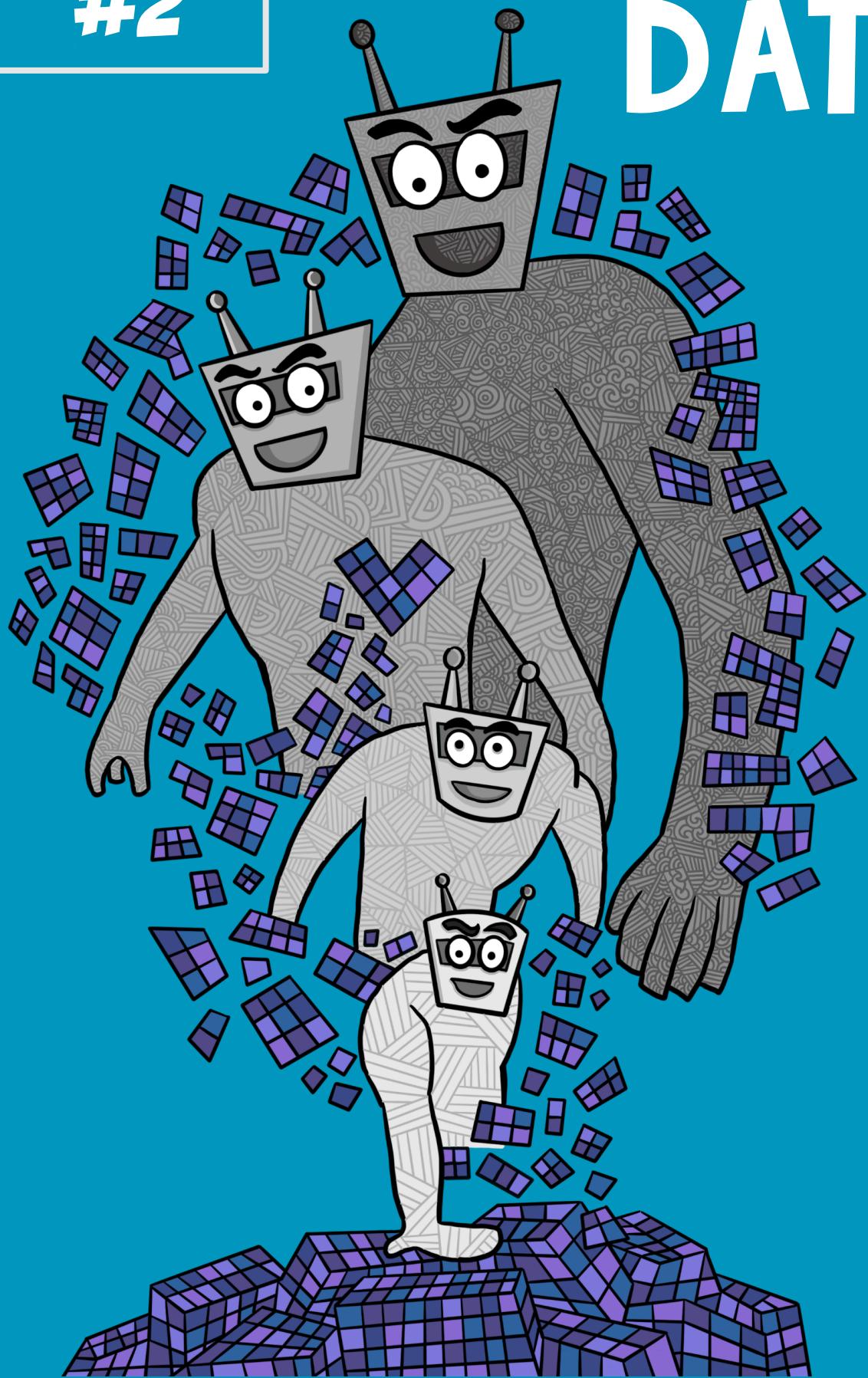


WE ARE AI
#2

Learning From **DATA**



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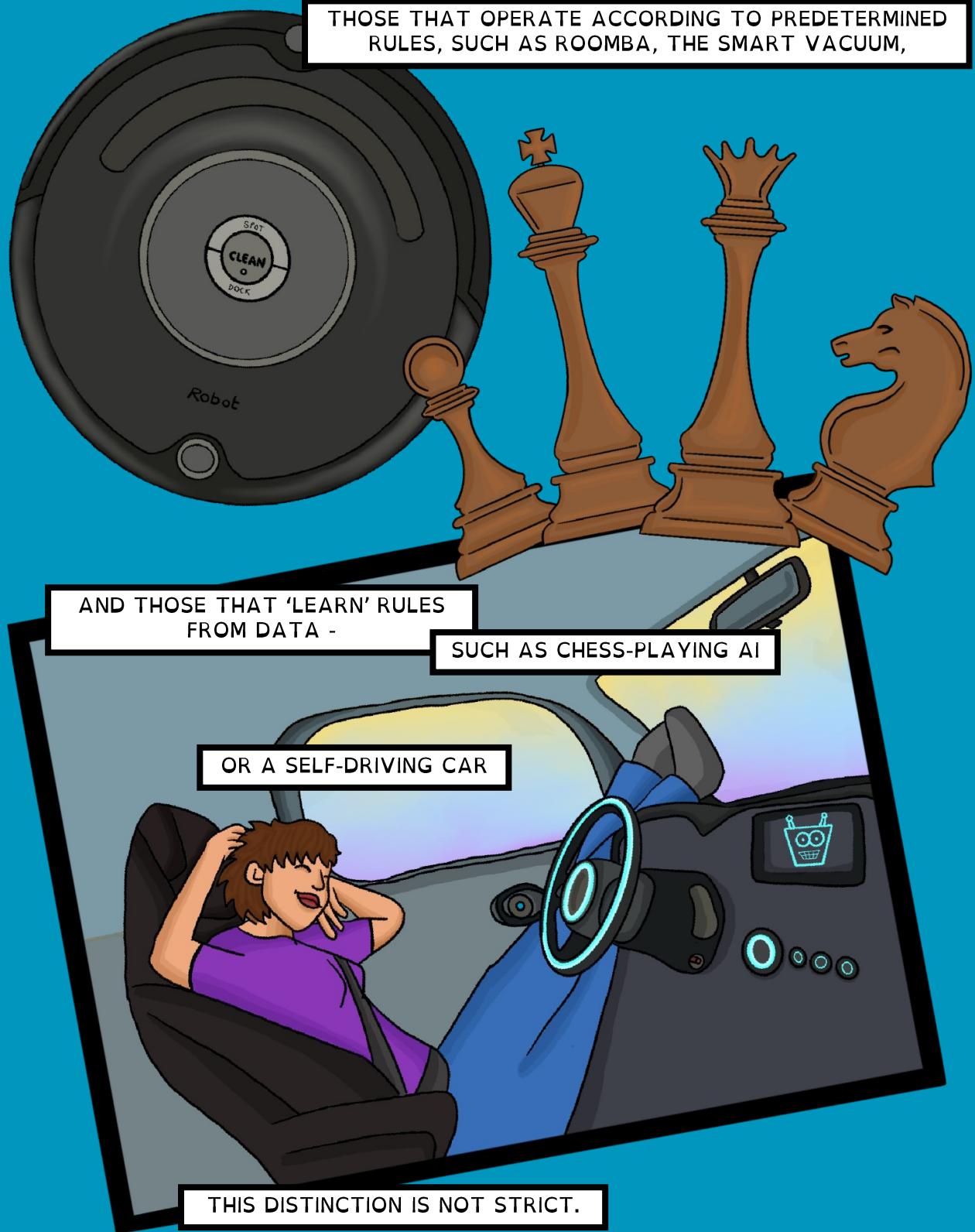
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WHEN TALKING ABOUT ARTIFICIAL INTELLIGENCE (AI), WE USUALLY MAKE A DISTINCTION BETWEEN 'CLASSICAL AI' SYSTEMS -

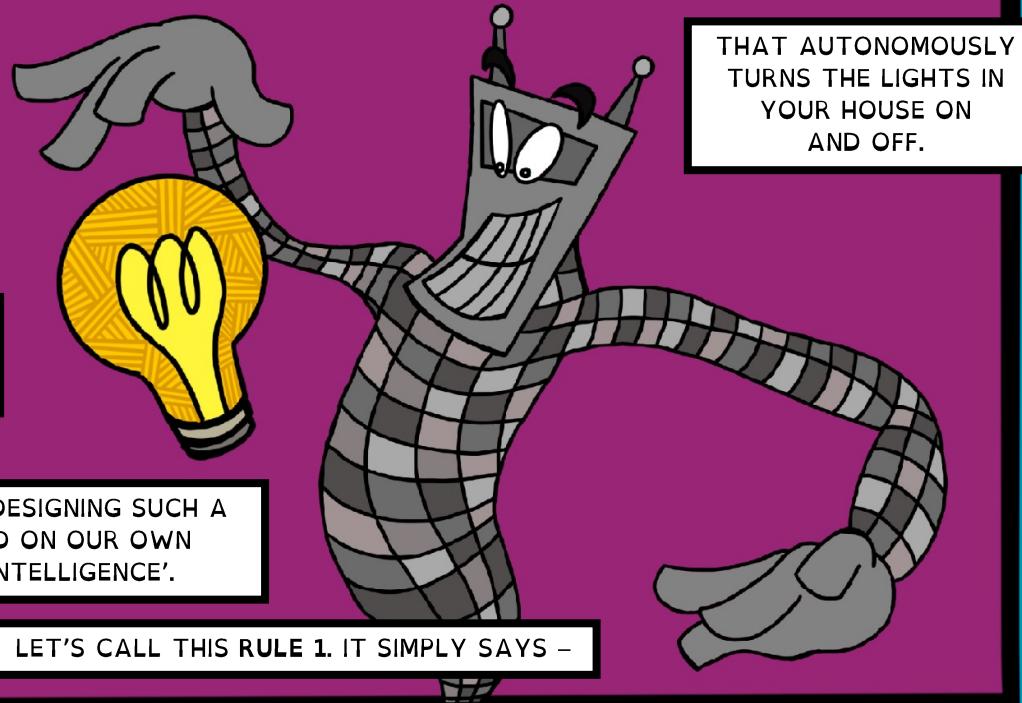
THOSE THAT OPERATE ACCORDING TO PREDETERMINED RULES, SUCH AS ROOMBA, THE SMART VACUUM,



IN FACT, MOST AI SYSTEMS OUT THERE IN THE WORLD TODAY COMBINE HAND-CRAFTED RULES WITH SOME FORM OF LEARNING.

LET'S SEE EXAMPLES OF SUCH RULES, AND SEE HOW MACHINES LEARN THEM FROM DATA!

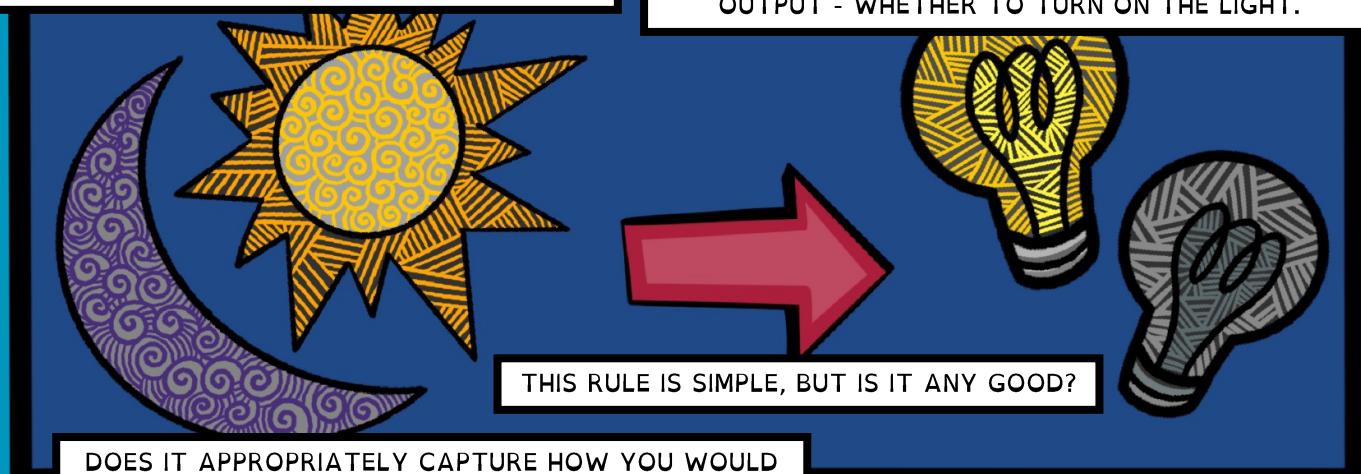
SUPPOSE THAT YOU ARE TASKED WITH DESIGNING A SMART LIGHTING SYSTEM -



THIS ALGORITHM IS VERY SIMPLE, IT'S JUST ONE STEP -

IT TAKES THE OUTSIDE CONDITIONS (WHETHER IT'S DARK OUTSIDE) AS AN INPUT,

AND USING RULE 1, PREDICTS THE APPROPRIATE OUTPUT - WHETHER TO TURN ON THE LIGHT.



DOES IT APPROPRIATELY CAPTURE HOW YOU WOULD MANUALLY OPERATE THE LIGHTS IN YOUR HOUSE?

LET'S RUN AN EXPERIMENT TO FIND OUT!

WE'LL COLLECT DATA ABOUT WHETHER IT'S DARK OUTSIDE AND WHETHER THE LIGHTS ARE ON IN THE HOUSE.

FOR EACH OBSERVATION, WE WILL CHECK WHETHER THE PREDICTION MADE BY OUR ALGORITHM IN FACT MATCHES WHAT WE OBSERVED.

A

FOR OBSERVATIONS A AND B, IT'S DARK OUT BUT WE'RE WATCHING TV AND EATING DINNER,



AND SO WE'VE LEFT THE LIGHTS ON.

AND THIS IS INDEED WHAT RULE 1 HAS PREDICTED!

THIS MEANS THAT A AND B BOTH SUPPORT THE HYPOTHESIS ENCODED BY RULE 1.

B



OBSERVATION C ALSO SUPPORTS THE HYPOTHESIS -

IT'S NICE AND BRIGHT OUTSIDE AND SO WE'VE KEPT THE LIGHTS OFF.

C



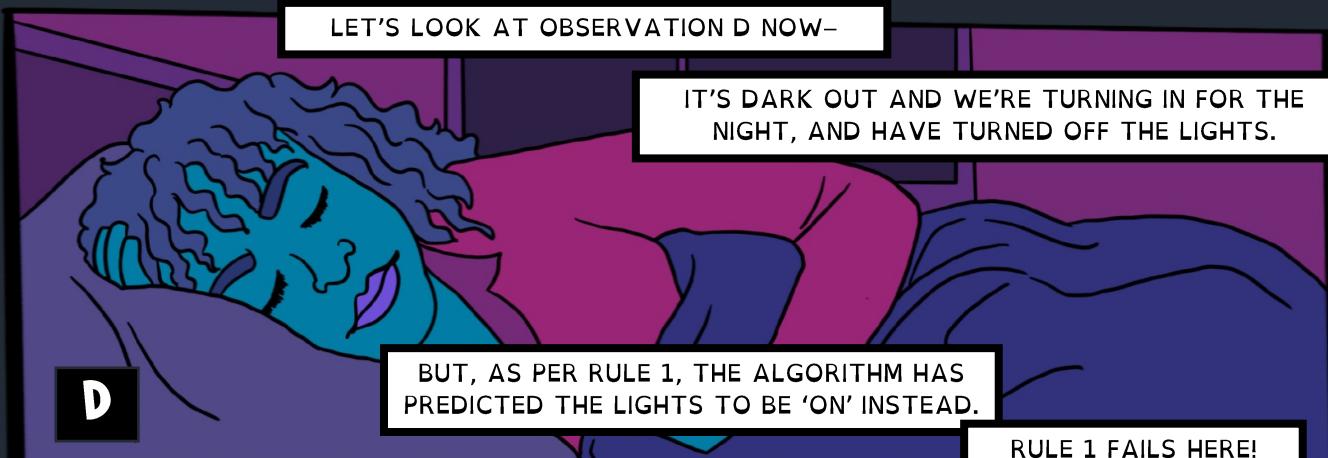
LET'S LOOK AT OBSERVATION D NOW-

IT'S DARK OUT AND WE'RE TURNING IN FOR THE NIGHT, AND HAVE TURNED OFF THE LIGHTS.

D

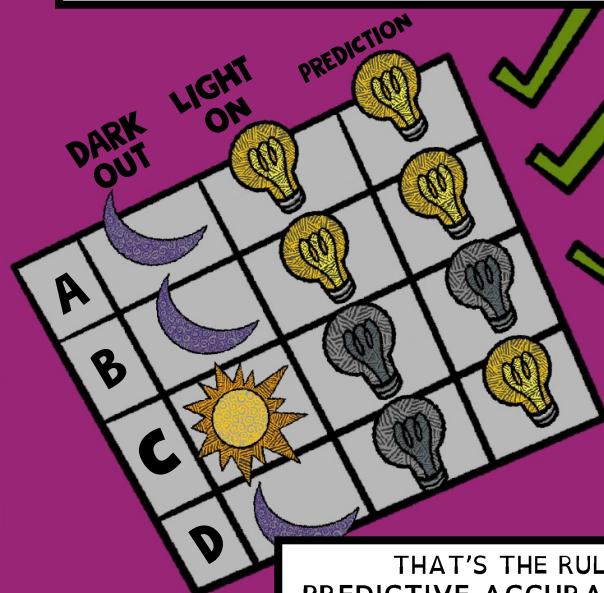
BUT, AS PER RULE 1, THE ALGORITHM HAS PREDICTED THE LIGHTS TO BE 'ON' INSTEAD.

RULE 1 FAILS HERE!

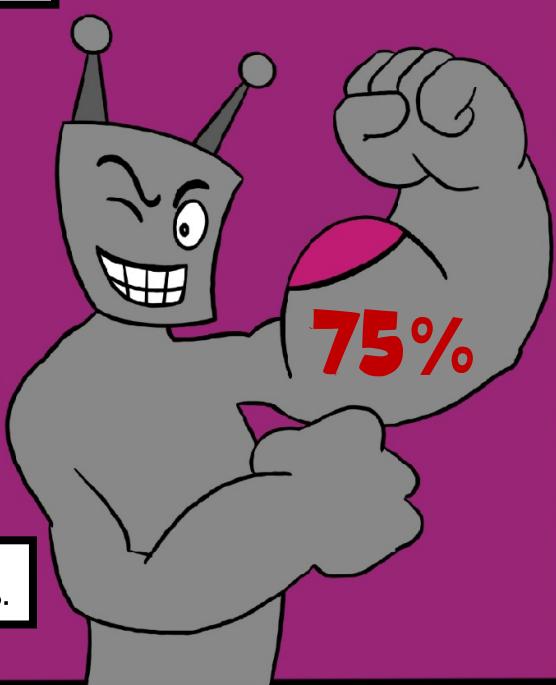


LET'S LOOK AT WHAT WE'VE LEARNED ABOUT RULE 1 FROM OUR EXPERIMENT-

OUR RULE WAS ABLE TO PREDICT THE OUTPUT CORRECTLY 3 TIMES OUT OF 4.



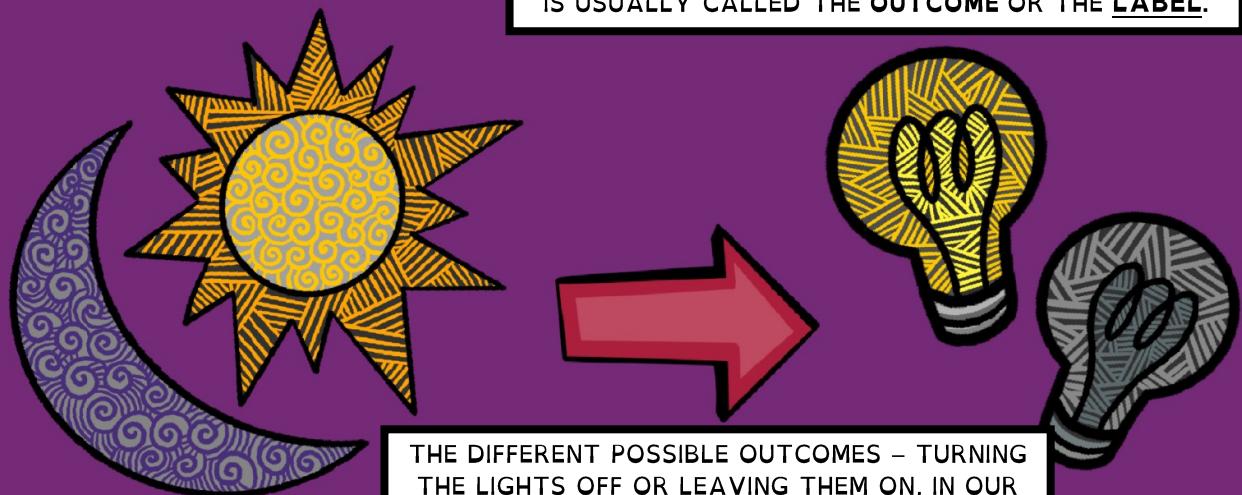
THAT'S THE RULE'S PREDICTIVE ACCURACY - 75%.



LET'S FIX SOME MORE TERMINOLOGY HERE -

IT'S CUSTOMARY TO REFER TO THE INPUT OF THE RULE - WHETHER IT'S DARK OUT, IN OUR EXAMPLE - AS THE INPUT FEATURE, OR JUST FEATURE.

THE OUTPUT - THE STATE OF OUR LIGHTS (ON/OFF) - IS USUALLY CALLED THE OUTCOME OR THE LABEL.



THE DIFFERENT POSSIBLE OUTCOMES - TURNING THE LIGHTS OFF OR LEAVING THEM ON, IN OUR EXAMPLE - ARE CALLED 'CLASSES'.

THE RULE WE ARE WORKING WITH IS CALLED A 'CLASSIFIER' - IT ASSIGNS A CLASS LABEL TO AN OBSERVATION.

THE CLASSIFIER WE DESIGNED USING RULE 1 CAN MAKE ONE OF TWO CHOICES - TURN THE LIGHTS EITHER ON OR OFF.

WE CALL SUCH CLASSIFIERS 'BINARY'.

BACK TO OBSERVATION D,
WHICH RULE 1 MISCLASSIFIED:

WHAT IS THE COST OF
THIS MISTAKE?

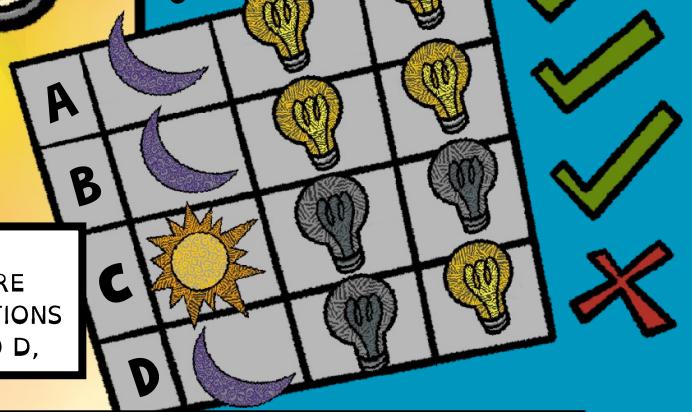
AS YOU PROBABLY GUessed, IT'S
THAT THE SMART LIGHT WOKE YOU
UP IN THE MIDDLE OF THE NIGHT!

WHAT CAN WE
DO ABOUT THIS?



DARK OUT LIGHT ON PREDICTION

IF WE
COMPARE
OBSERVATIONS
A, B AND D,



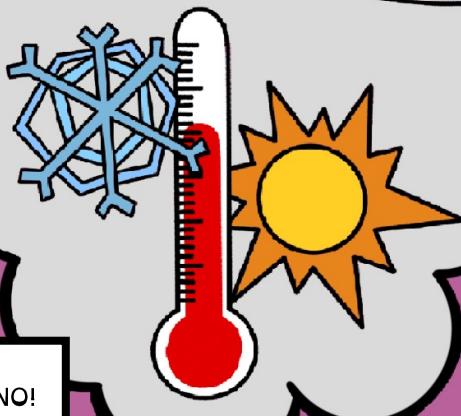
WE SEE THAT THEY HAVE THE SAME VALUE OF THE INPUT
FEATURE (IT'S DARK OUT), BUT DIFFERENT OUTPUTS.

THIS MAKES US THINK THAT WE NEED SOME ADDITIONAL
FEATURES TO DISTINGUISH BETWEEN THESE SITUATIONS.

NOW, A DECISION THAT YOU, AS THE
DESIGNER OF THIS SYSTEM, HAVE TO MAKE IS:

WHAT ARE SOME OTHER INPUTS
THAT MAY BE USEFUL?

BASED ON YOUR
EXPERIENCE,
WHAT FEATURES
DO YOU THINK
WILL BE HELPFUL
IN PREDICTING
THE OUTCOME?



THE OUTSIDE
TEMPERATURE? NO!

THE PRICE OF TEA IN CHINA? NO!

WELL, WHAT ABOUT -
WHETHER IT'S BEDTIME?



LET'S GET TO WORK TO REFINe OUR RULE!

HERE'S OUR REFINED RULE –

WE'LL CALL IT
RULE 2

"TURN ON THE
LIGHTS IF IT'S
DARK OUTSIDE,

AND IT'S NOT
YET BEDTIME.

OTHERWISE KEEP
THE LIGHTS OFF."

E

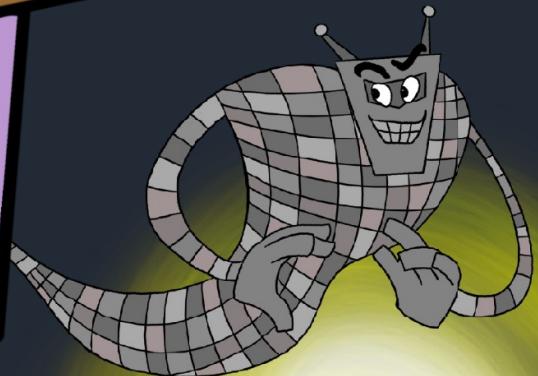
LET'S RE-RUN OUR EXPERIMENT,
COLLECT SOME MORE OBSERVATIONS
AND EVALUATE OUR NEW RULE.

VOILA! IT SEEMS TO BE
WORKING PERFECTLY –

F

WE DON'T NEED THE LIGHTS ON UNLESS IT'S DARK
OUTSIDE AND WE'RE AWAKE DOING SOMETHING!

G

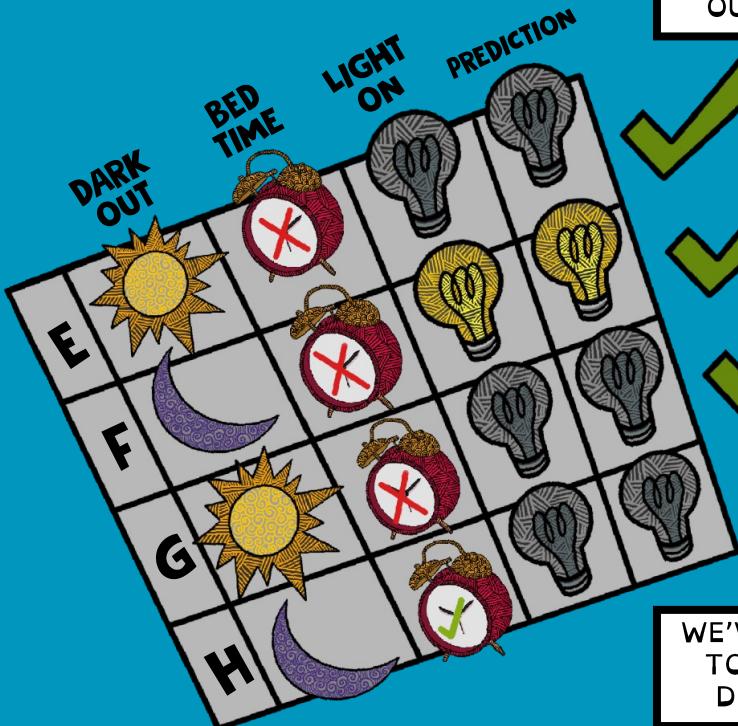


H

AND LOOK, THIS TIME IT'S TURNING OFF THE LIGHTS FOR US IF WE
FALL ASLEEP ON THE COUCH (PAST OUR BEDTIME) – SO CARING!

RULE 2 HAS SHOWN PERFECT ACCURACY -

OUR ALGORITHM IS ABLE TO PREDICT THE OUTCOME CORRECTLY 100% OF THE TIME!



100%

WE'VE USED OUR INTUITION AND EXPERIENCE TO DEVISE A SUITABLE RULE, COLLECTED DATA TO VALIDATE ITS PERFORMANCE,

AND MADE THE NECESSARY ADJUSTMENTS UNTIL WE REACHED A PERFORMANCE THAT WE'RE HAPPY WITH!

IN FACT, WE ARE SO HAPPY WITH OUR SMART LIGHT

— WITH HOW CONVENIENT IT IS, AND HOW IT'S HELPING US CONSERVE ENERGY —

THAT WE WANT TO OFFER IT TO OTHERS TO USE.

LET'S SEE IF IT WORKS FOR OUR FRIEND ANN TO USE AT HER OFFICE.

BUT BEFORE WE GO AHEAD AND REWIRE ANN'S ENTIRE OFFICE BUILDING, LET'S COLLECT SOME USAGE PATTERNS TO SEE WHETHER OUR RULE WOULD BE EFFECTIVE.

YOU KNOW THE DRILL – LET'S RUN AN EXPERIMENT!

RECALL RULE 2 -

"TURN ON THE LIGHTS IF IT'S DARK OUTSIDE, AND IT'S NOT YET BEDTIME. OTHERWISE KEEP THE LIGHTS OFF."

I



AT THE OFFICE, WE KEEP THE LIGHTS ON THROUGH THE DAY WHEN PEOPLE ARE WORKING.

BUT RULE 2 WOULD INCORRECTLY TURN THEM OFF, SINCE IT'S BRIGHT OUTSIDE

J



MOST EVENINGS, WHEN EVERYONE'S GONE HOME, THE LIGHTS ARE TURNED OFF.

K



BUT RULE 2 WOULD INCORRECTLY TURN THEM ON, SINCE IT'S DARK OUT!

L

ON WEEKENDS, THE OFFICE IS EMPTY AND SO THE LIGHTS ARE OFF THROUGHOUT THE DAY!

IN THIS CASE, RULE 2 WORKS CORRECTLY – IT KEEPS THE LIGHTS OFF, SINCE IT IS BRIGHT OUTSIDE.

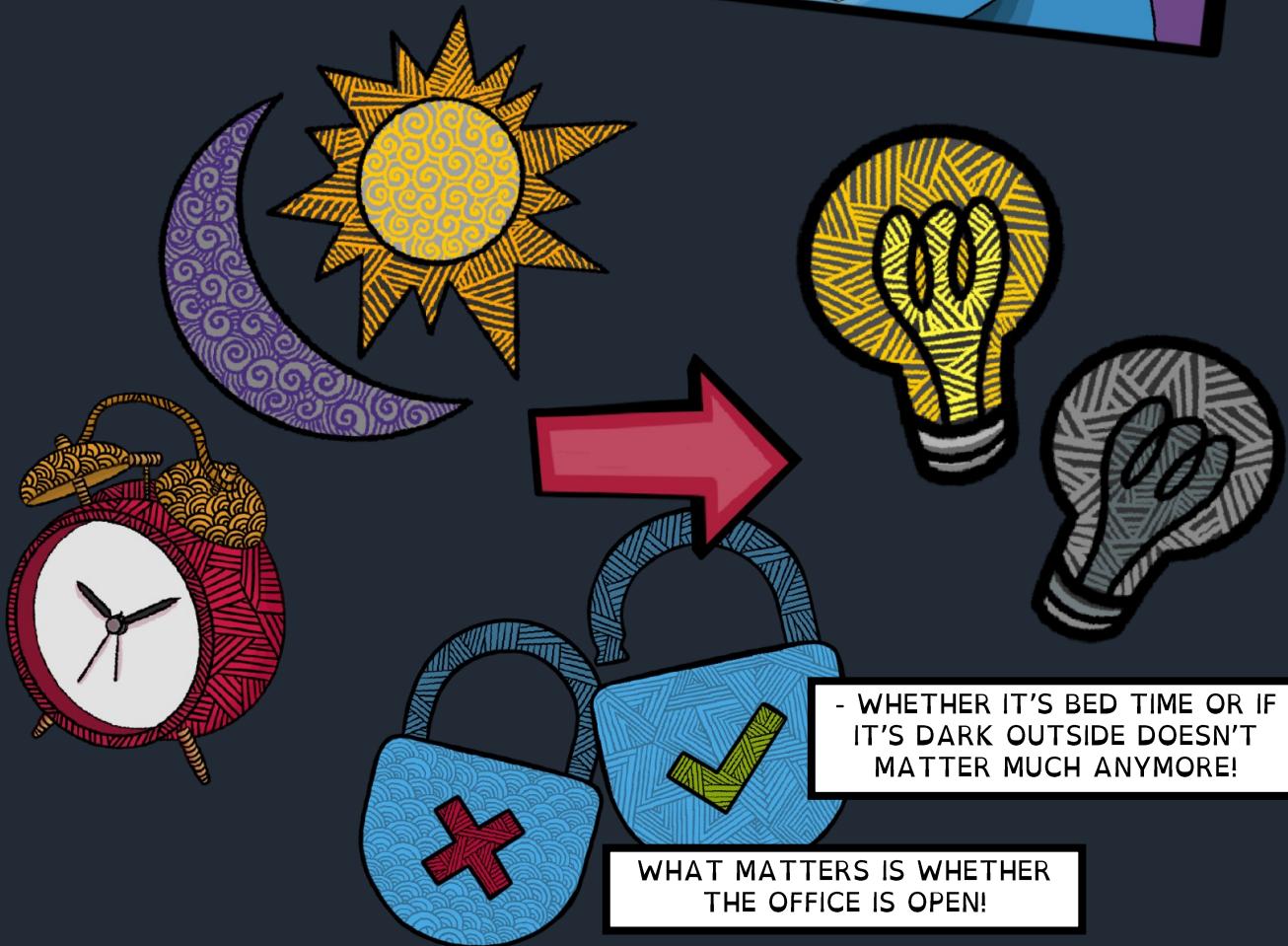
EVERY SO OFTEN SOMEONE STAYS LATE AT THE OFFICE, FINISHING UP DELIVERABLES IN TIME FOR A CRITICAL DEADLINE.



WE NEED THE LIGHTS ON IN THIS SCENARIO, BUT RULE 2 IS WRONG AGAIN- IT WOULD TURN THE LIGHTS OFF, SINCE IT'S LATE (PAST OUR USUAL BEDTIME).

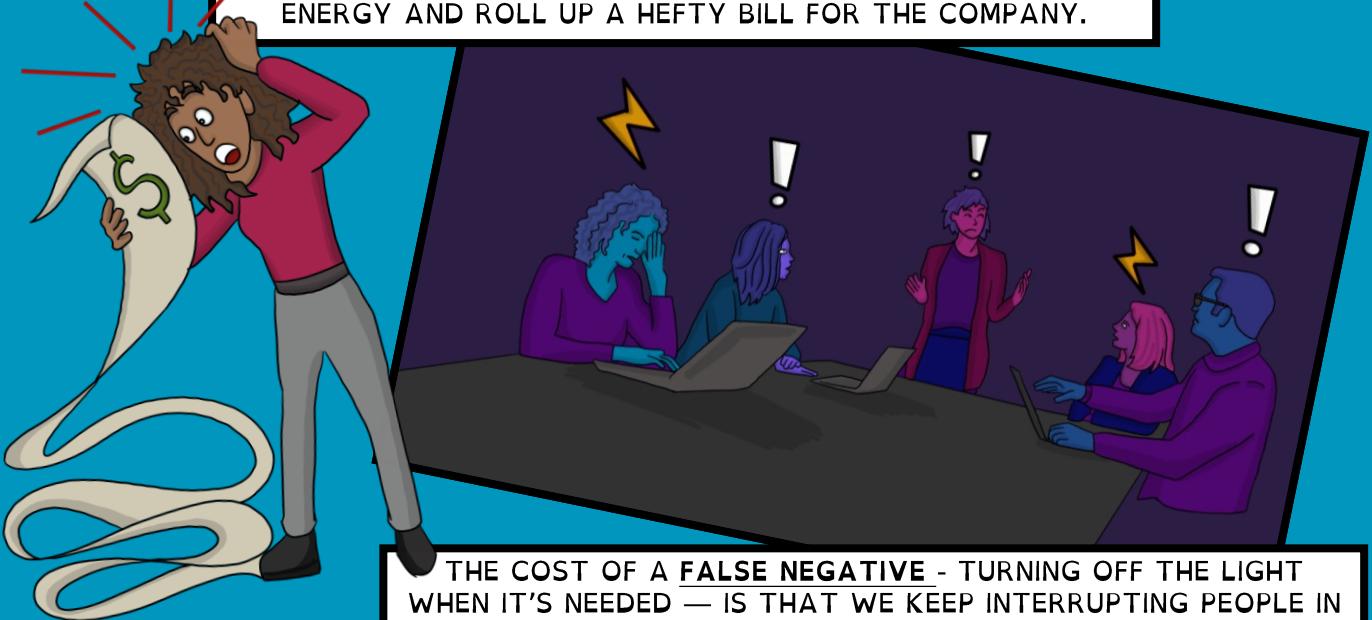
OH, NO! THAT MEANS WE ONLY GOT 1 CORRECT PREDICTION OUT OF 4!

IF WE ASSUME THAT LIGHTS ARE ON ABOUT HALF THE TIME,
WE WOULD HAVE DONE BETTER HAD WE JUST FLIPPED A COIN
TO DECIDE WHETHER TO TURN ON THE LIGHTS!



WHAT'S THE COST OF A MISTAKE HERE?

THE COST OF A **FALSE POSITIVE** - UNNECESSARILY TURNING ON THE LIGHT WHEN IT SHOULD BE OFF - IS THAT WE WASTE ENERGY AND ROLL UP A HEFTY BILL FOR THE COMPANY.



THE COST OF A **FALSE NEGATIVE** - TURNING OFF THE LIGHT WHEN IT'S NEEDED — IS THAT WE KEEP INTERRUPTING PEOPLE IN THE MIDDLE OF THEIR WORK AND THEIR PRODUCTIVITY SUFFERS.

WHAT SHOULD WE DO? GO BACK TO THE DRAWING BOARD AGAIN?

THINK ABOUT WHAT ADDITIONAL FEATURES TO USE, COLLECT THAT DATA,

AND RUN AN EXPERIMENT TO CHECK WHETHER OUR RULE IN FACT WORKS?

BUT THIS IS TEDIOUS!

AND MOST IMPORTANTLY - IT WILL BE VERY HARD FOR US TO CONTINUE DERIVING THESE RULES THAT ARE GETTING MORE AND MORE COMPLEX,

DEPENDING ON THE LOCATIONS WHERE THE SMART LIGHT IS USED, AND THEIR DIFFERENT REQUIREMENTS!

THE ANSWER IS – USE A MACHINE LEARNING ALGORITHM TO IDENTIFY STATISTICAL PATTERNS IN OUR DATA - TO 'LEARN' THE RULES AUTOMATICALLY!

BUT JUST AS WE DESIGNED EXPERIMENTS TO CHECK WHETHER THE RULES WE CAME UP WITH WERE ANY GOOD,

SO, TOO, SHOULD WE DESIGN EXPERIMENTS TO TEST WHETHER THE RULES THAT ARE AUTOMATICALLY LEARNED WORK WHEN DEPLOYED.

THIS IS BECAUSE WHAT RULE IS LEARNED IS FULLY DEPENDENT ON HISTORICAL DATA -

IF THAT DATA IS REPRESENTATIVE OF FUTURE USE OF THE SMART LIGHT SYSTEM,

THEN THE RULE WILL WORK WELL.

BUT IF THE ACTUAL USE CASE IS DIFFERENT,

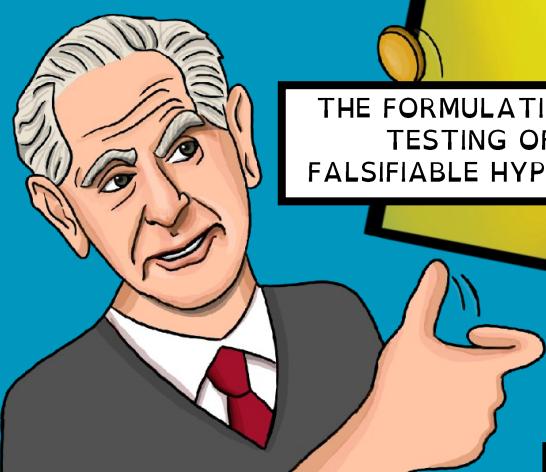
THEN THE RULE WILL MAKE LOTS OF MISTAKES,



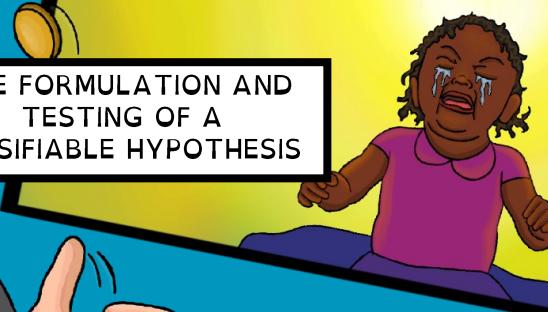
SUCH AS TURNING ON THE LIGHT IN EMPTY OFFICE BUILDINGS,

OR WAKING UP YOUR TODDLER IN THE MIDDLE OF HIS AFTERNOON NAP.

WHETHER THE RULES ARE WRITTEN DOWN BY HUMANS, OR LEARNED FROM HISTORICAL DATA BY MACHINES, WE SHOULD BE SURE TO USE THE SCIENTIFIC METHOD -

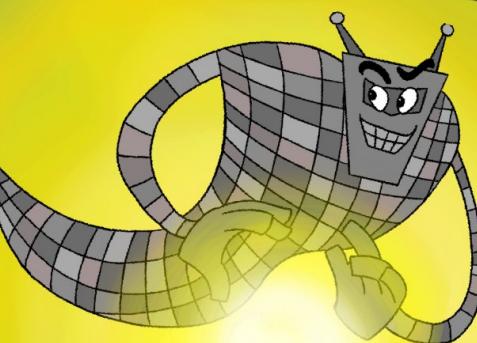


THE FORMULATION AND TESTING OF A FALSIFIABLE HYPOTHESIS



AS PHILOSOPHER OF SCIENCE KARL POPPER FAMOUSLY SAID:

"A THEORY OR IDEA SHOULDN'T BE SCIENTIFIC UNLESS IT COULD, IN PRINCIPLE, BE PROVEN FALSE."



1. THE SCIENTIFIC METHOD STARTS WITH AN OBSERVATION.

OBSERVATION

2. IT IS FOLLOWED BY THE FORMULATION OF A FALSIFIABLE HYPOTHESIS -

ONE THAT CAN BE PROVEN FALSE.

THE SCIENTIFIC METHOD

CONCLUSION

HYPOTHESIS

4. AND, IF SO, WE REFINE THE HYPOTHESIS, DESIGN A NEW EXPERIMENT, RINSE, AND REPEAT.

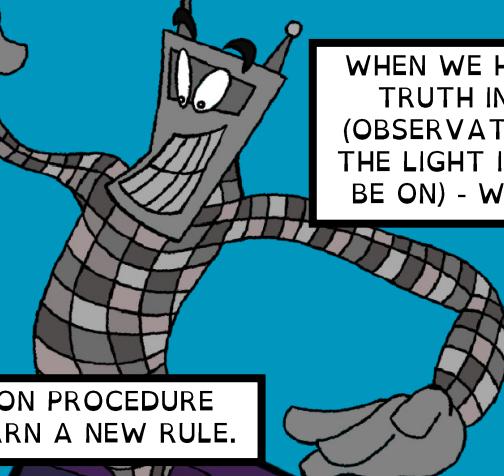
EXPERIMENT

3. NEXT, AN EXPERIMENT IS DESIGNED TO CHECK WHETHER THE HYPOTHESIS IS FALSIFIED.

THE CRUCIAL QUESTION: "DOES THE CLASSIFIER WORK?" IS FORMALIZED AS "ARE THE CLASSIFIER'S PREDICTIONS MORE ACCURATE THAN A RANDOM GUESS"?

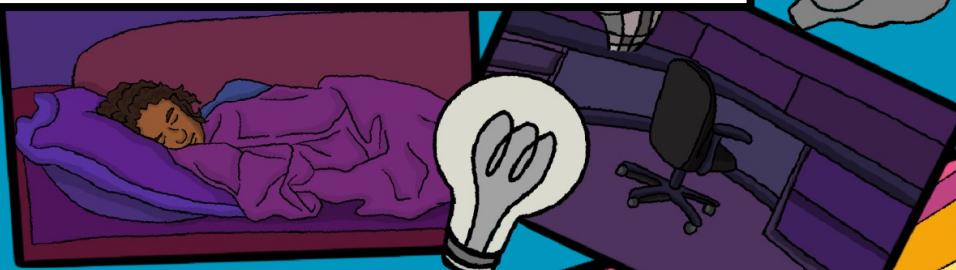
THIS IS THE LOWEST BAR FOR ACCURACY -

WE DON'T WANT TO END UP BUILDING FANCY AI TO BE FLIPPING COINS.



AND IF THE HYPOTHESIS IS FALSIFIED, WE DON'T USE IT.

WE DESIGN A NEW DATA GENERATION PROCEDURE AND WE RETRAIN THE MODEL TO LEARN A NEW RULE.



IMPORTANTLY, EVEN WITH ALL THIS ADDITIONAL SOPHISTICATION, IT IS STILL UNLIKELY THAT WE'LL SEE PERFECT ACCURACY.



ONE OF THE REASONS FOR THIS IS THAT THERE IS UNCERTAINTY IN THE WORLD.

AND ANOTHER IS THAT RULES ARE SOMETIMES BROKEN: PEOPLE MAY COME TO WORK OVER THE WEEKEND, OR THEY STAY AT WORK LONGER TO MEET A DEADLINE.

AND SO THE BEST WE CAN HOPE FOR, IN REAL-LIFE SITUATIONS, IS THAT THE CLASSIFIER WILL WORK MOST OF THE TIME.



BUT ONCE IN A WHILE, SOMEONE WILL NEED TO GET UP AND TURN ON OR TURN OFF THE LIGHT.

FIN.