after_diet
```

subsetting vectors

```
weight[1]
```

```
weight[1]

weight[-1]
```

```
weight[1]

weight[-1]

weight[2:5]
```

```
weight[1]

weight[-1]

weight[2:5]

weight[1:length(weight)-1]
```

```
weight[1]

weight[-1]

weight[2:5]

weight[1:length(weight)-1]

weight[c(TRUE, FALSE, TRUE, TRUE, FALSE)]
```

```
weight[1]

weight[-1]

weight[2:5]

weight[1:length(weight)-1]

weight[c(TRUE, FALSE, TRUE, TRUE, FALSE)]

weight[weight > 80]
```

```
weight[1]

weight[-1]

weight[2:5]

weight[1:length(weight)-1]

weight[c(TRUE, FALSE, TRUE, TRUE, FALSE)]

weight[weight > 80]

weight[weight > 80 & weight < 100]
```

special values

```
NA
NULL
NaN
Inf
-Inf
```

factors

```
category <- factor(c("heavy", "medium", "light", "medium", "heavy"))
category <- factor(c("heavy", "medium", "light", "medium", "heavy"))

levels(weight_category)
```

```
category <- factor(c("heavy", "medium", "light", "medium", "heavy"))

levels(weight_category)

category_reordered <- factor(category,
                             levels = c("light", "medium", "heavy"))
```

```r
category <- factor(c("heavy", "medium", "light", "medium", "heavy"))

levels(weight_category)

category_reordered <- factor(category,
                             levels = c("light", "medium", "heavy"))

category_ordered <- factor(category,
                           levels = c("light", "medium", "heavy"),
                           ordered = TRUE)
```

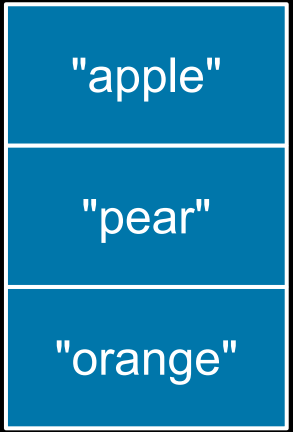
{{ forcats }}

as_factor()

```
fct_reorder
fct_relevel
fct_infreq
fct_rev
fct_lump
```

DATA FRAMES

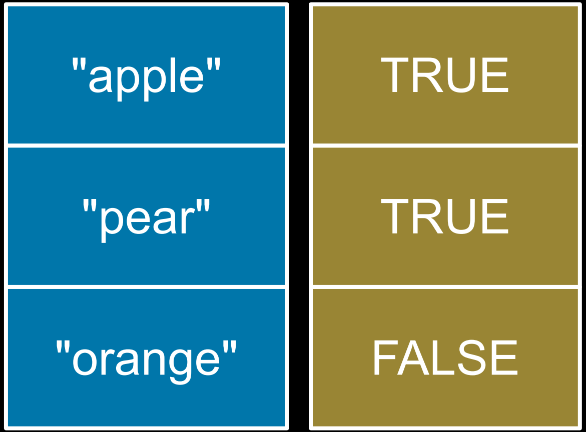
BACK



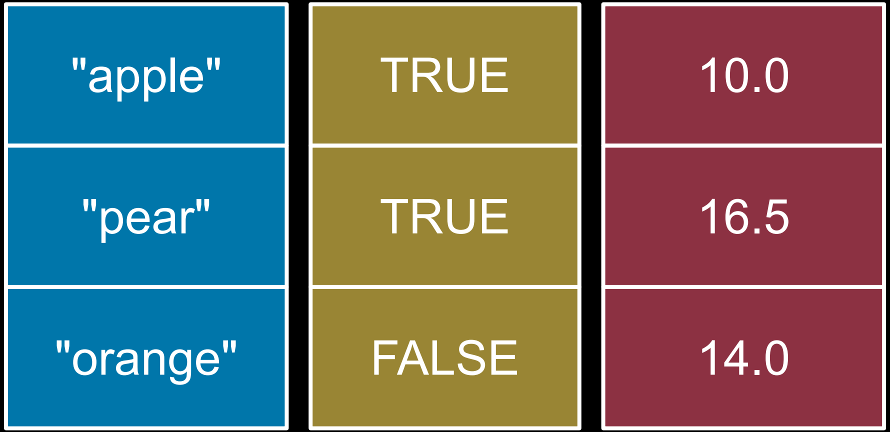
"apple"

"pear"

"orange"



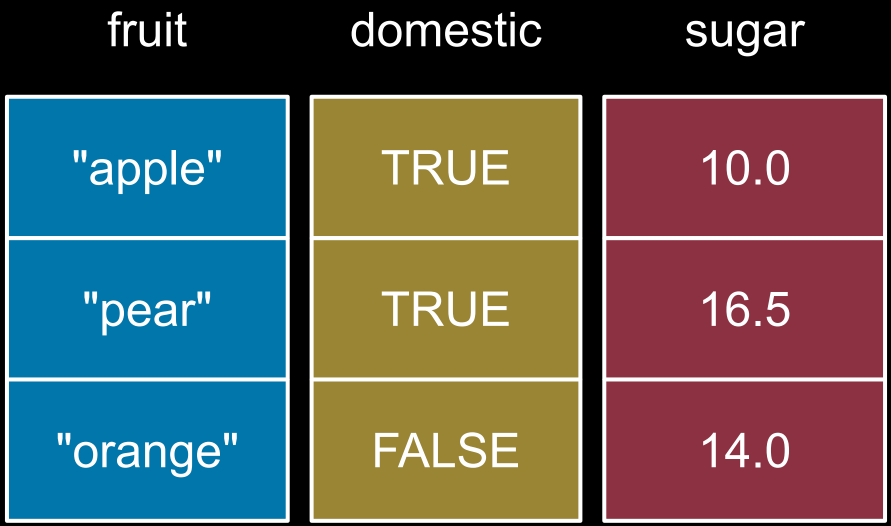
"apple"	TRUE
"pear"	TRUE
"orange"	FALSE



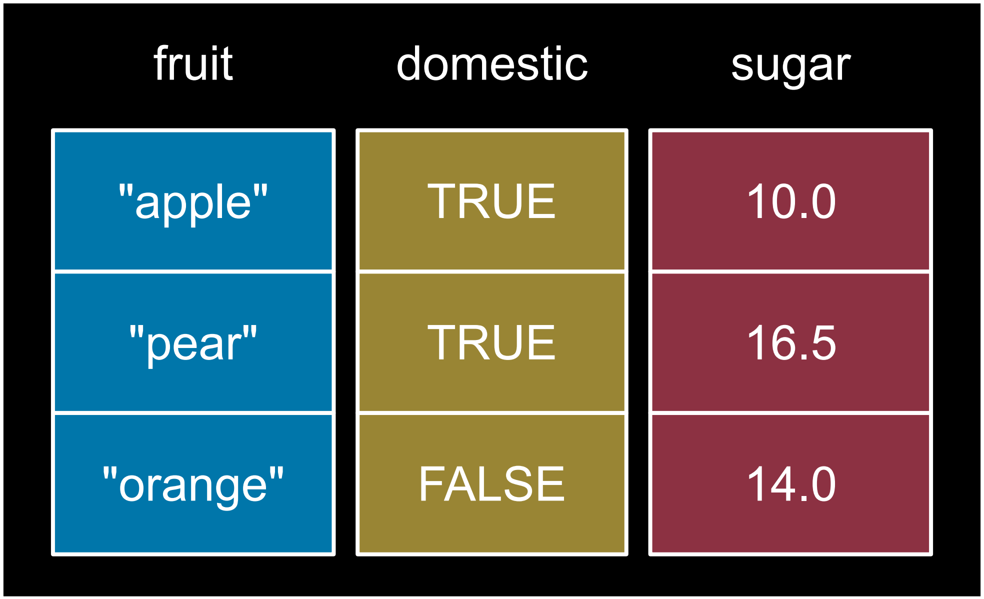
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

fruit		
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

fruit	domestic	
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

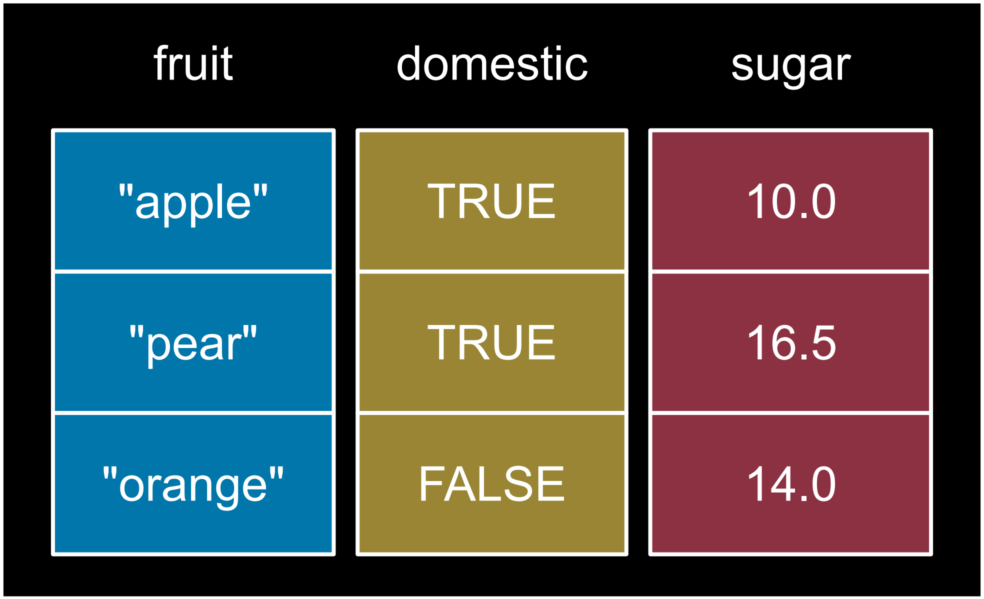


fruit	domestic	sugar
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0



fruit	domestic	sugar
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

data frame "fruits"



fruit	domestic	sugar
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

creating data frames

```
data.frame()
read.csv()
```

comma separated values (CSV)

data frame meta data

```
ncol()
nrow()
dim()
colnames()
```

accessing data frames

accessing data frames

accessing columns

```
monty$prize_door
monty$contestant_choice
monty$decision
```

```r
monty$prize_door
monty$contestant_choice
monty$decision
```

return a vector

```
monty["prize_door"]
monty["contestant_choice"]
monty["decision"]
```

```
monty["prize_door"]
monty["contestant_choice"]
monty["decision"]
```

return a data frame

```
# multiple columns by name
monty(c("prize_door", "contestant_choice"))
```

```
monty[, 1]               # first column
monty[, 1:2]             # first two columns
monty[, ncol(monty)]     # last column
```

accessing data frames

accessing rows

```
monty[1,]               # first row
monty[1:10,]            # first 10 rows
monty[nrow(monty),]     # last row
```

changing columns

```r
monty$decision <- as.factor(monty$decision)
```

adding columns

```
monty$correct_guess <-
   monty$contestant_choice == monty$prize_door
```

rename columns

```
colnames(monty)[2] <- "choice"
```

subsetting data frames

```
switched <-
   monty[monty_hall$decision == "switch, ]
```

```
switched <-
   monty[
      monty_hall$decision == "switch &
      monty$won == TRUE, ]
```

`subset()`

```
subset(monty, decision == "switch")
subset(
    monty,
    decision == "switch" & won == TRUE
)
```

sorting rows

```
monty[order(monty$prize_door),]
```

```
monty[order(monty$prize_door),]

monty[order(
        monty$prize_door,
        decreasing = TRUE
        ),]
```

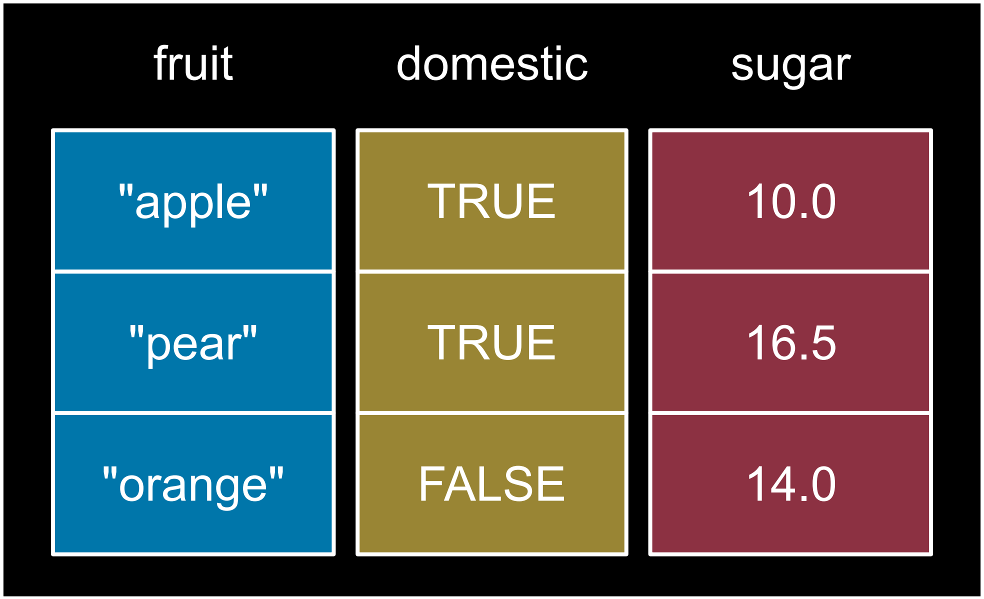
saving data frames

write.csv()

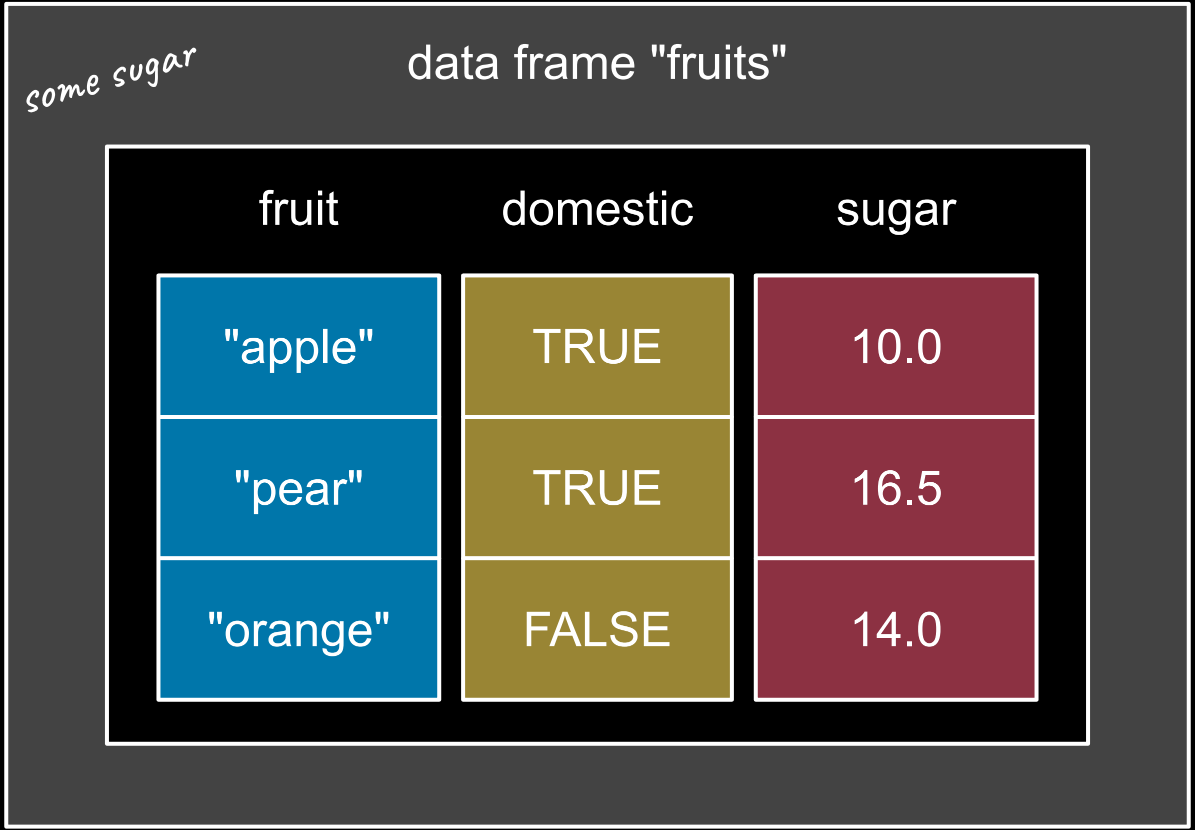
tibbles

{{ tibble }}

data frame "fruits"



fruit	domestic	sugar
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0



some sugar

data frame "fruits"

fruit	domestic	sugar
"apple"	TRUE	10.0
"pear"	TRUE	16.5
"orange"	FALSE	14.0

tibble "tbl_fruits"

```
as_tibble()
```

some sugar

better printing
subsets stay tibbles
better data type guessing
support for extended data types
…

LOAD DATA

{{ readr }}

```
read_csv()
read_delim()
```

{{ readxl }}

```
read_excel()
```

TIDY DATA

BACK

tidy data

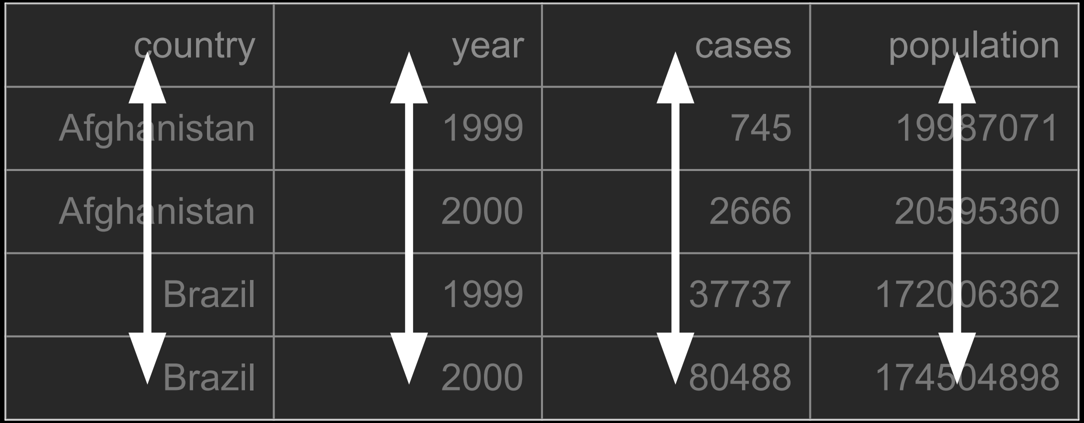
each variable is a column;
each column is a variable.

each observation is a row;
each row is an observation.

each value is a cell;
each cell is a single value.

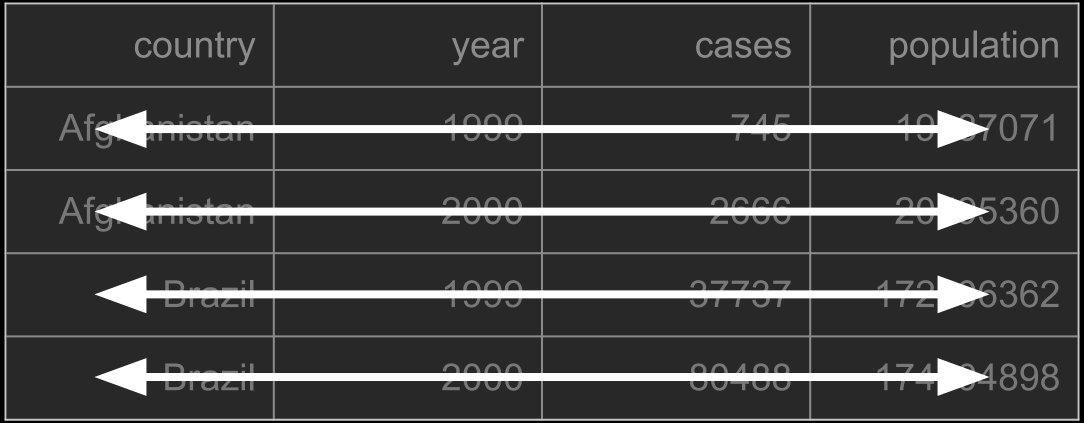
country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

Example from: Wickham, Hadley, et al. R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd edition, O’Reilly Media, Inc, 2023. Chapter 5.



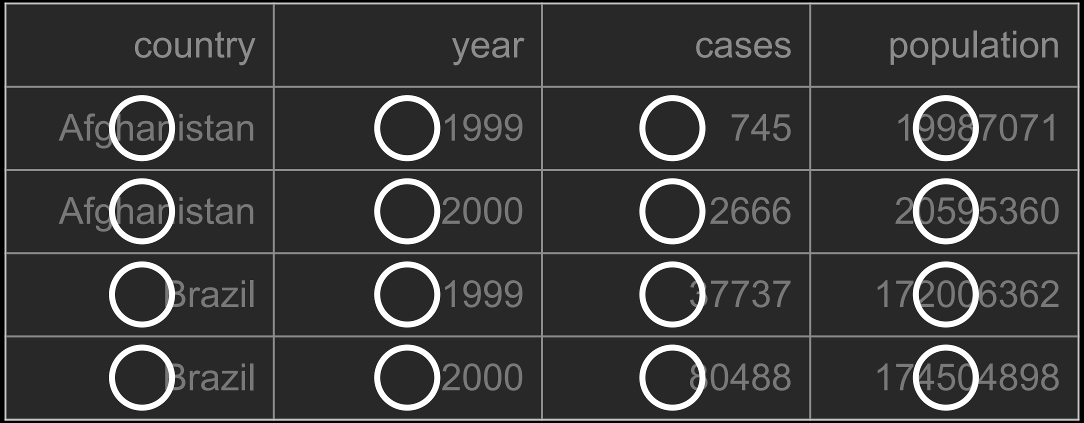
country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

variables



country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

observations



country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

values

country	year	type	count
Afghanistan	1999	cases	745
Afghanistan	1999	population	19987071
Afghanistan	2000	cases	2666
Afghanistan	2000	population	20595360
Brazil	1999	cases	37737
Brazil	1999	population	172006362
Brazil	2000	cases	80488
Brazil	2000	population	174504898

longer

country	year	type	count
Afghanistan	1999	cases	745
Afghanistan	1999	population	19987071
Afghanistan	2000	cases	2666
Afghanistan	2000	population	20595360
Brazil	1999	cases	37737
Brazil	1999	population	172006362
Brazil	2000	cases	80488
Brazil	2000	population	174504898

wider

country	cases_1999	cases_2000	pop_1999	pop_2000
Afghanistan	745	2666	19987071	20595360
Brazil	37737	172006362	80488	174504898

compressed

→ ←

country	year	rate
Afghanistan	1999	745 / 19987071
Afghanistan	2000	2666 / 20595360
Brazil	1999	37737 / 172006362
Brazil	2000	80488 / 174504898

tidy

country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

tidy

country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898

vector

{{ tidyr }}

pivot_wider()

pivot_longer()

STRINGS

BACK

{{ stringr }}

```
str_trim()
str_squish()
```

```
str_starts()
str_ends()
str_detect()
```

“Annabel Miller”

“Annabel Miller”

```
str_starts(txt, "Anna")
```

“Annabel Miller”

```
str_ends(txt, "Miller")
```

“Annabel Miller”

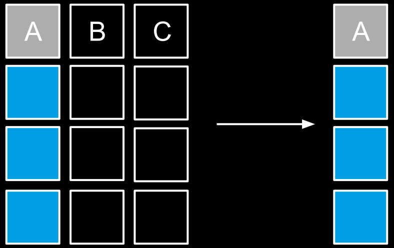
```
str_detect(txt, "Mill")
```

TRANSFORM DATA

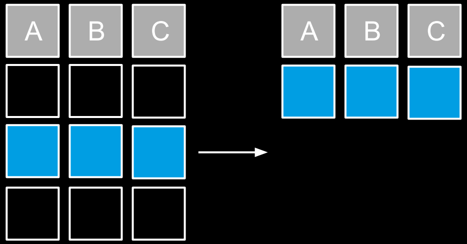
{{ dplyr }}

types of transformations

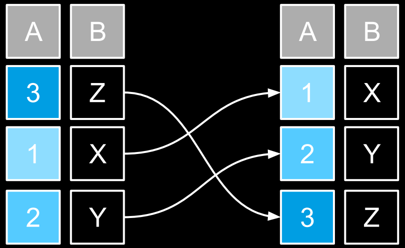
select()



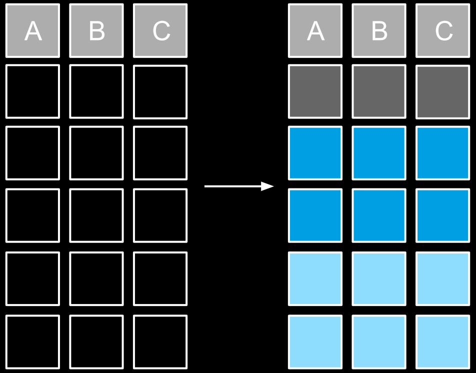
filter()



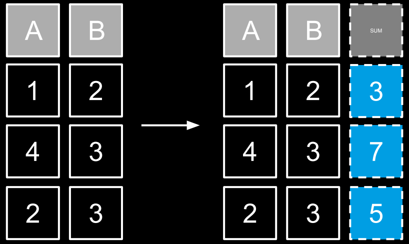
arrange()



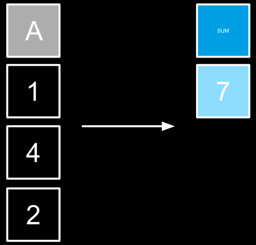
group_by()



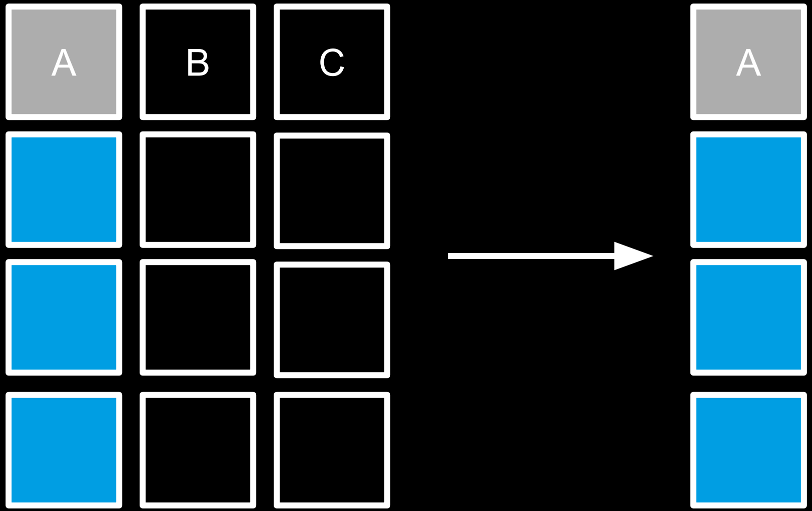
mutate()



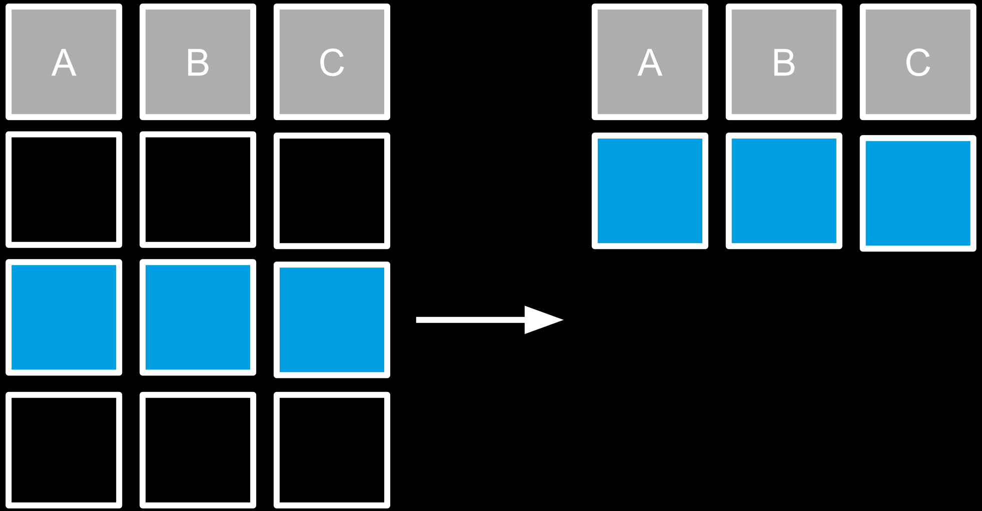
summarize()



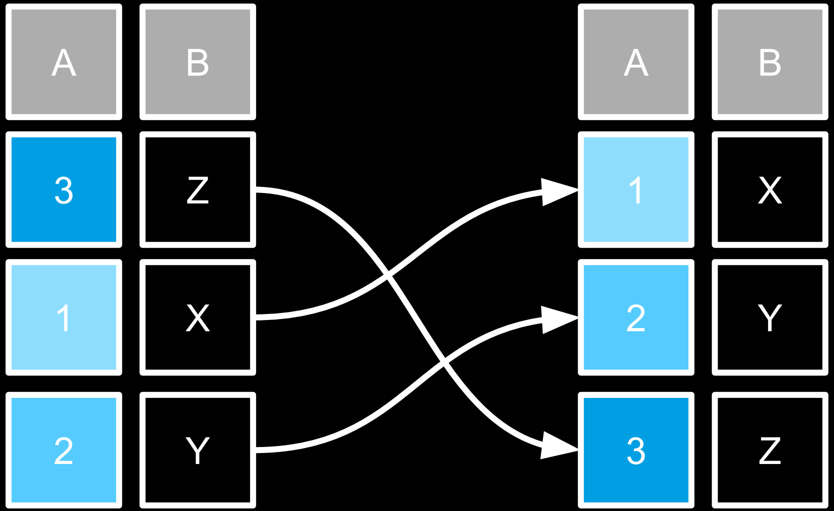
`select()`



`filter()`



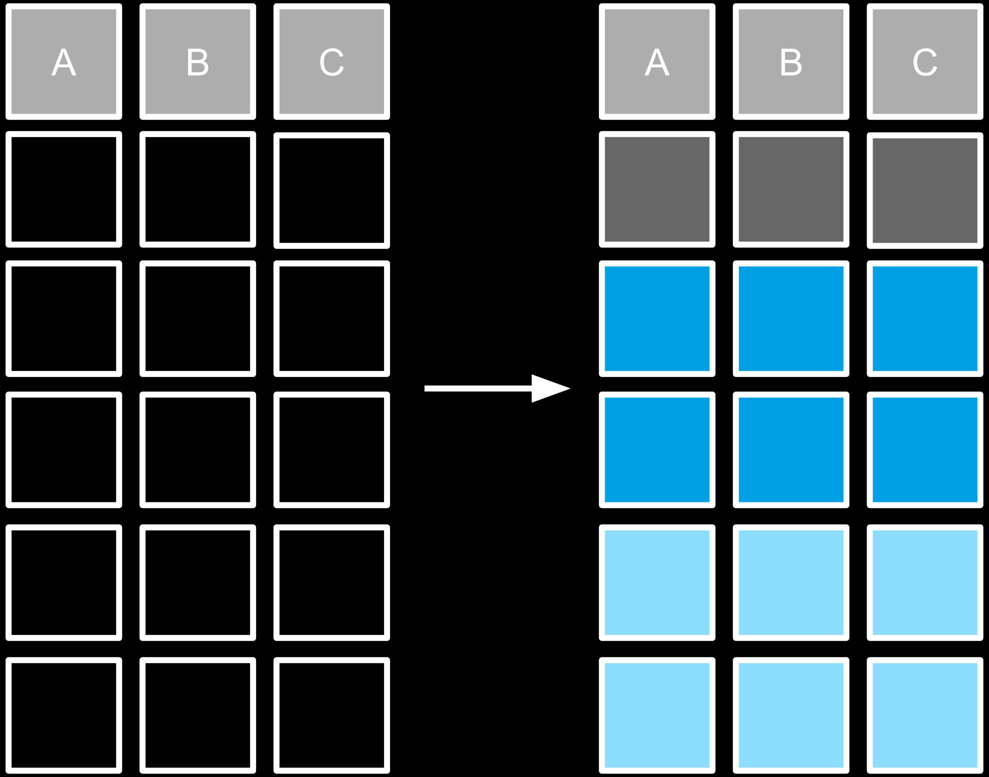
arrange()



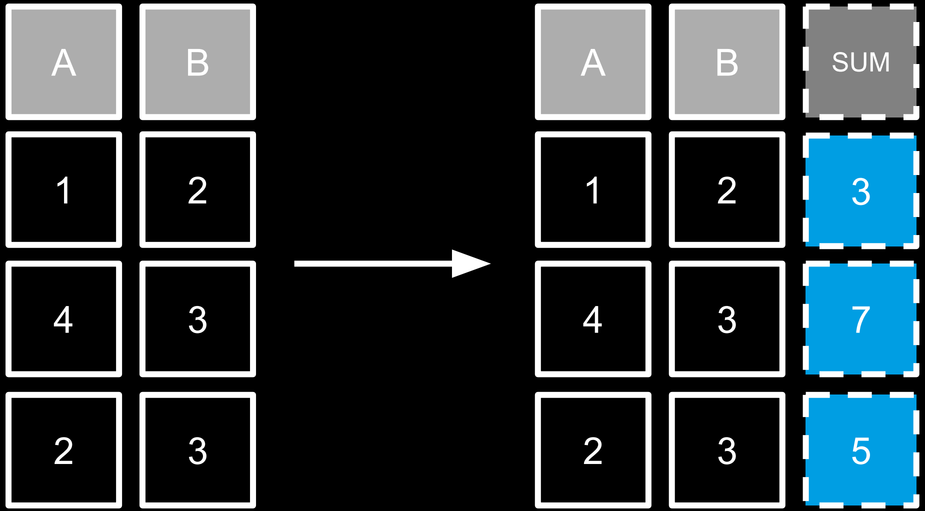
A	B
3	Z
1	X
2	Y

A	B
1	X
2	Y
3	Z

`group_by()`



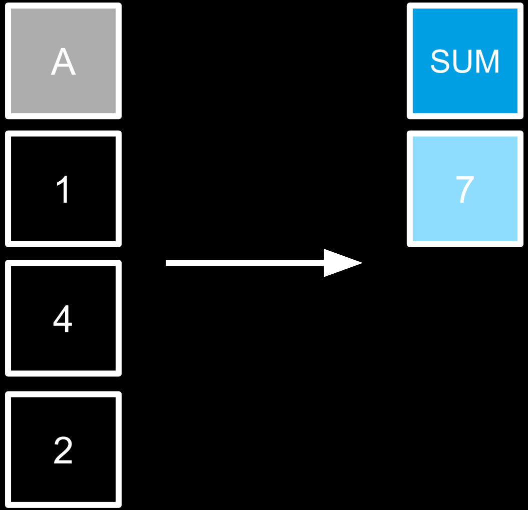
mutate()



A	B
1	2
4	3
2	3

A	B	SUM
1	2	3
4	3	7
2	3	5

`summarize()`

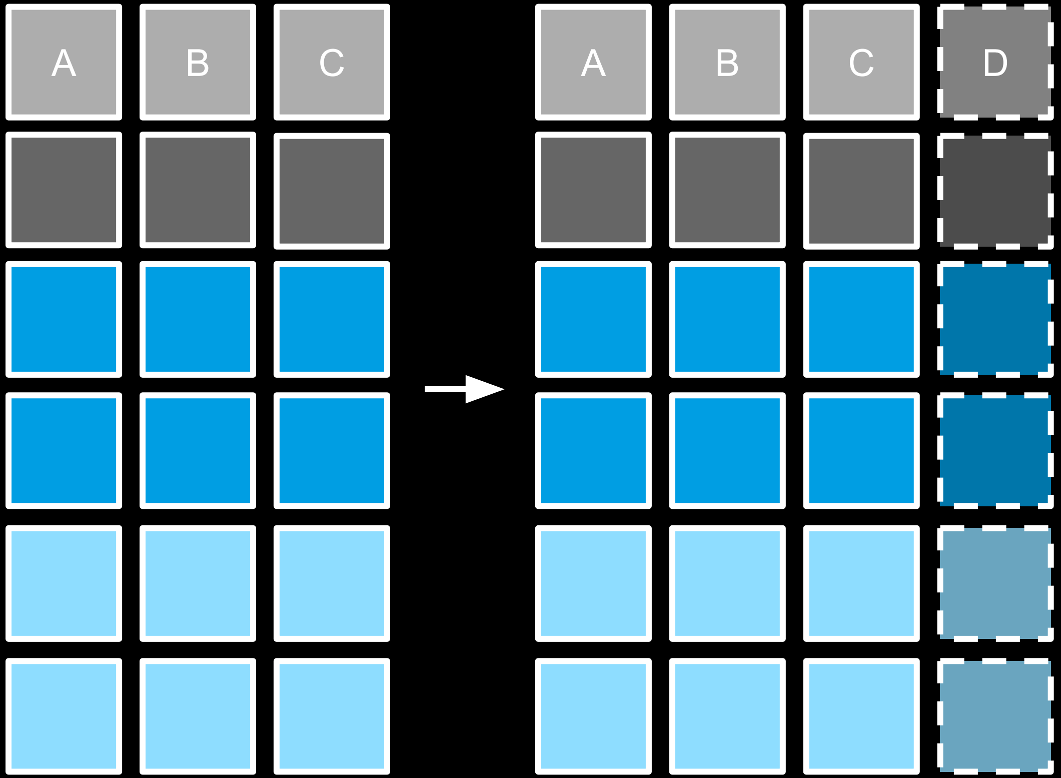


A
1
4
2

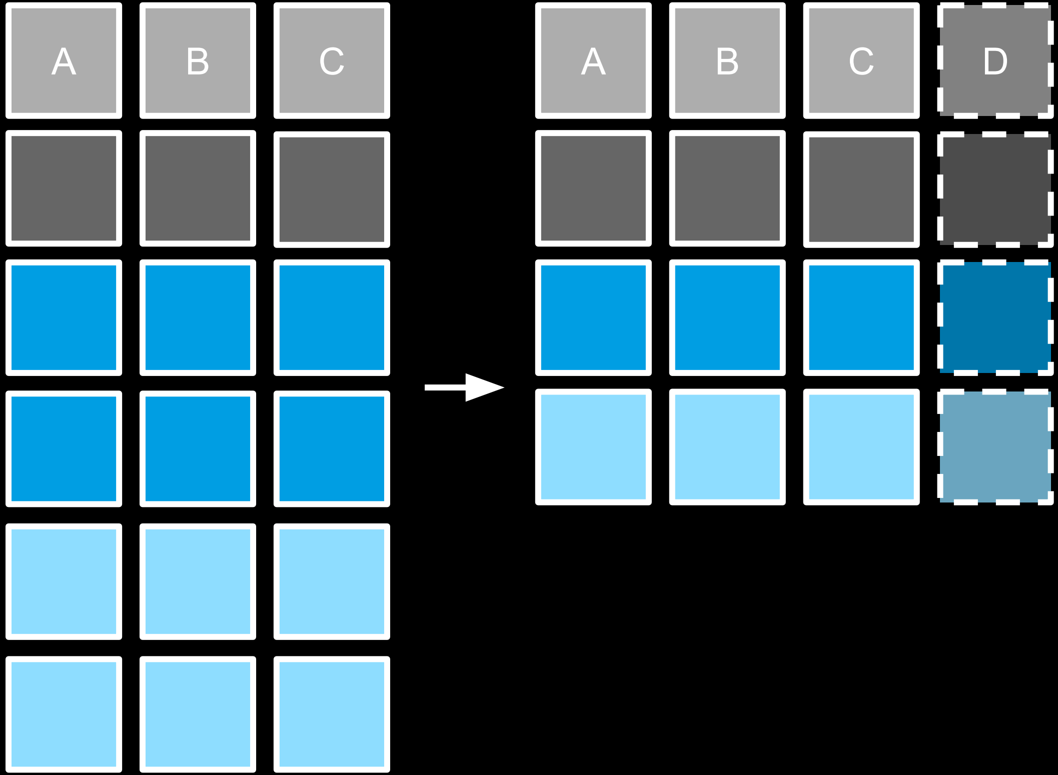
→

SUM
7

```
group_by()
+
mutate()
```

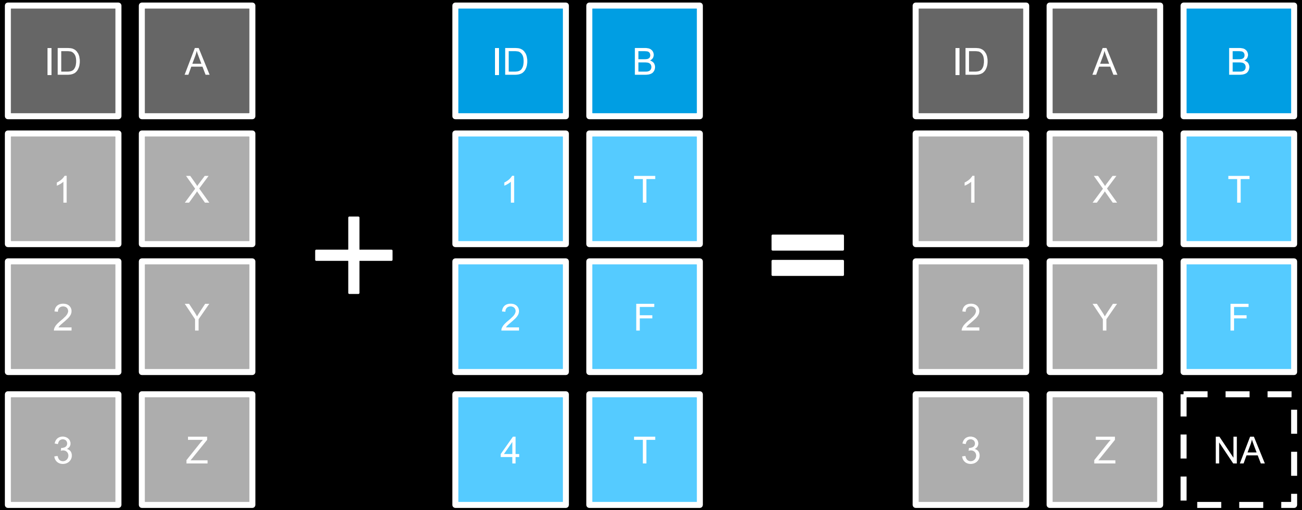


```
group_by()
+
summarize()
```



joining data

```
left_join()
```



ID	A
1	X
2	Y
3	Z

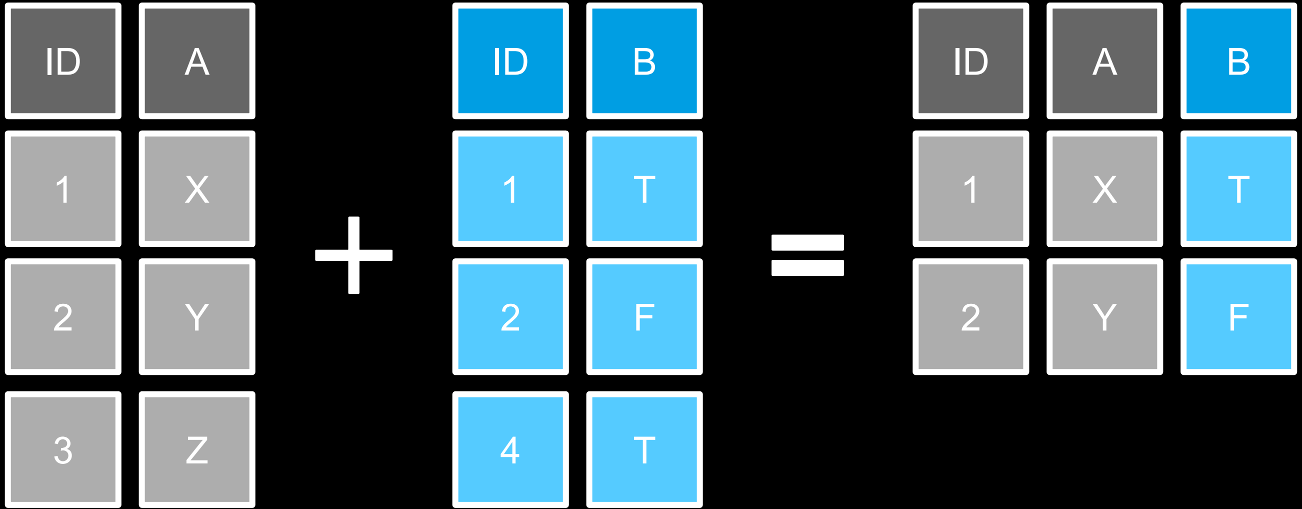
+

ID	B
1	T
2	F
4	T

=

ID	A	B
1	X	T
2	Y	F
3	Z	NA

```
inner_join()
```



ID	A
1	X
2	Y
3	Z

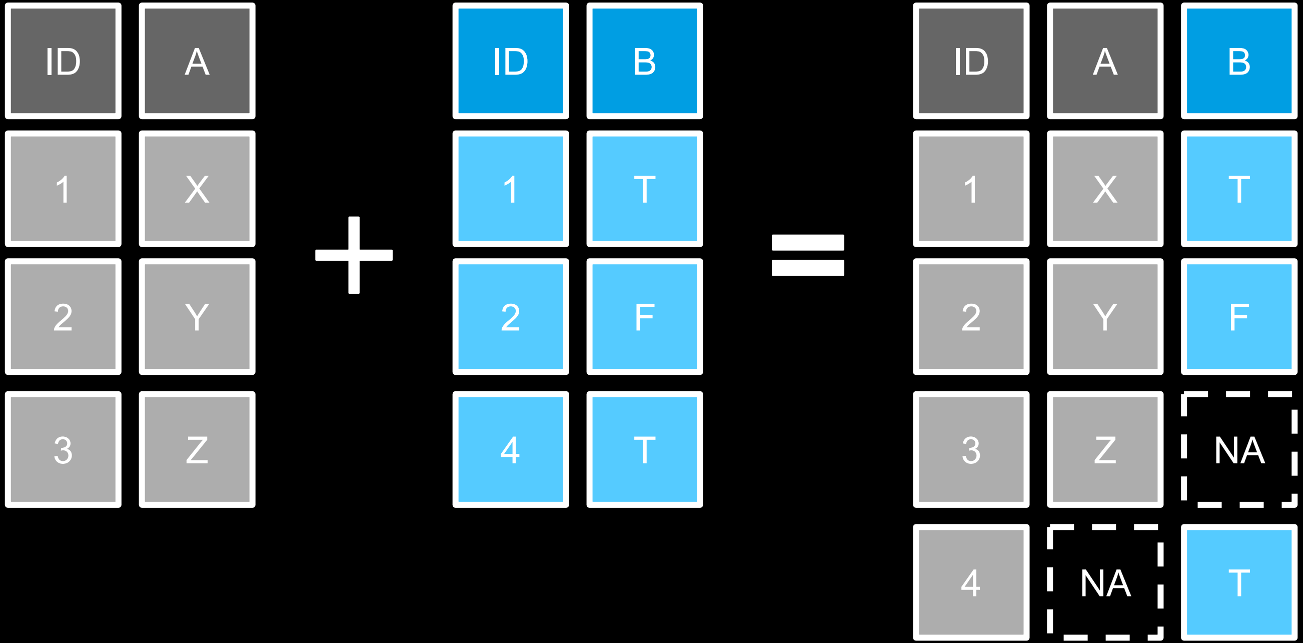
+

ID	B
1	T
2	F
4	T

=

ID	A	B
1	X	T
2	Y	F

`full_join()`



ID	A
1	X
2	Y
3	Z

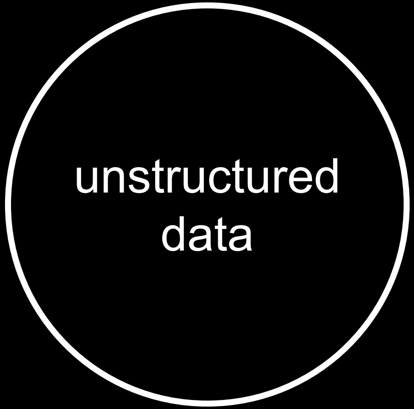
+

ID	B
1	T
2	F
4	T

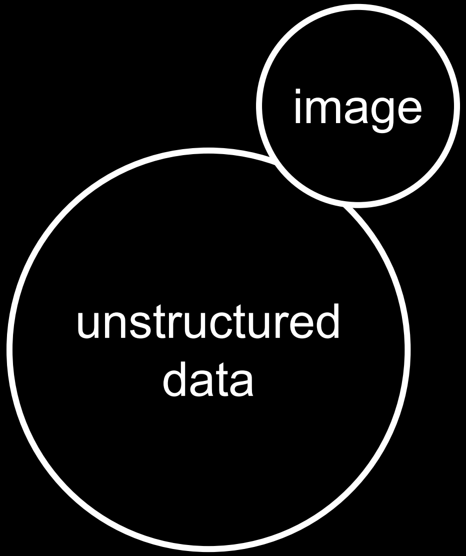
=

ID	A	B
1	X	T
2	Y	F
3	Z	NA
4	NA	T

UNSTRUCTURED DATA



unstructured data



image

unstructured data

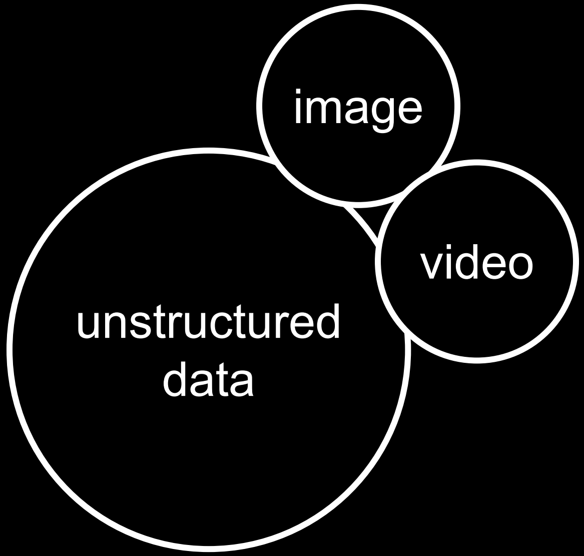
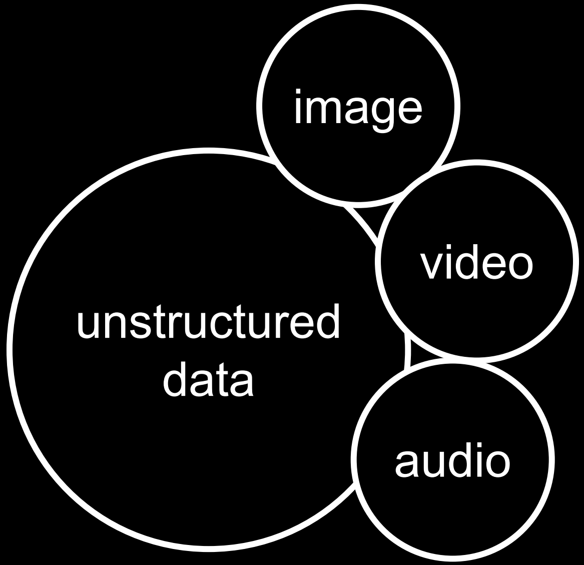


image
video
unstructured data



image

video

unstructured data

audio

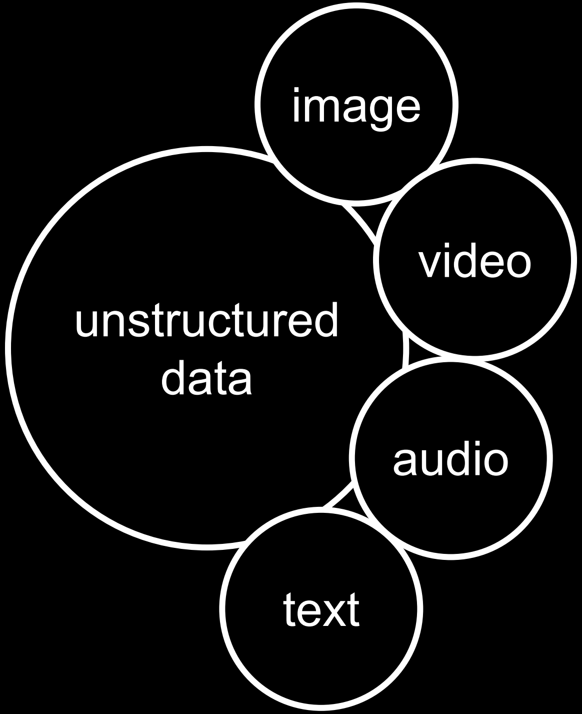
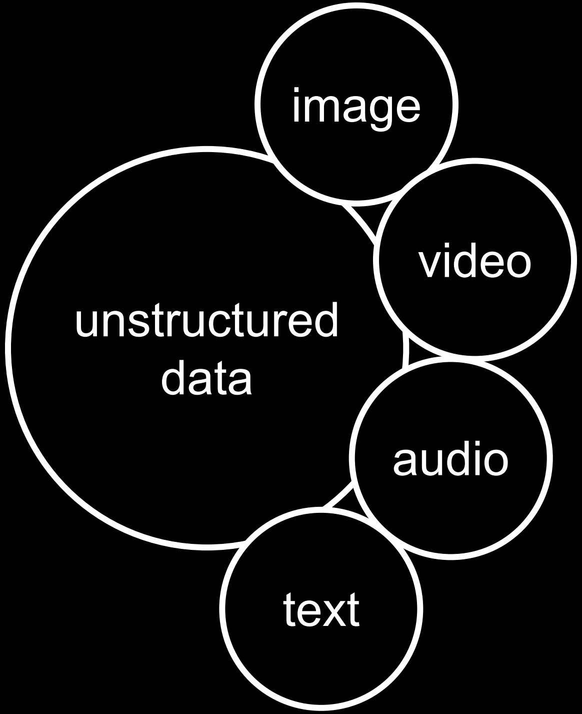
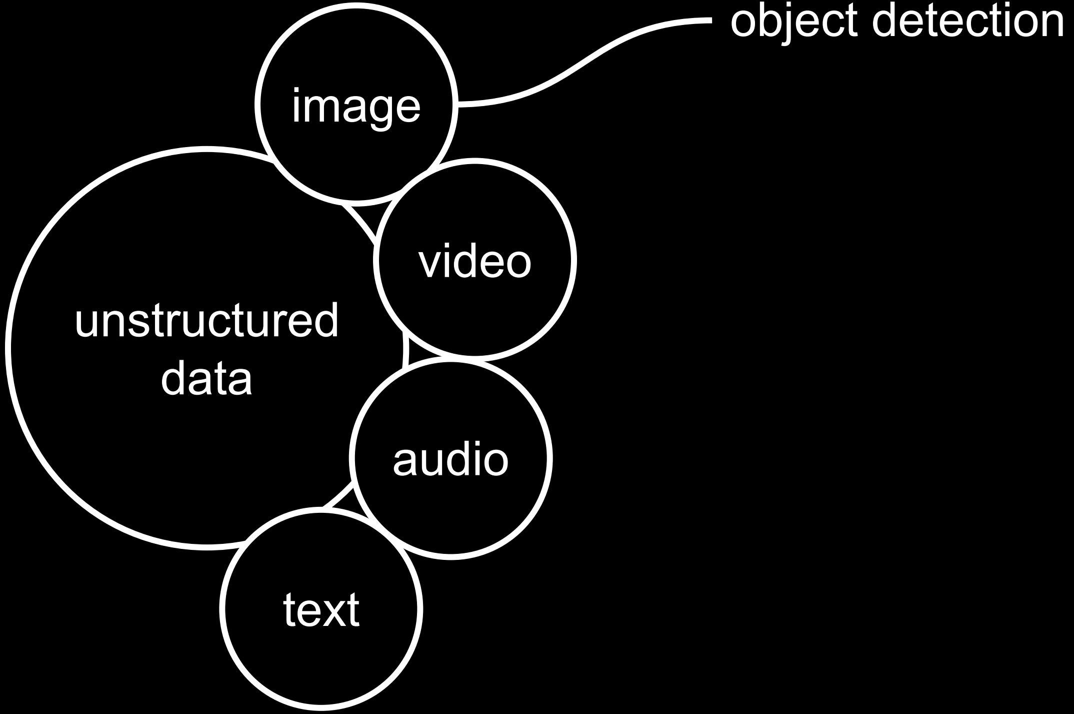


image
video
unstructured data
audio
text

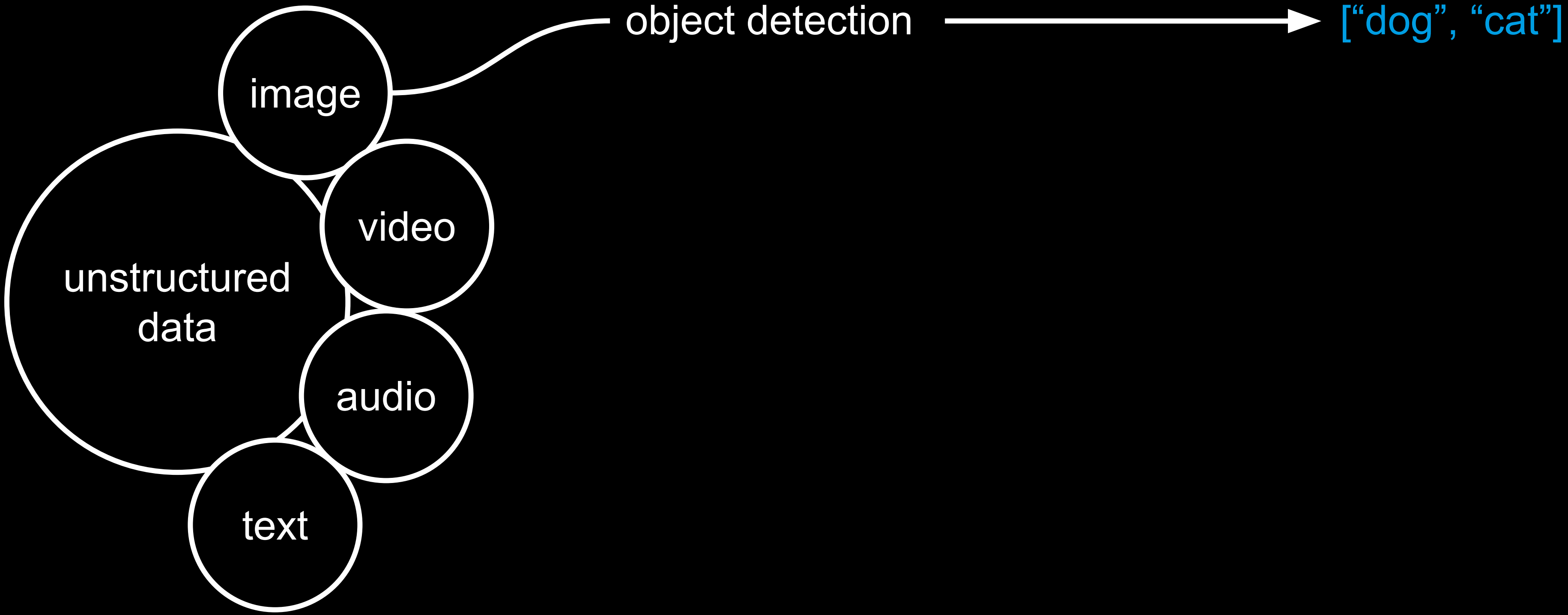
no handles to grab



no handles to grab



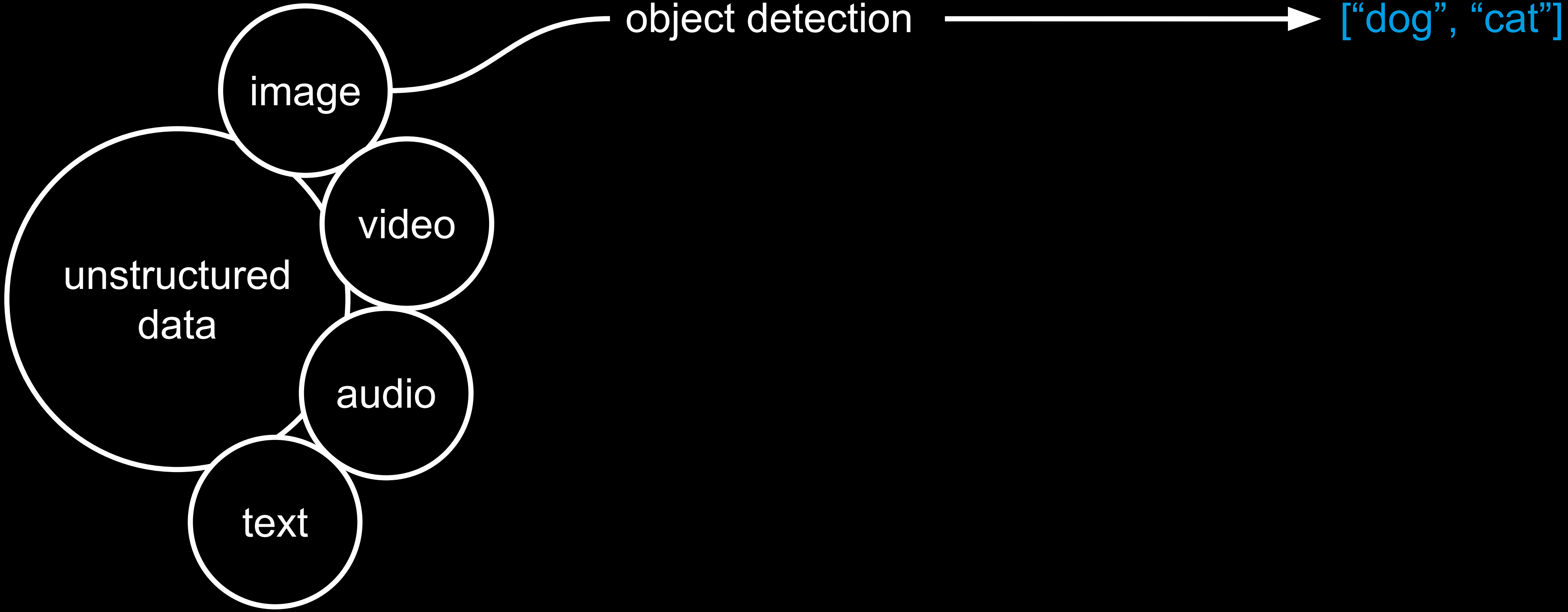
no handles to grab



no handles to grab

algorithm

extracted, structured information



unstructured data

image

video

audio

text

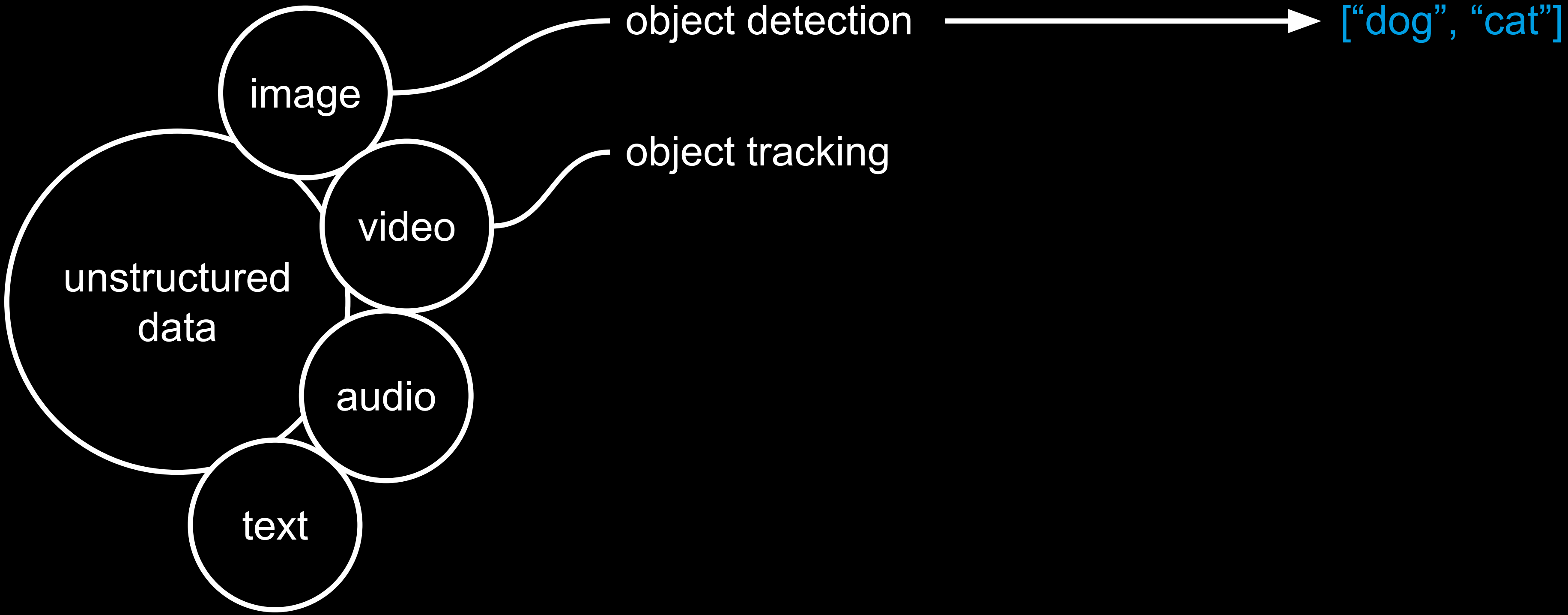
object detection

[“dog”, “cat”]

no handles to grab

algorithm

extracted, structured information



unstructured data

image

video

audio

text

object detection

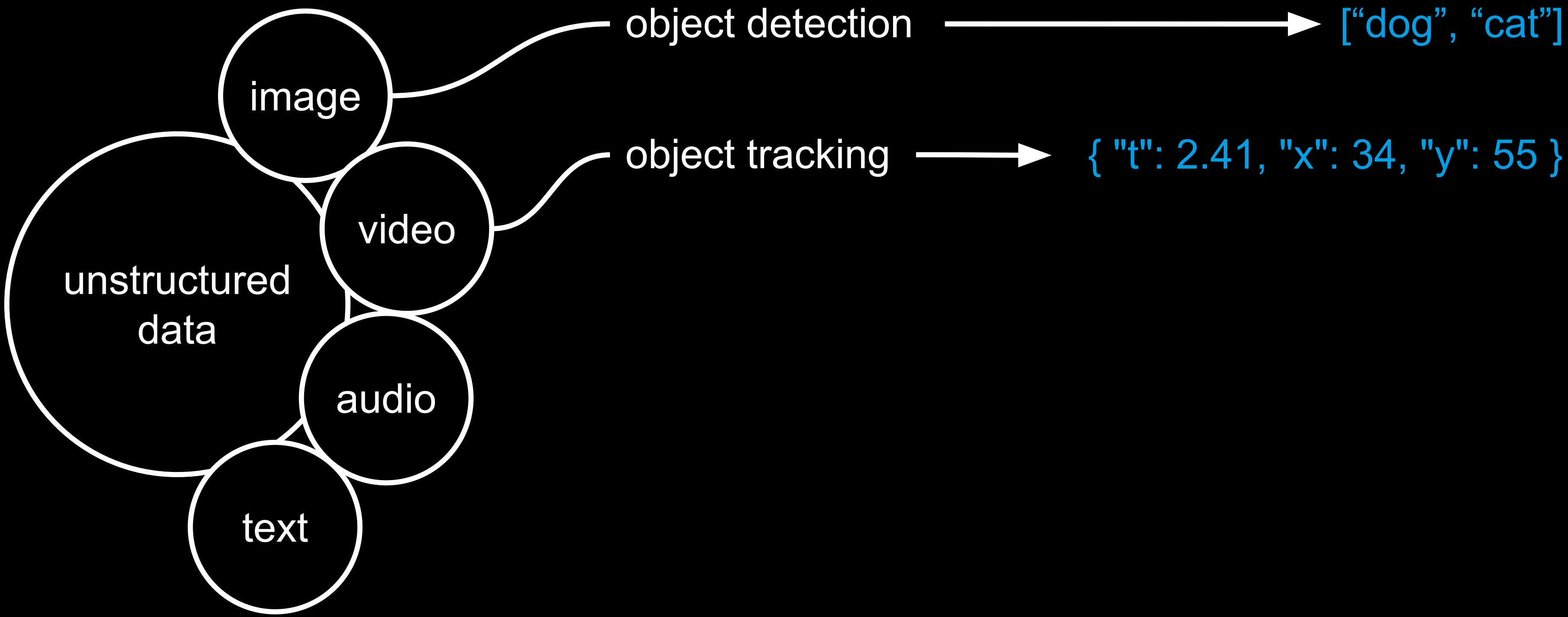
object tracking

["dog", "cat"]

no handles to grab

algorithm

extracted, structured information



unstructured data

image

video

audio

text

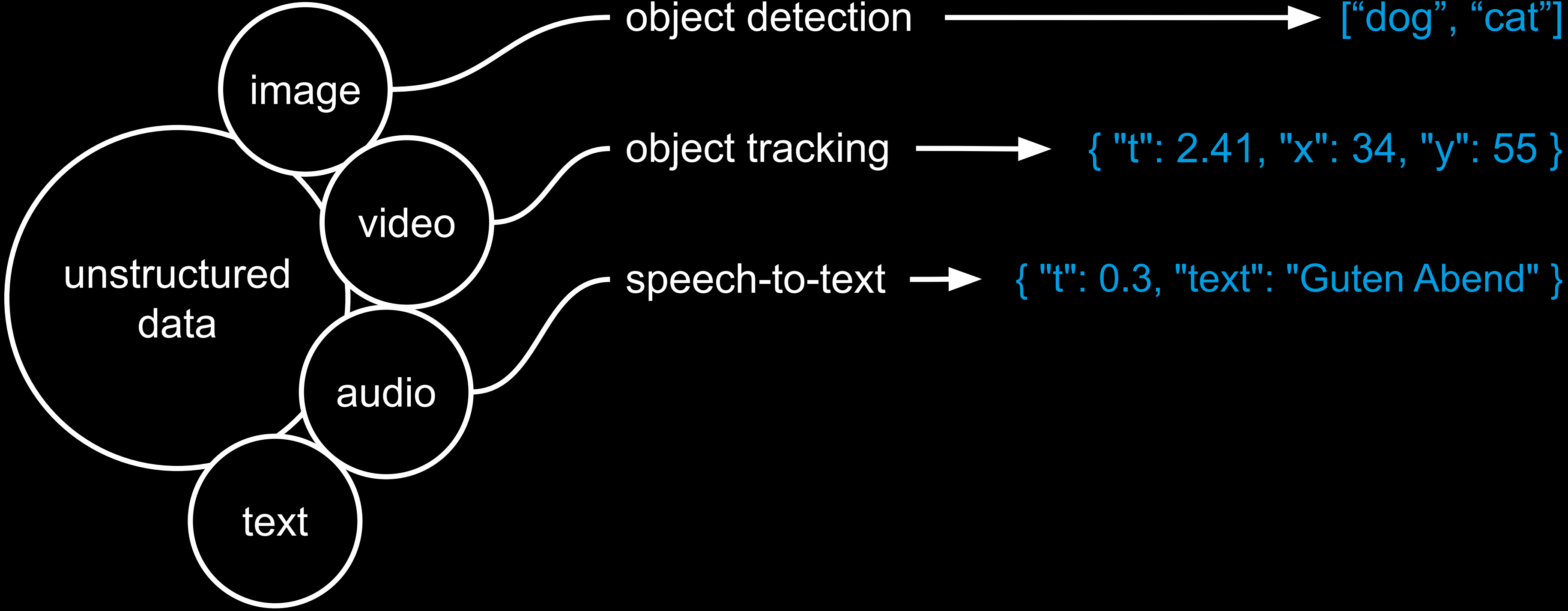
object detection → [“dog”, “cat”]

object tracking → { "t": 2.41, "x": 34, "y": 55 }

no handles to grab

algorithm

extracted, structured information



unstructured data

image

video

audio

text

object detection → ["dog", "cat"]

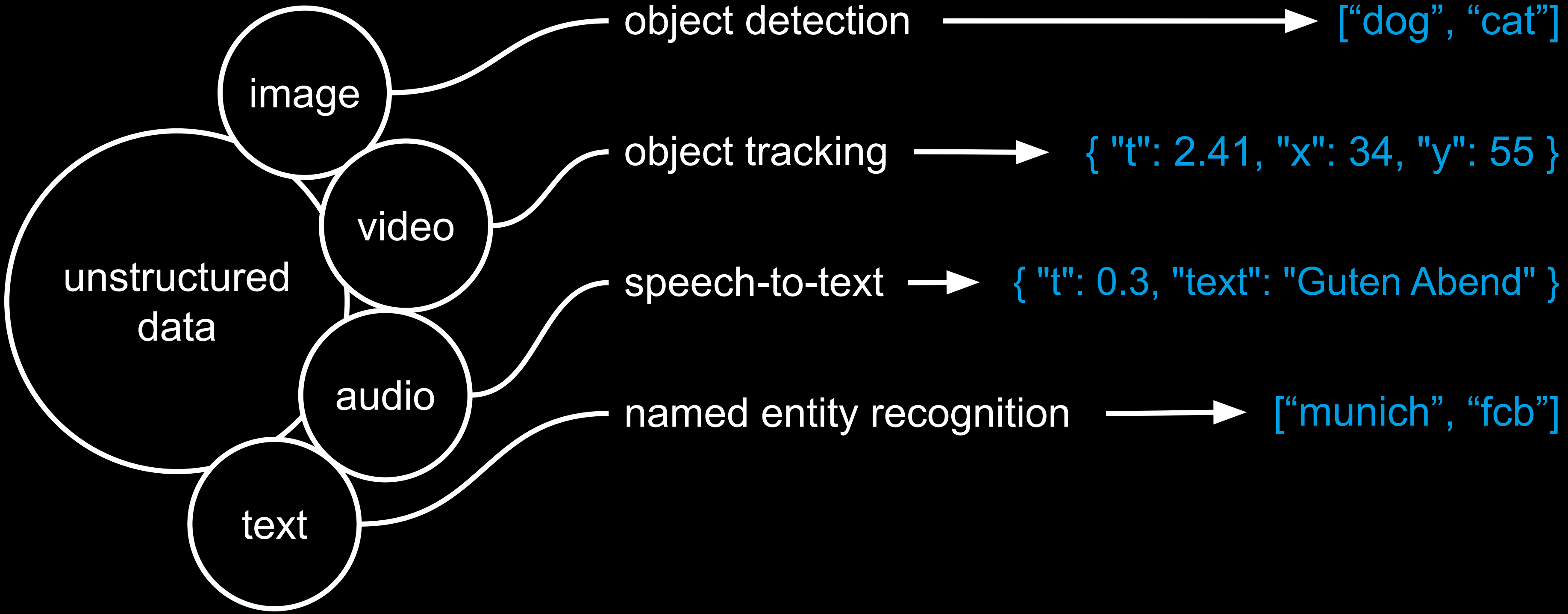
object tracking → { "t": 2.41, "x": 34, "y": 55 }

speech-to-text → { "t": 0.3, "text": "Guten Abend" }

no handles to grab

algorithm

extracted, structured information



unstructured data

image → object detection → [“dog”, “cat”]

video → object tracking → { "t": 2.41, "x": 34, "y": 55 }

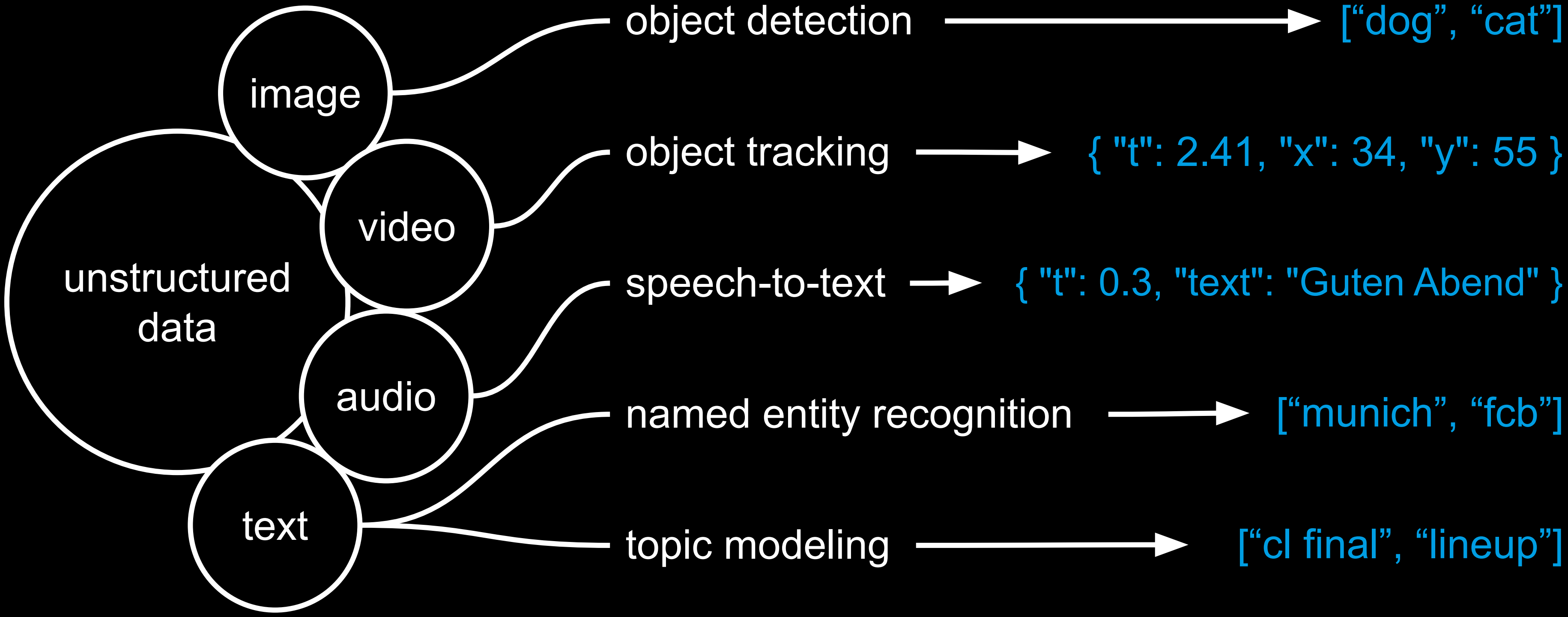
audio → speech-to-text → { "t": 0.3, "text": "Guten Abend" }

text → named entity recognition → [“munich”, “fcb”]

no handles to grab

algorithm

extracted, structured information



unstructured data

image

video

audio

text

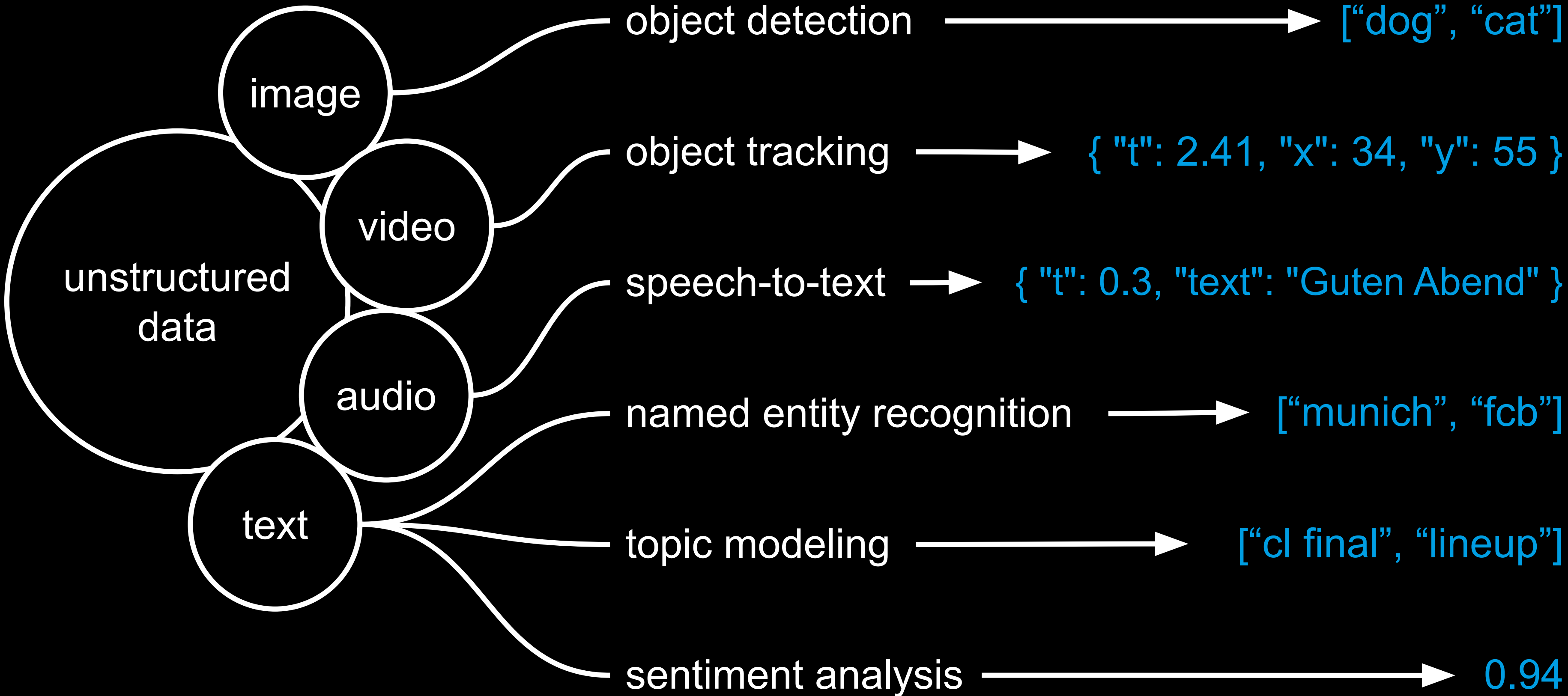
object detection → [“dog”, “cat”]

object tracking → { "t": 2.41, "x": 34, "y": 55 }

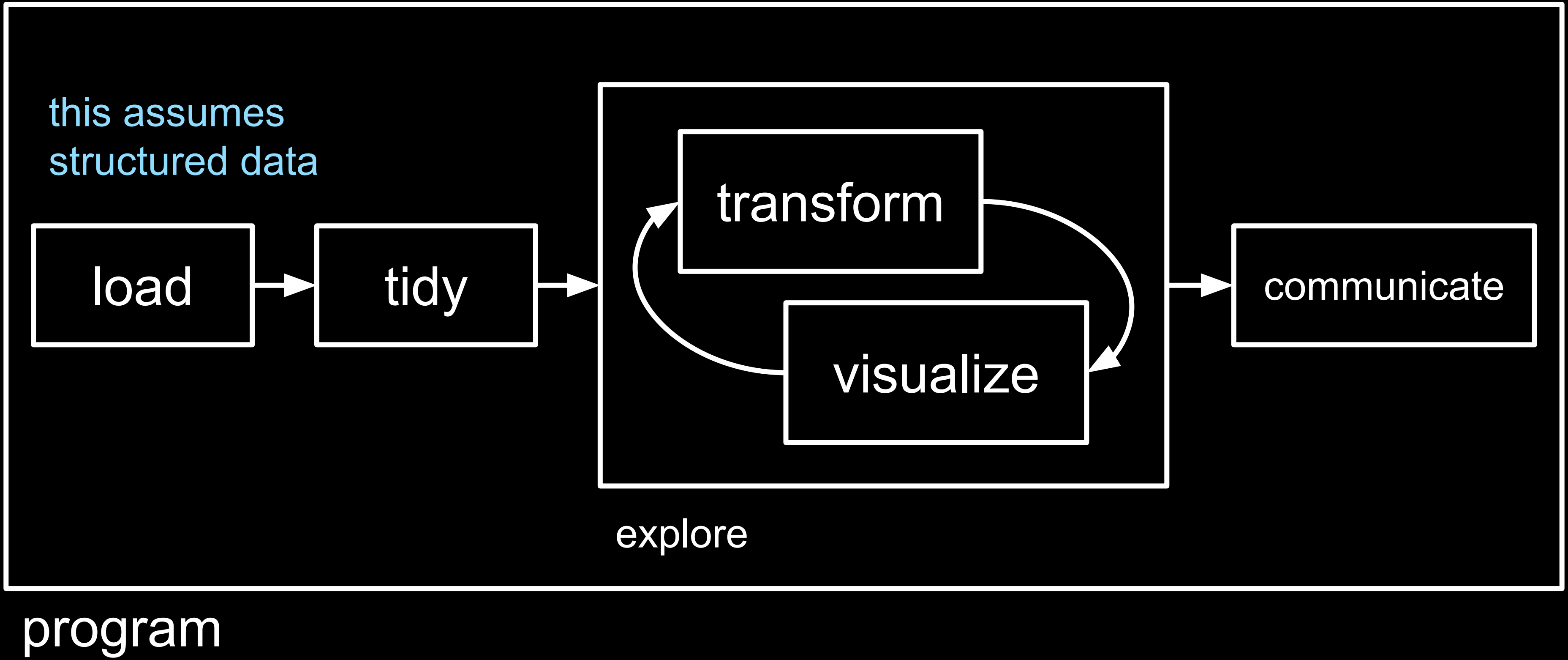
speech-to-text → { "t": 0.3, "text": "Guten Abend" }

named entity recognition → [“munich”, “fcb”]

topic modeling → [“cl final”, “lineup”]



no handles to grab	algorithm	extracted, structured information
unstructured data: image	object detection	[“dog”, “cat”]
video	object tracking	{ "t": 2.41, "x": 34, "y": 55 }
audio	speech-to-text	{ "t": 0.3, "text": "Guten Abend" }
text	named entity recognition	[“munich”, “fcb”]
text	topic modeling	[“cl final”, “lineup”]
text	sentiment analysis	0.94



this assumes structured data

load

tidy

transform

visualize

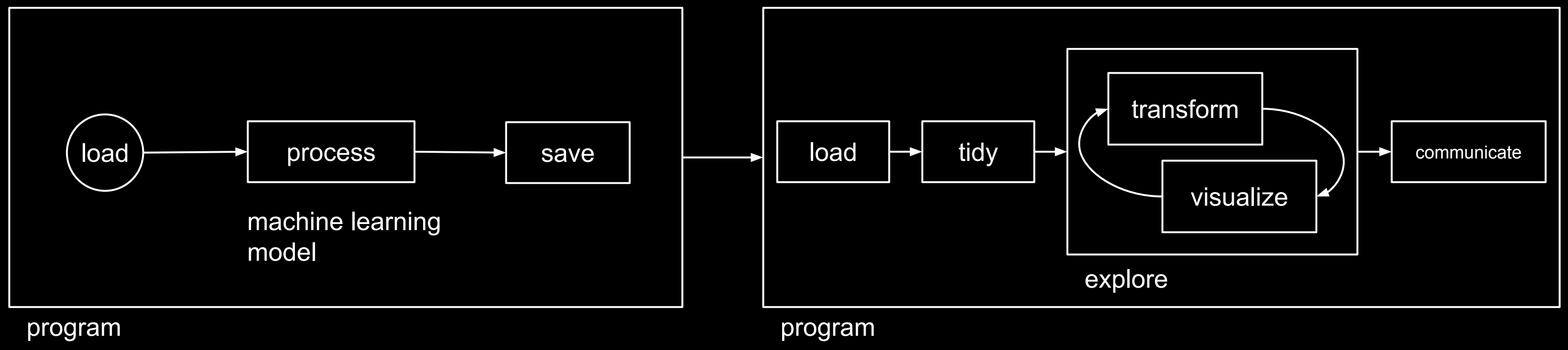
explore

communicate

program

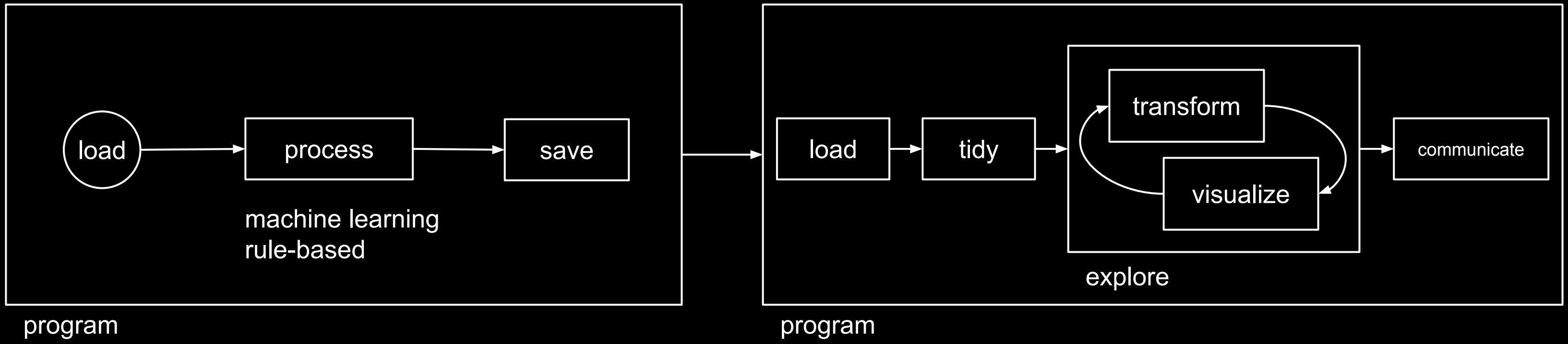
pre-process
unstructured data

exploratory data
analysis



pre-process unstructured data

exploratory data analysis



load

process

save

machine learning
rule-based

program

load

tidy

transform

visualize

explore

communicate

program

MACHINE LEARNING

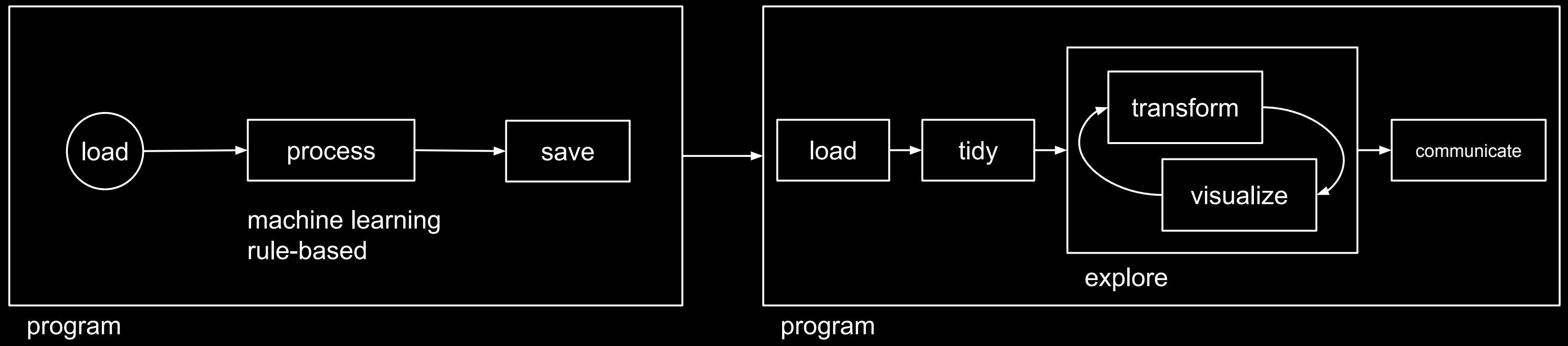
BACK

Highly recommended for background information

3Blue1Brown's YouTube Course on Neural Networks and Deep Learning

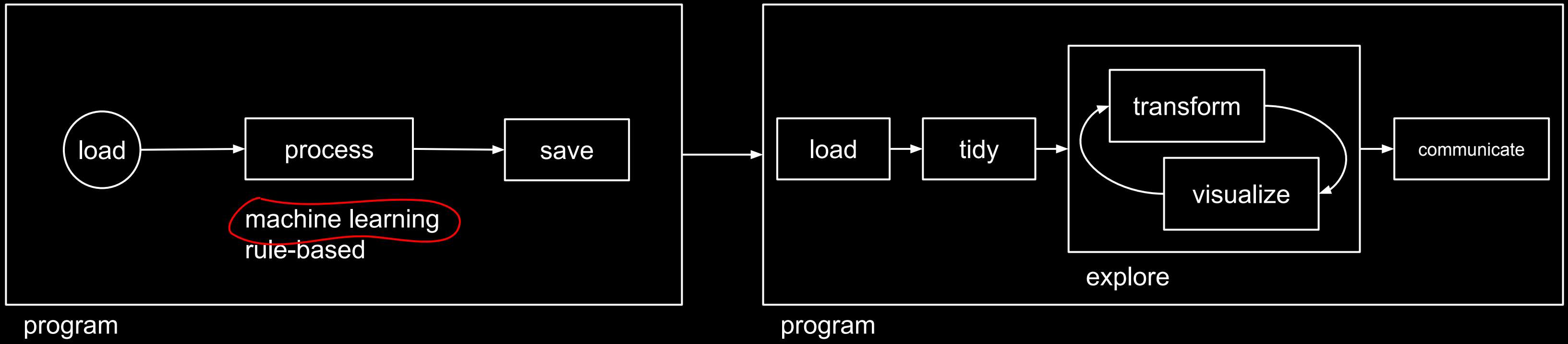
pre-process unstructured data

exploratory data analysis



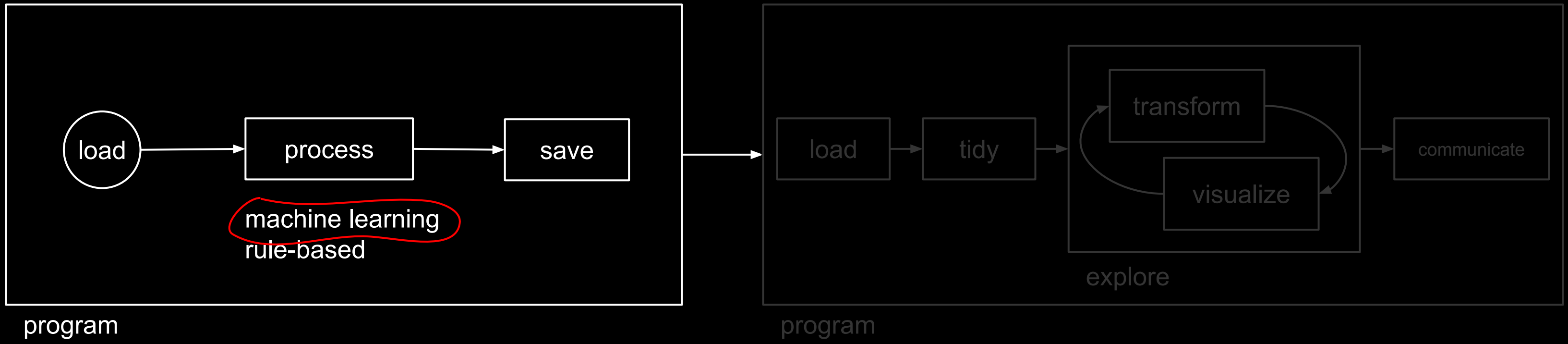
pre-process unstructured data

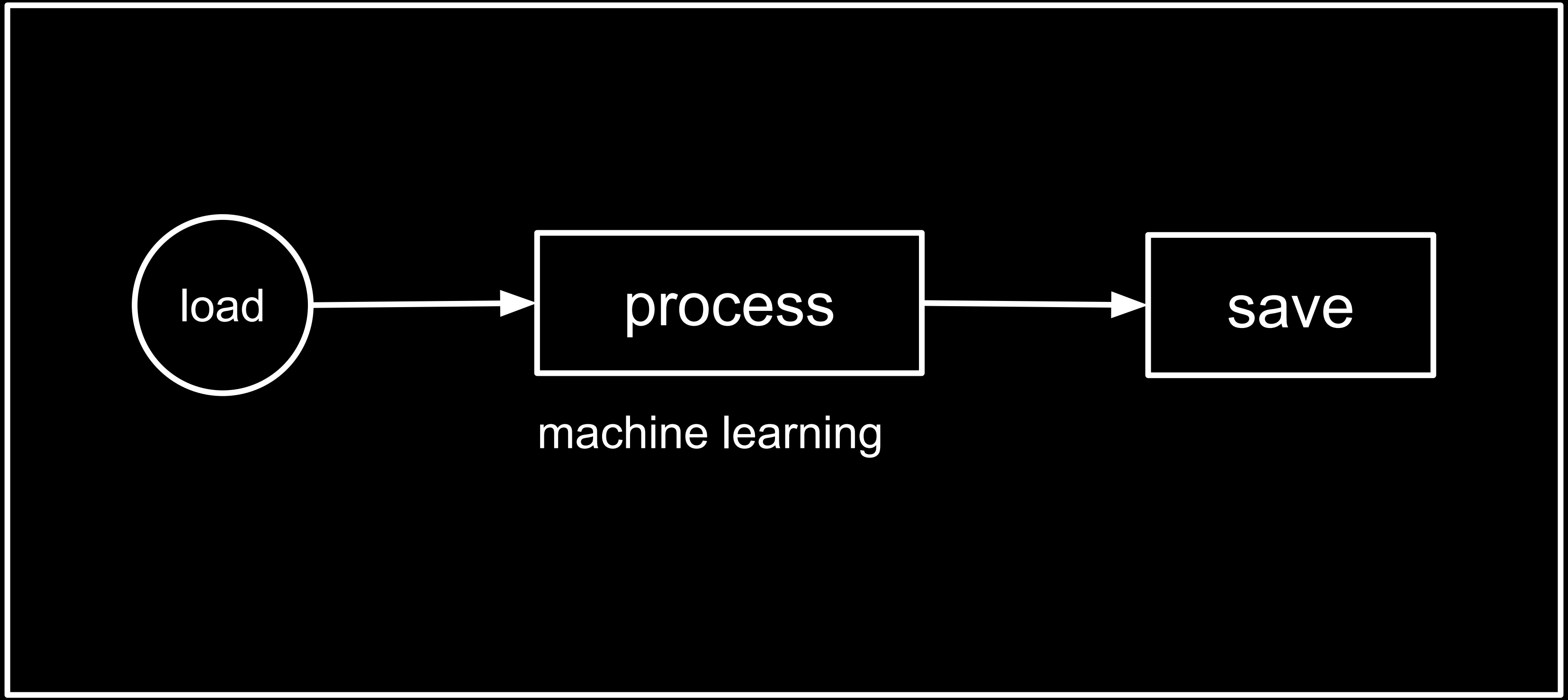
exploratory data analysis



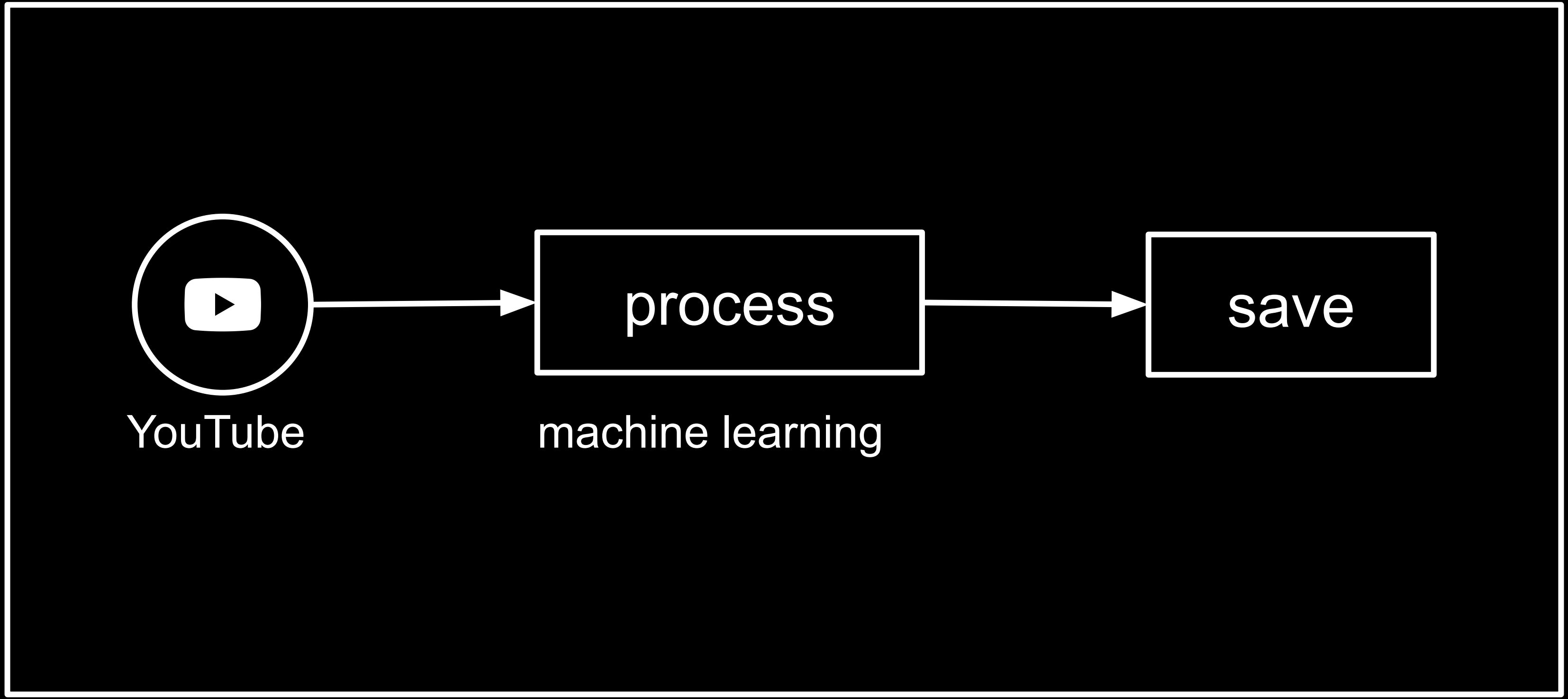
pre-process unstructured data

exploratory data analysis





program



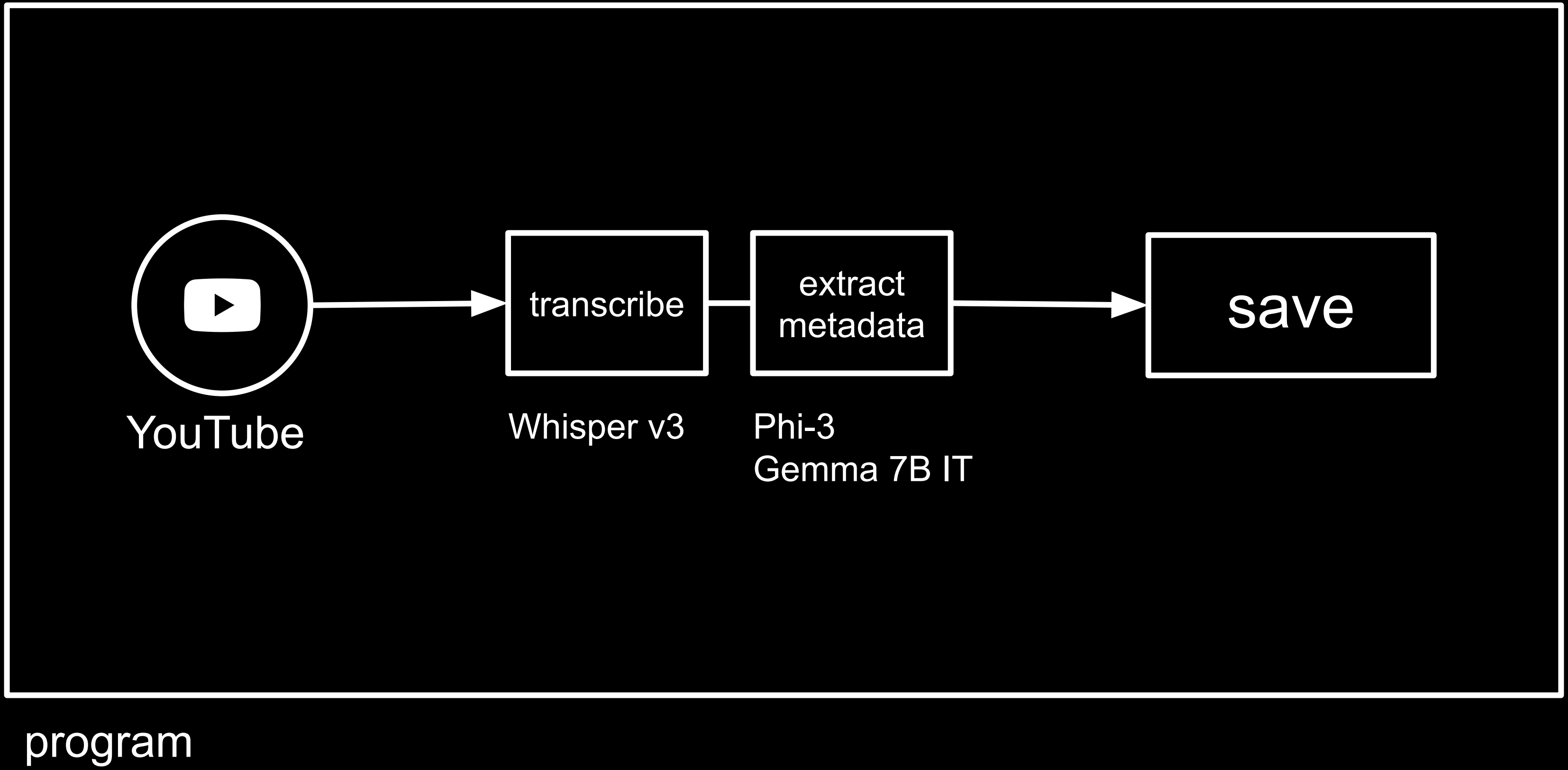
process

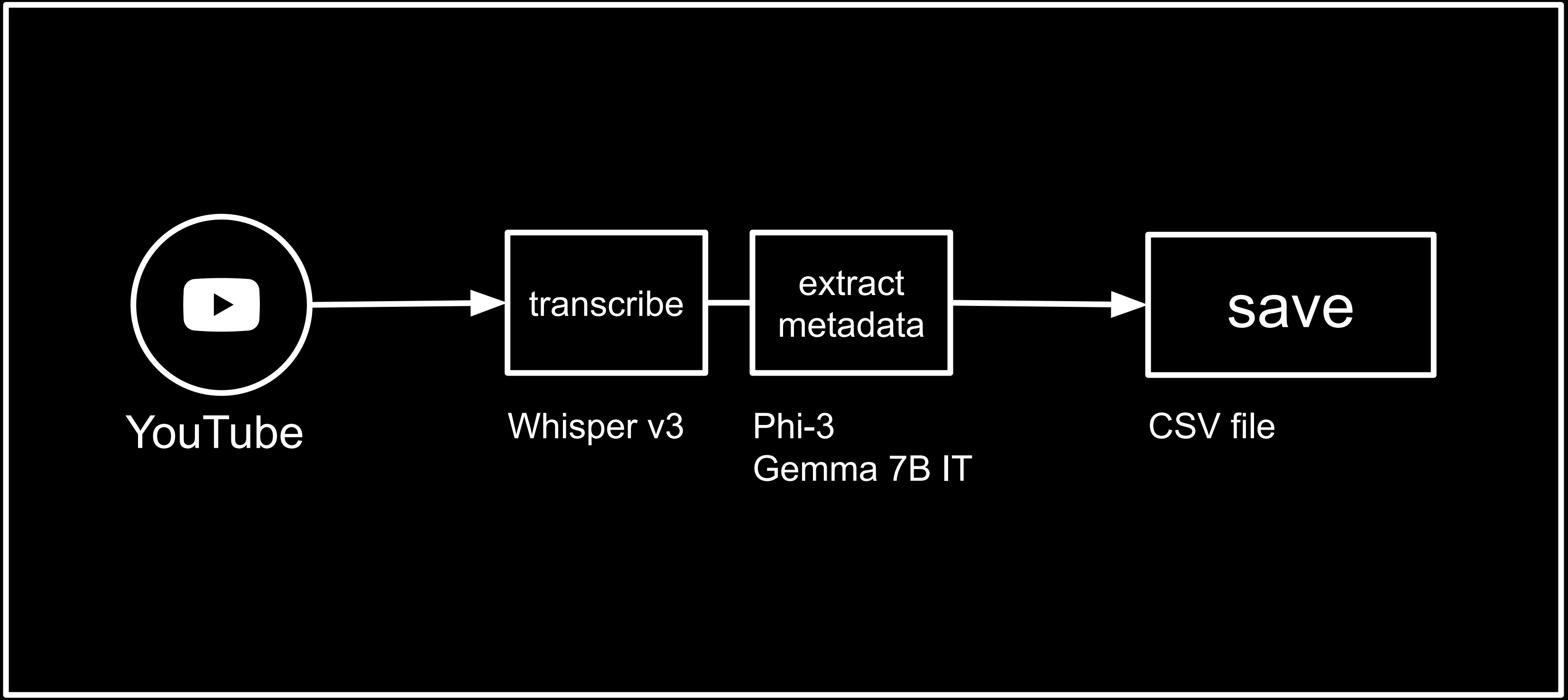
save

YouTube

machine learning

program


YouTube
transcribe
extract metadata
save
Whisper v3
Phi-3
Gemma 7B IT
program


YouTube
transcribe
Whisper v3
extract metadata
Phi-3
Gemma 7B IT
save
CSV file

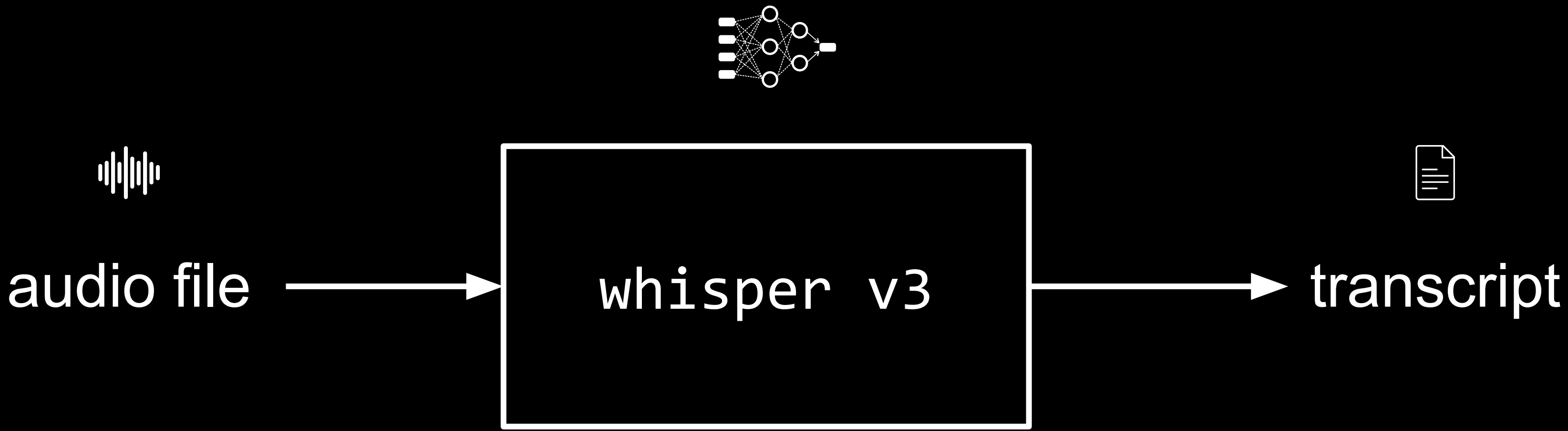
program

YouTube API

Whisper v3

https://arxiv.org/abs/2212.04356

https://huggingface.co/openai/whisper-large-v3



audio file

whisper v3

transcript

Large Language Models (LLM)

what has been said so far?

(*prompt / context*)

what has been said so far?
(*prompt / context*)

→

prediction of next token based on
learnt probability distribution

what has been said so far?
(*prompt / context*)

→

prediction of next token based on
learnt probability distribution

+

(randomness)

what has been said so far?
(*prompt / context*)

➡

prediction of next token based on
learnt probability distribution

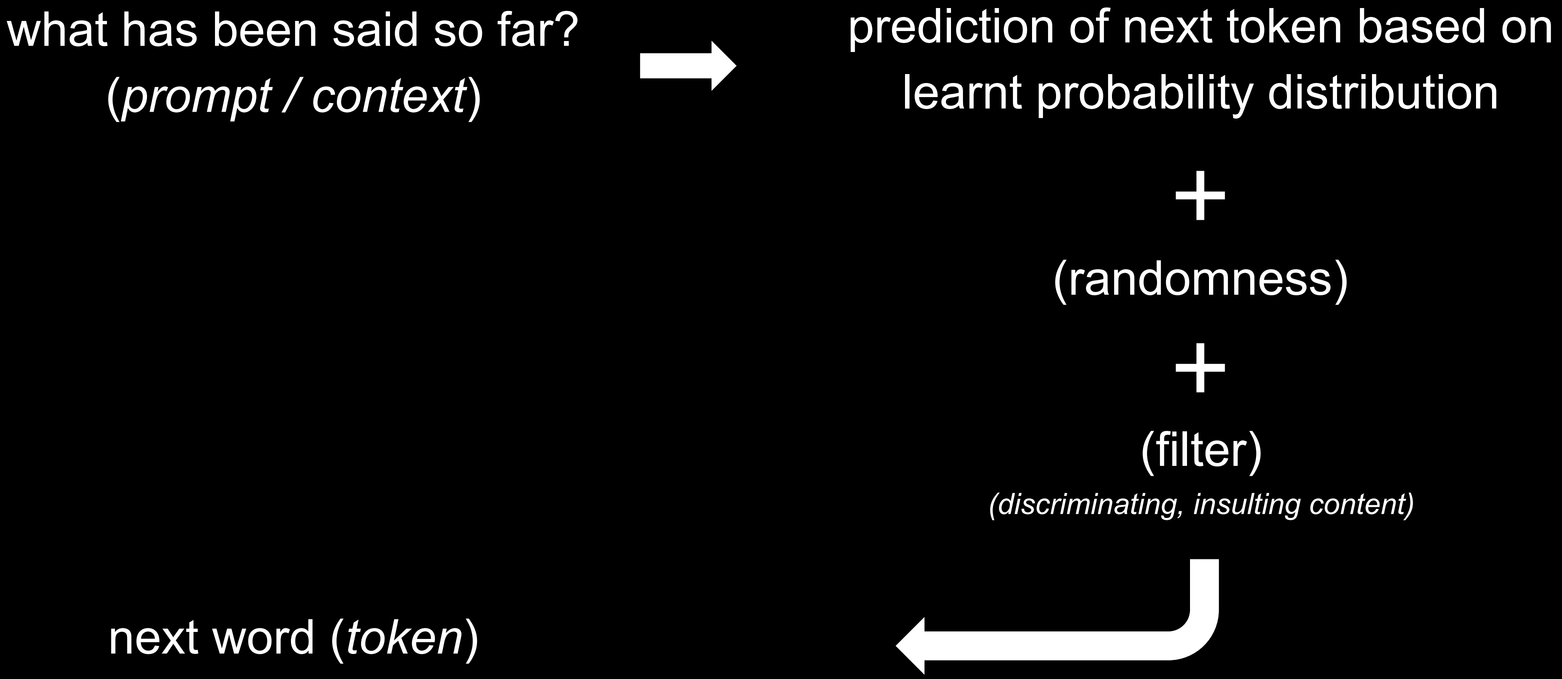
+

(randomness)

+

(filter)

(discriminating, insulting content)



what has been said so far?
(*prompt / context*)

prediction of next token based on learnt probability distribution

+

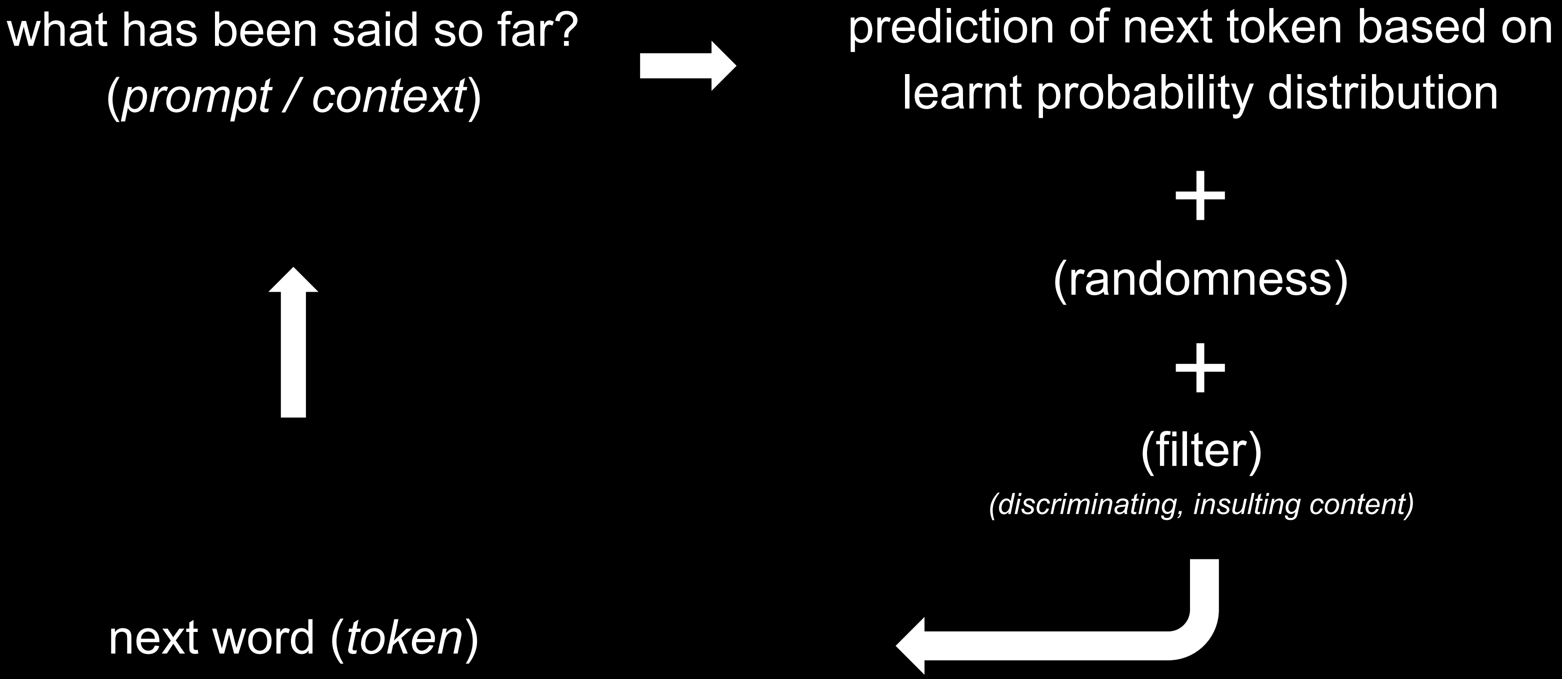
(randomness)

+

(filter)

(discriminating, insulting content)

next word (*token*)



what has been said so far?
(*prompt / context*)

prediction of next token based on learnt probability distribution

+

(randomness)

+

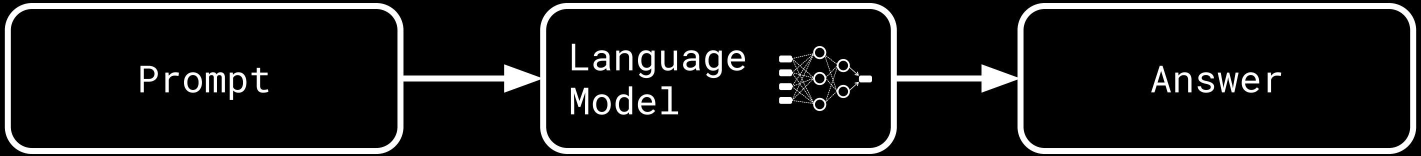
(filter)

(discriminating, insulting content)

next word (*token*)

PROMPTING

https://www.promptingguide.ai/



Prompt

Language Model

Answer

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Explain the binary number system.
```

elements of a prompt

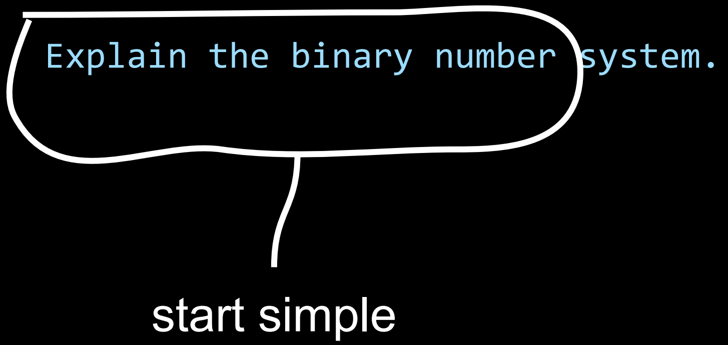
```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt



```
Explain the binary number system.
```

start simple

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
You are a friendly tutor and your
task is to explain complex
concepts as simple as possible.

Explain the binary number system.
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
You are a friendly tutor and your
task is to explain complex
concepts as simple as possible.

Your answers are never longer
than 10 sentences.

Explain the binary number system.
```

ZERO-SHOT PROMPTING

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Classify the text into neutral,
negative or positive.

Text: "What a great dinner!"

Sentiment:
```

elements of a prompt

```
<instruction>

<context>

<input data>

<output indicator>
```

example prompt

```
Classify the text into neutral,
negative or positive.

Text: "What a great dinner!"

Sentiment:
```

this will be replaced with data later…

FEW-SHOT PROMPTING

IN-CONTEXT LEARNING

examples in the context to learn from

```
Extract all references to countries and their continent in the following text
using the format from the examples below.

Example 1: "They played the team called 'Die Mannschaft' in the world cup final"
Correct answer: Germany, Europe

Example 2: "The Three Lions once again lost to Germany in a semi final"
Correct answer: England, Europe, Germany, Europe

Text: "The Selecao was destroyed 1:7 by the DFB selection in their home stadium."
Answer:
```

examples in the context to learn from

```
Extract all references to countries and their continent in the following text
using the format from the examples below.

Example 1: "They played the team called 'Die Mannschaft' in the world cup final"
Correct answer: Germany, Europe

Example 2: "The Three Lions once again lost to Germany in a semi final"
Correct answer: England, Europe, Germany, Europe

Text: "The Selecao was destroyed 1:7 by the DFB selection in their home stadium."
Answer:
```

more prompting strategies

chain-of-thought (CoT)

self-consistency

generate knowledge prompting

prompt chaining (subtasks)

tree-of-thoughts (ToT)

retrieval-augmented-generation (RAG)

…

Phi-3

https://arxiv.org/abs/2404.14219

~~https://huggingface.co/microsoft/Phi-3-mini-128k-instruct~~

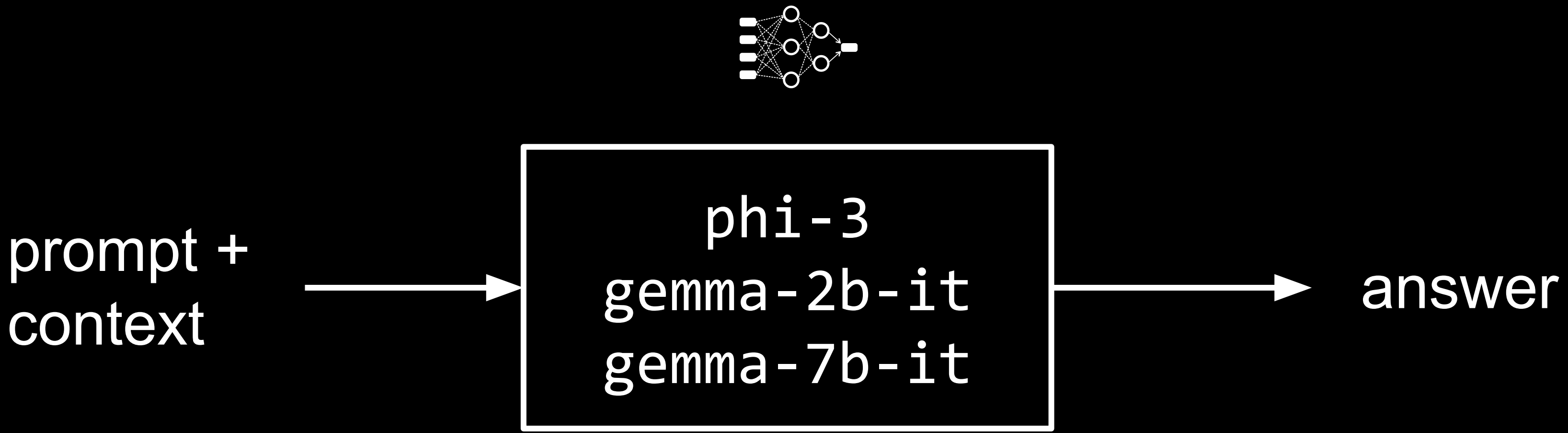
https://huggingface.co/microsoft/Phi-3-medium-128k-instruct

Gemma 2B / 7B Instruct

https://arxiv.org/abs/2403.08295

https://huggingface.co/google/gemma-2b-it

https://huggingface.co/google/gemma-7b-it



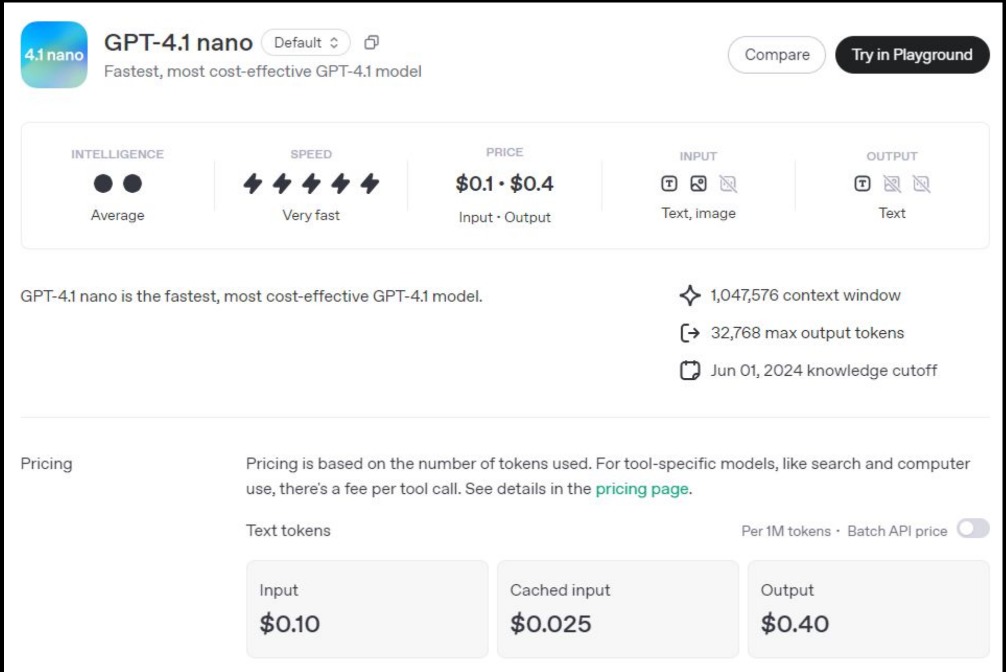
prompt + context

phi-3
gemma-2b-it
gemma-7b-it

answer

OpenAI's GPT-4.1 family

https://platform.openai.com/docs/models



GPT-4.1 nano

Fastest, most cost-effective GPT-4.1 model

INTELLIGENCE	SPEED	PRICE	INPUT	OUTPUT
●●	⚡⚡⚡⚡⚡	$0.1 · $0.4		
Average	Very fast	Input · Output	Text, image	Text

GPT-4.1 nano is the fastest, most cost-effective GPT-4.1 model.

- 1,047,576 context window
- 32,768 max output tokens
- Jun 01, 2024 knowledge cutoff

Pricing

Pricing is based on the number of tokens used. For tool-specific models, like search and computer use, there's a fee per tool call. See details in the pricing page.

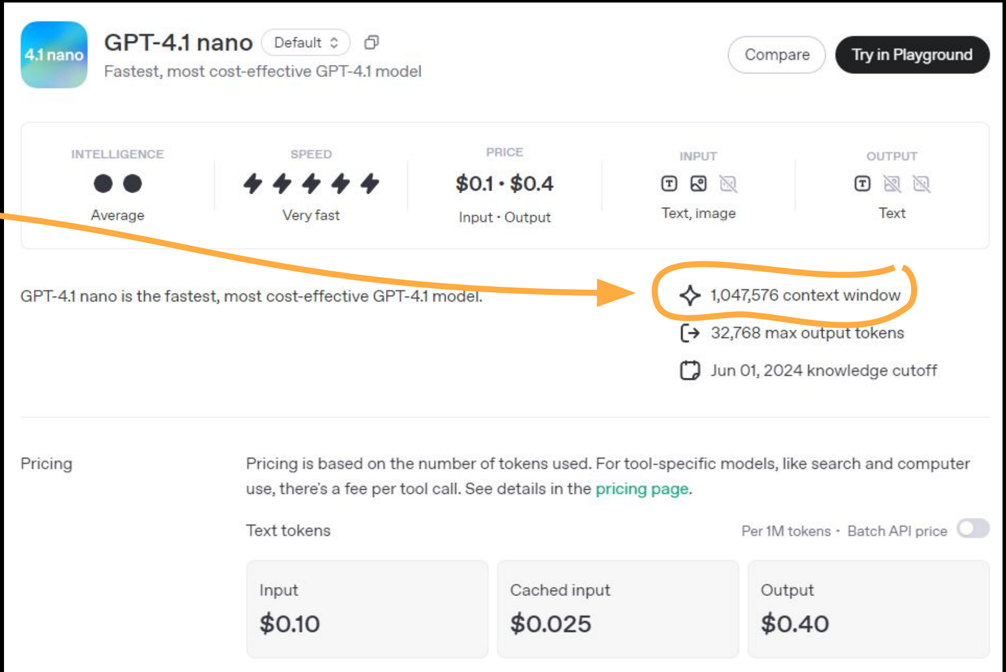
Text tokens

Per 1M tokens · Batch API price

Input	Cached input	Output
$0.10	$0.025	$0.40

https://platform.openai.com/docs/models/gpt-4.1-nano

1 mio. token →
~2500 pages



GPT-4.1 nano

Fastest, most cost-effective GPT-4.1 model

INTELLIGENCE	SPEED	PRICE	INPUT	OUTPUT
●●	⚡⚡⚡⚡⚡	$0.1 · $0.4		
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Text tokens

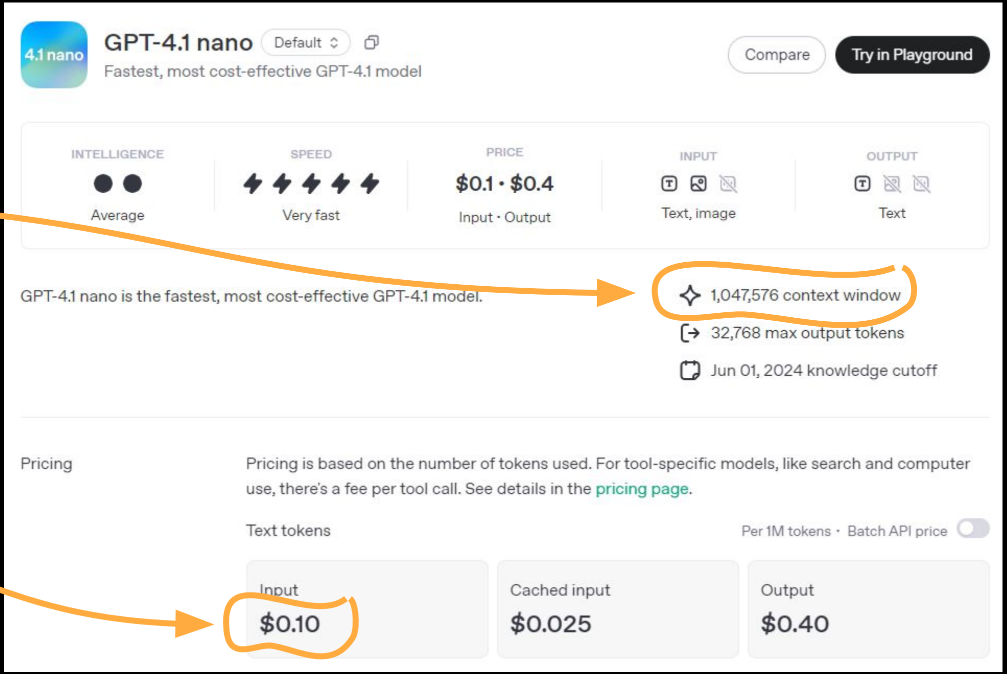
Per 1M tokens · Batch API price ○

Input	Cached input	Output
$0.10	$0.025	$0.40

https://platform.openai.com/docs/models/gpt-4.1-nano

1 mio. token →
~2500 pages

roughly 10 cents
as input



GPT-4.1 nano

Fastest, most cost-effective GPT-4.1 model

INTELLIGENCE	SPEED	PRICE	INPUT	OUTPUT
●●	⚡⚡⚡⚡⚡	$0.1 • $0.4		
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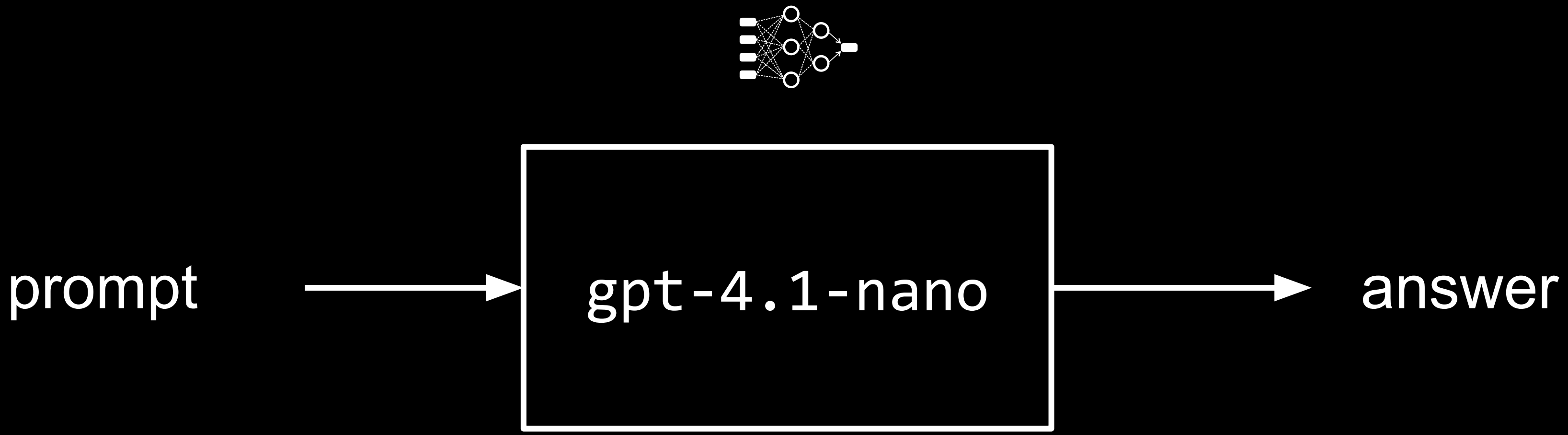
Per 1M tokens • Batch API price

Input	Cached input	Output
$0.10	$0.025	$0.40

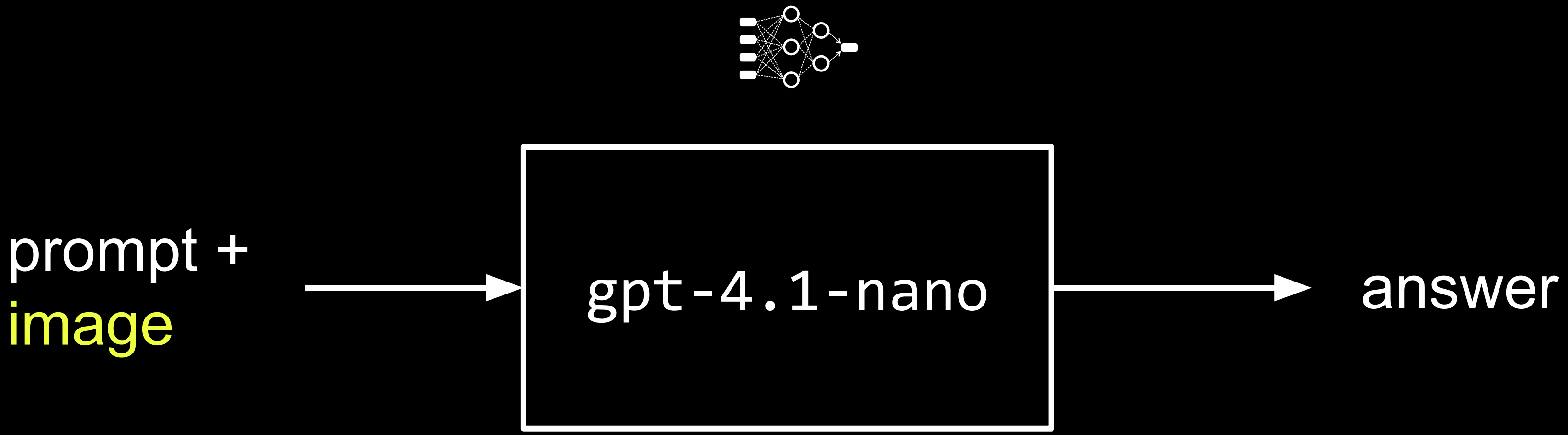
https://platform.openai.com/docs/models/gpt-4.1-nano



prompt

gpt-4.1-nano

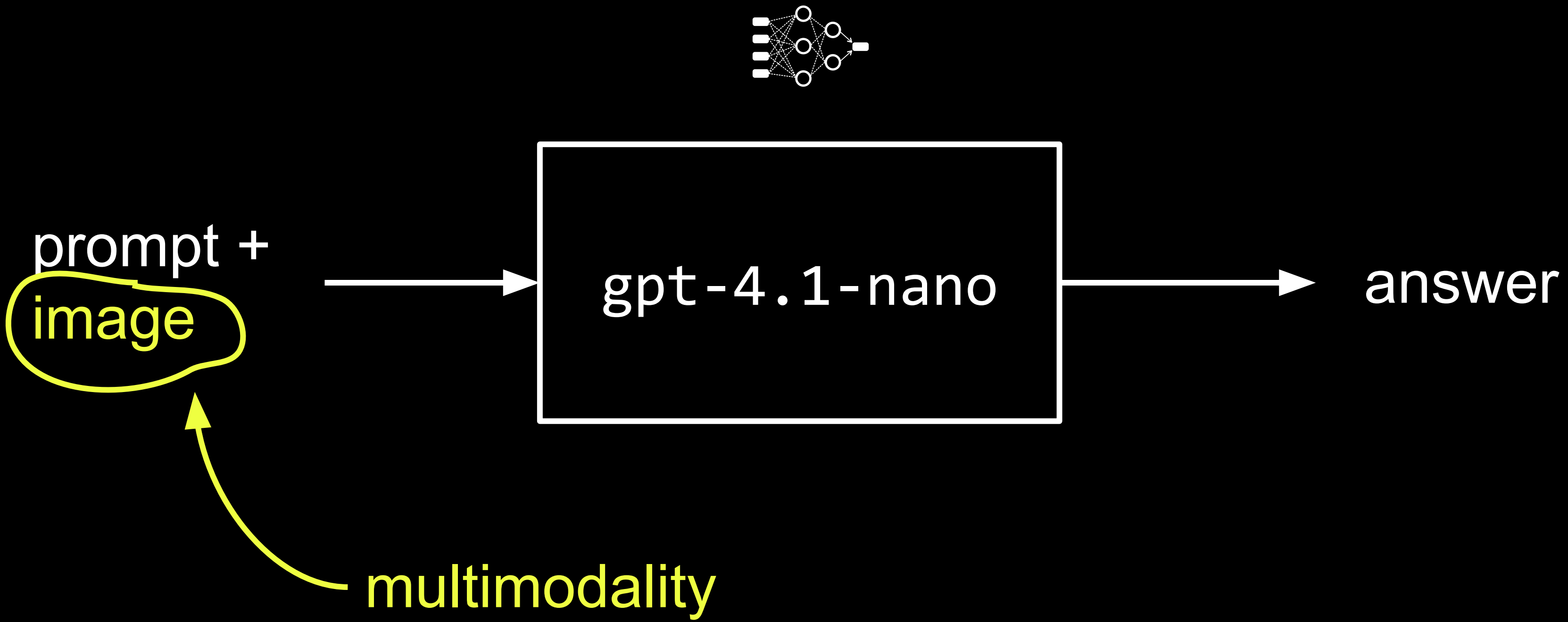
answer



prompt +
image

gpt-4.1-nano

answer



prompt +
image

gpt-4.1-nano

answer

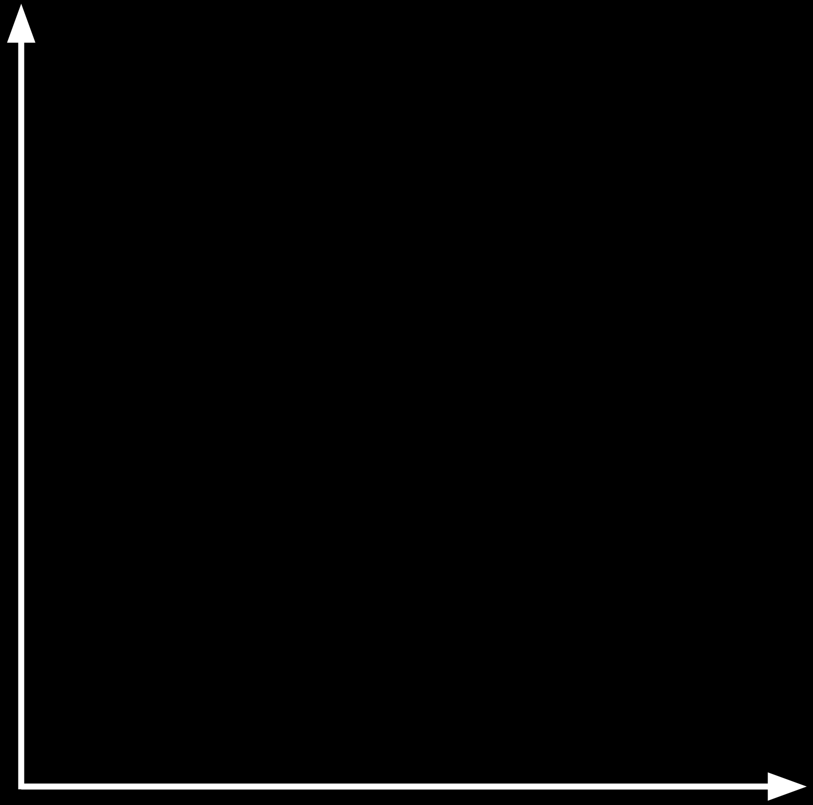
multimodality

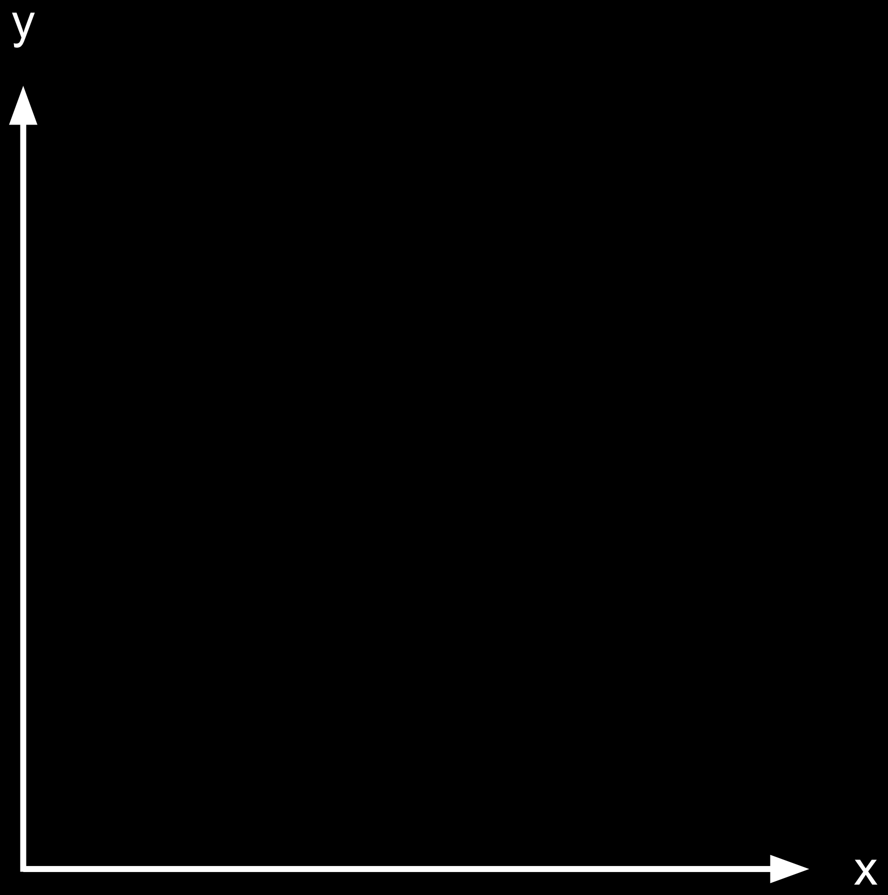
VISUALIZE DATA

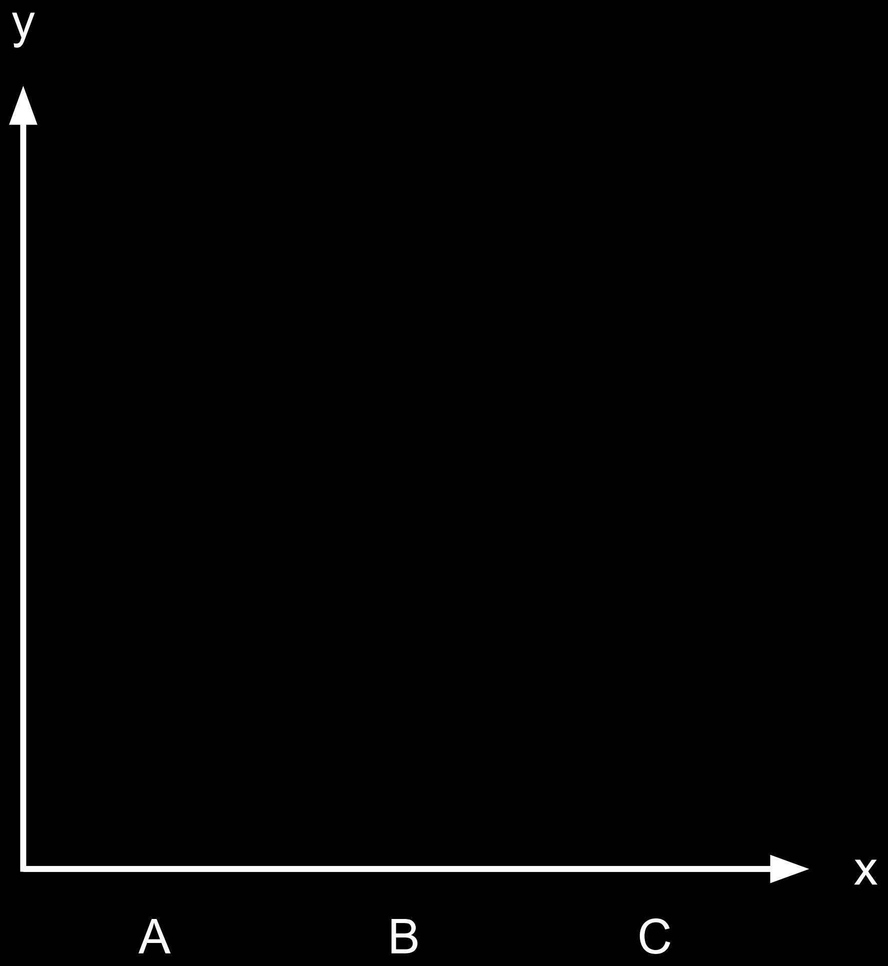
BACK

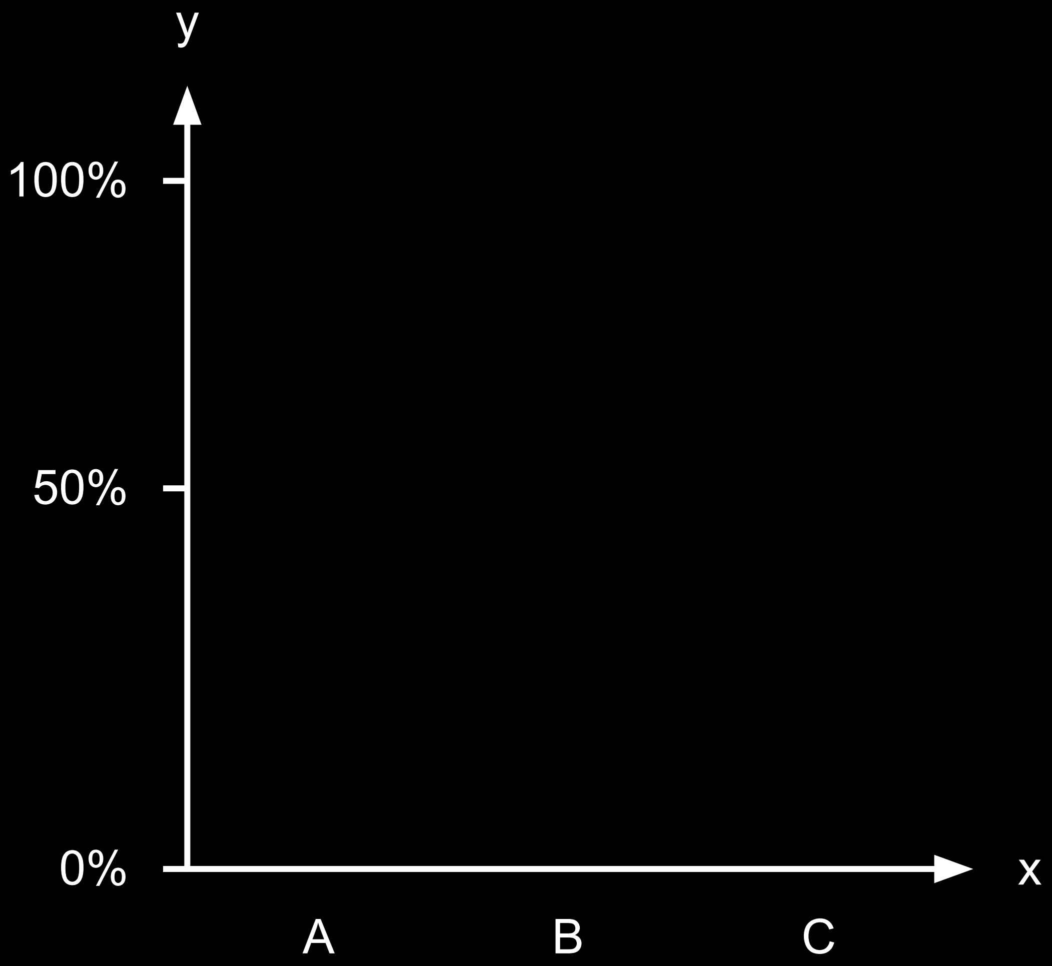
data

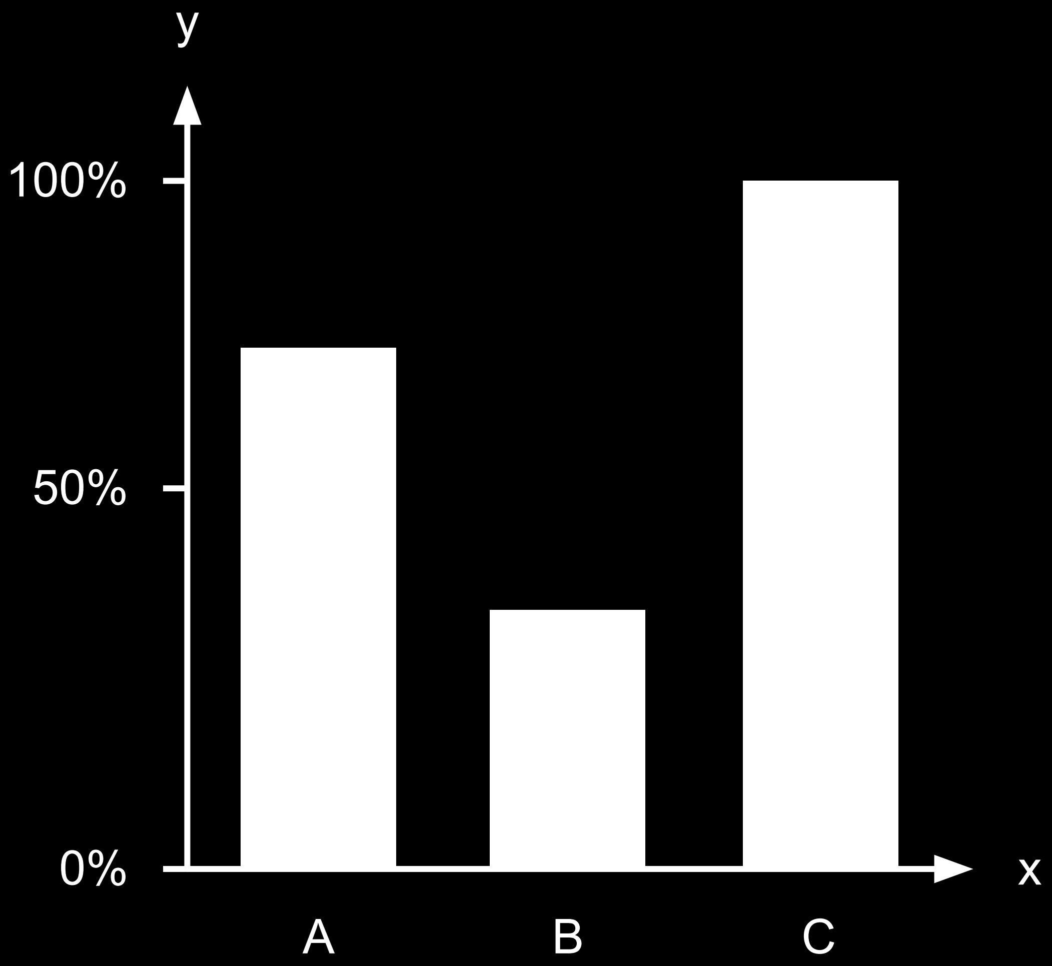
category	pct
A	75
B	33
C	100



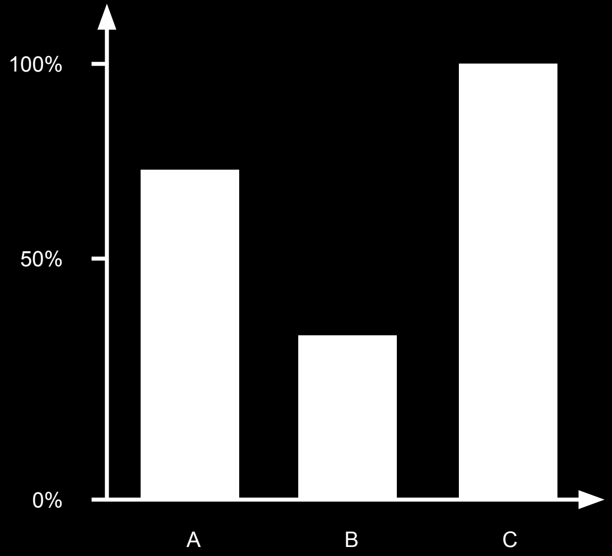

y
x


y
x
A
B
C


y
100%
50%
0%
x
A
B
C


y
100%
50%
0%
x
A
B
C

category	pct
A	75
B	33
C	100



{{ ggplot2 }}

why visualize?

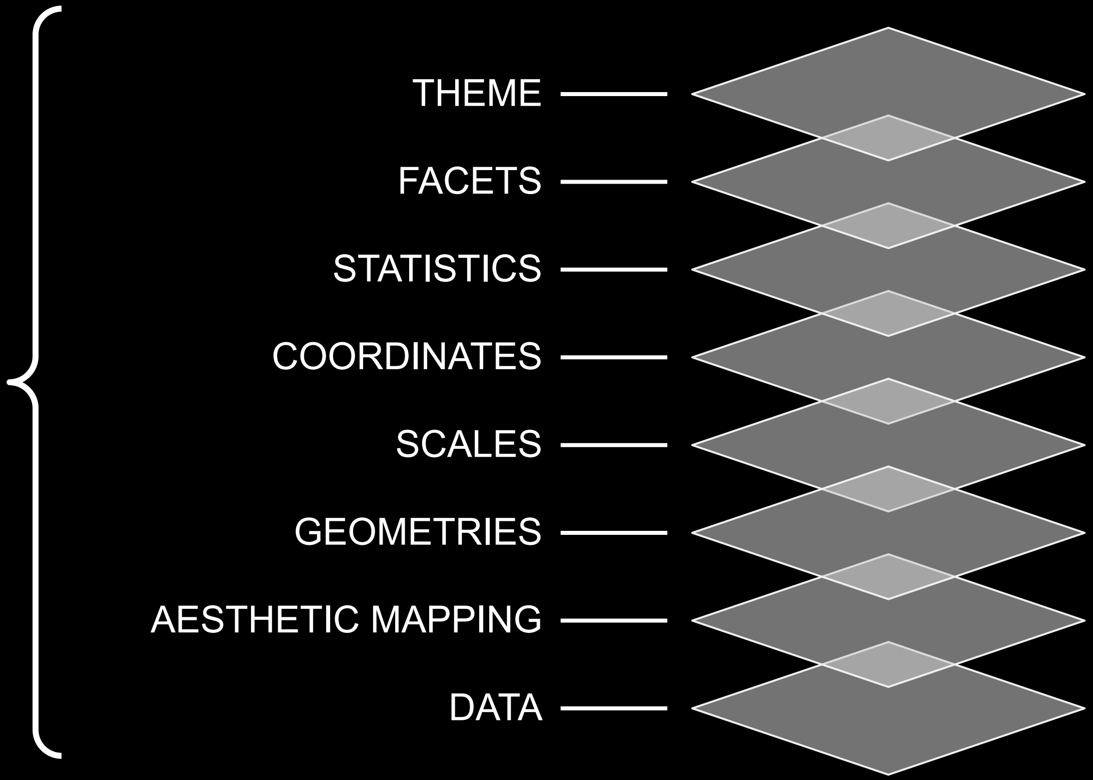
{{ ggplot2 }}

grammar of graphics

any

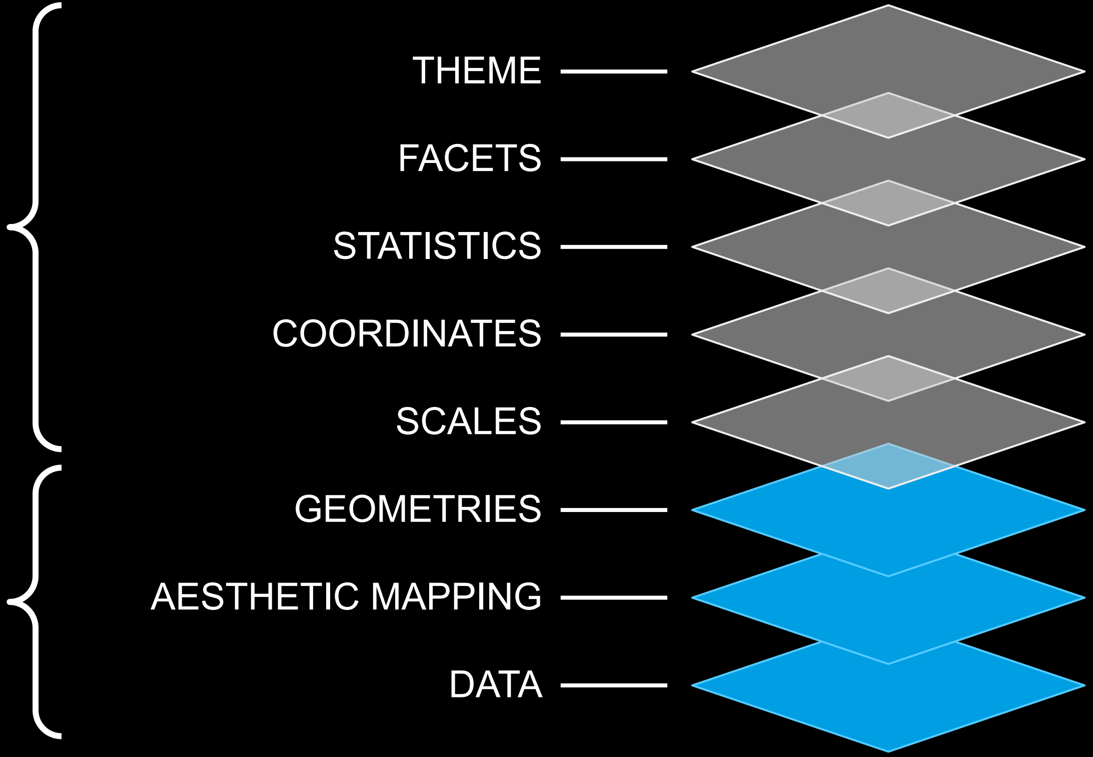
data

visualization



has useful defaults

mandatory



THEME

FACETS

STATISTICS

COORDINATES

SCALES

GEOMETRIES

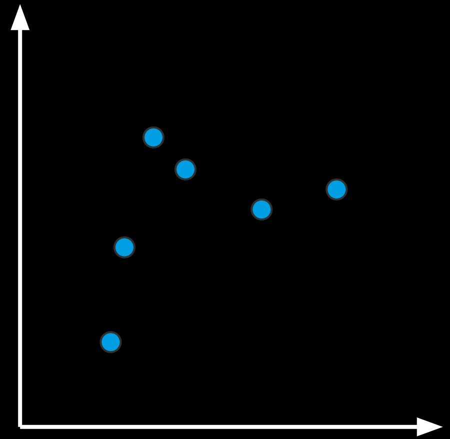
AESTHETIC MAPPING

DATA

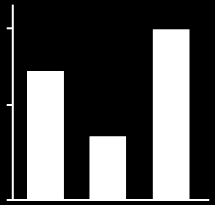
```
ggplot()
ggplot() +
  aes()
```

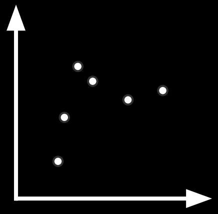
```
ggplot() +
  aes() +
  geom_point()
```

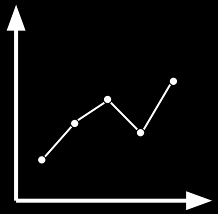
```
ggplot() +
  aes() +
  geom_point()
```

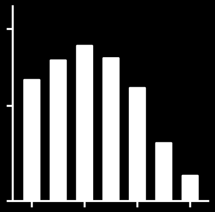


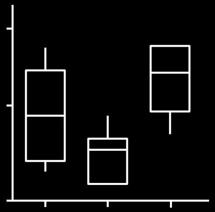
basic plots

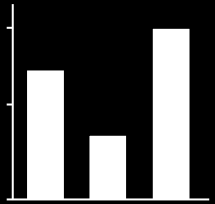




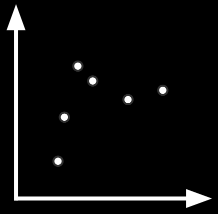




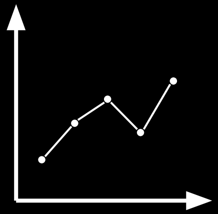




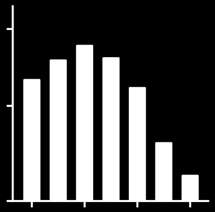
bar chart



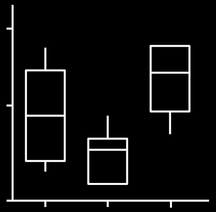
scatter plot



line chart

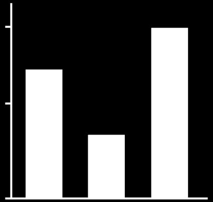


histogram



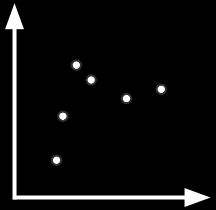
box plot

amounts
proportions
distributions (discrete)



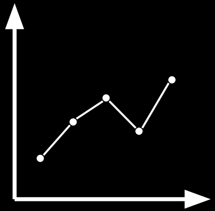
bar chart

associations
patterns



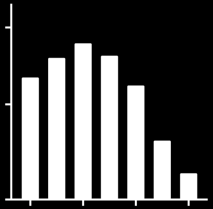
scatter plot

trends
developments



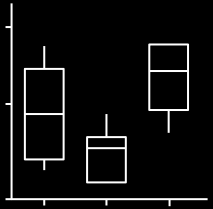
line chart

distributions (continuous)



histogram

compare distributions (continuous)



box plot

COMMUNICATE DATA

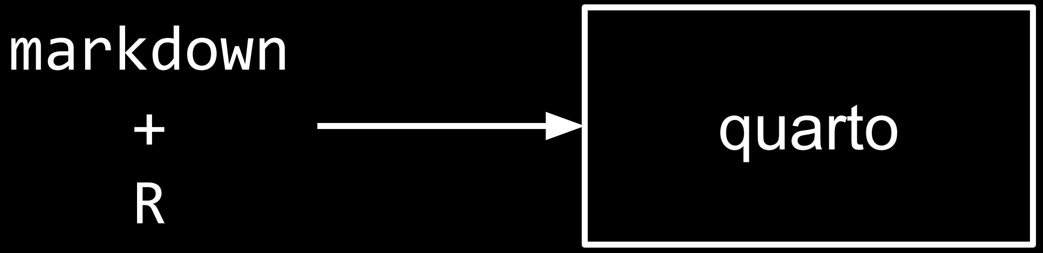
quarto

{{ quarto }}

markdown

+

R

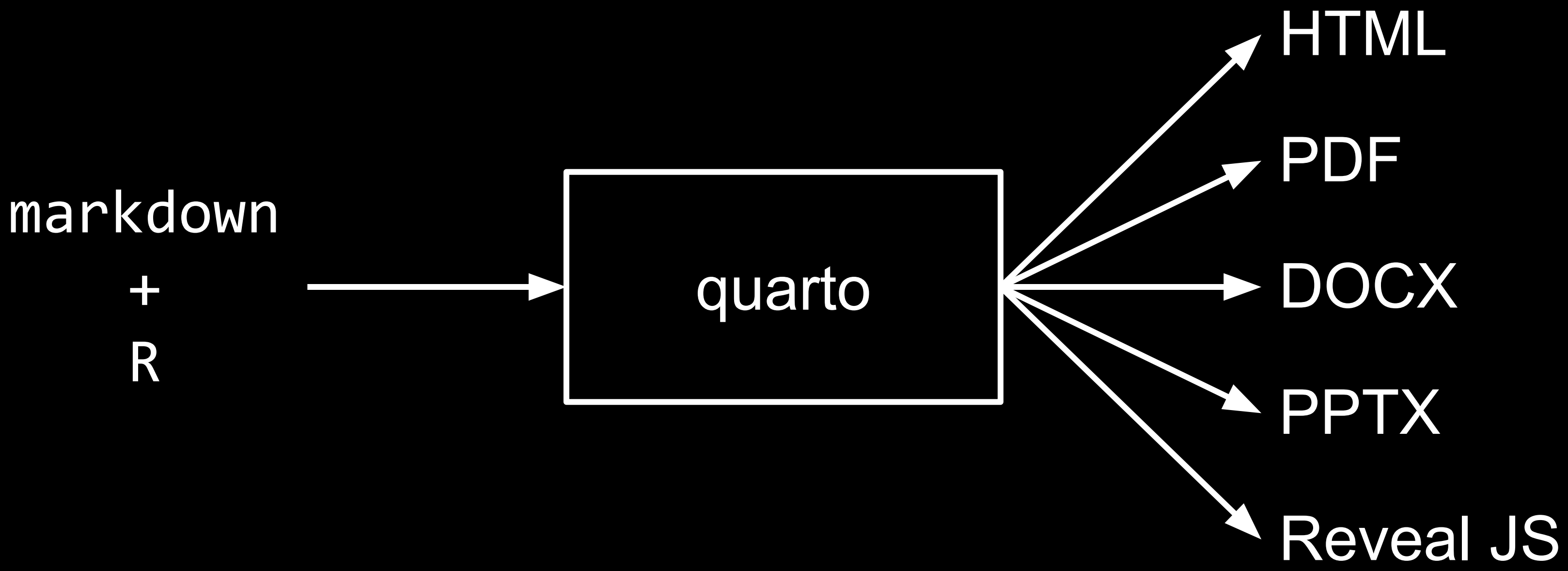


markdown

+

R

quarto



markdown
+
R

quarto

HTML

PDF

DOCX

PPTX

Reveal JS

markdown

```
# Heading 1

## Heading 2

### Heading 3

#### Heading 4
```

This is *italic*,

and this **bold**

This is rendered as `code`.

```
- List item A

- List item B

- List item C
```

1. First
2. Second
3. Third

```
![Image title](path/to/image.png)
```

```
![Image title](path/to/image.png){width=200}
```

```
![Image title](path/to/image.png){#fig-myimage}

For more details see @fig-myimage.
```

```
[Linked text](https://quarto.org)
```

~~~
```{r}
1 + 1
```
~~~

code options

~~~
```{r}
#| echo: false
1 + 1
```
~~~

~~~
```{r}
#| eval: false
x <- 1 + 1
```
~~~

~~~
```{r}
#| include: false
library(tidyverse)
```
~~~

~~~
```{r}
#| message: false
data <- read_csv("data.csv")
```
~~~

~~~
```{r}
#| warning: false
data <- read_csv("data.csv")
```
~~~

figures

~~~
```{r}
#| label: fig-tweets-per-user
#| fig-cap: "Tweets per User"
tweets |>
  ggplot() +
  aes(x = screen_name) +
  geom_bar()
```
~~~

~~~
```{r}
#| code-fold: true
#| code-summary: "Show code"
tweets |>
  ggplot() +
  aes(x = screen_name) +
  geom_bar()
```
~~~

cross references

~~~
```{r}
#| label: fig-tweets-per-user
#| fig-cap: "Tweets per User"
…
```

In @fig-tweets-per-user you can see an overview of the
number of tweets per user in the data set.
~~~

```
# Introduction {#sec-introduction}
…

# Analysis
As stated in @sec-introduction, the goal of this paper is
to analyze the user behavior with regard to the content
they tweet.
```

citation & bibliography

https://quarto.org/docs/authoring/citations.html

output formats

```
format: html
```

```yaml
format:
  html: default
  pdf: default
```

```yaml
format:
  html:
    code-fold: true
  pdf: default
```