CS 4530: Fundamentals of Software Engineering

Module 08 Writing Maintainable Code: Code-Level Design Principles

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Learning Objectives for this Lesson

- By the end of this lesson you should be able to:
  - Describe the purpose of our best practices for code-level design
  - List 5 principles for writing readable code, with examples
  - Identify some violations of the practices and suggest ways to mitigate them

Software systems must be comprehensible by humans

- Which humans?
  - The other members of your team
  - The folks who will maintain and modify your system
  - Management
  - Your clients
  - and ...
  - You, a week from now or 6 weeks from now

Three Scales of Design in Software Engineering

	PEOPLE	PROCESSES	PROGRAMS
PLANNING			
ORGANIZING			
IMPLEMENTING			

A Different Perspective On The Three Scales of Design

PROGRAMS

PLANNING

ORGANIZING

IMPLEMENTING

The Structural Scale

- key questions: what are the pieces? how do they fit together to form a coherent whole?

The Interaction Scale

- key questions: how do the pieces interact? how are they related?

The Code Scale

- key question: how can I make the actual code easy to test, understand, and modify?

Today's topic: design principles at the code scale

The Structural Scale

- key questions: what are the pieces? how do they fit together to form a coherent whole?

The Interaction Scale

- key questions: how do the pieces interact? how are they related?

The Code Scale

- key question: how can I make the actual code easy to test, understand, and modify?

Developers spend more time understanding code than writing it

- Study methodology:
  - Instrument 18 developer's IDEs for 740 development sessions
  - Record time spent in different tasks
- Conclusion: 70% of time spent in understanding-related tasks
- Other studies have shown similar statistics

Figure 3 summarizes the average distribution of activities of the developers and their sessions in our dataset.

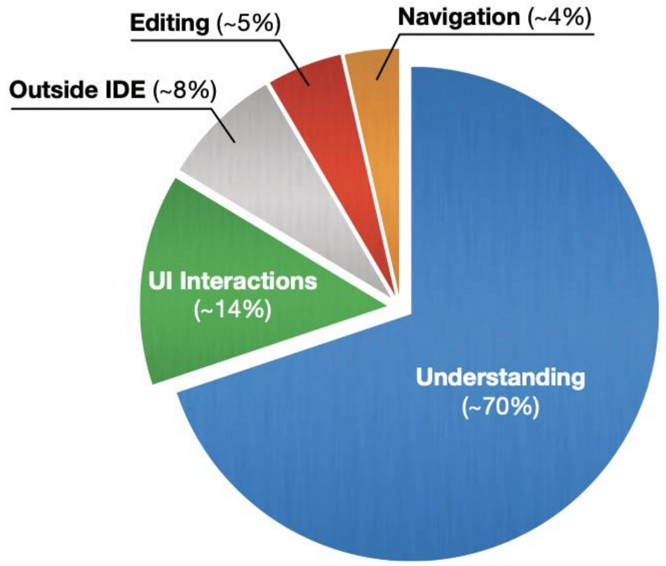


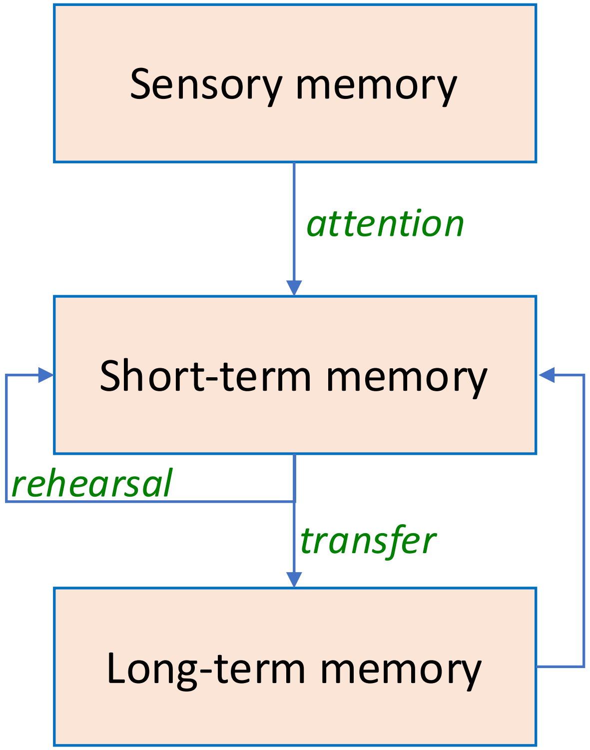
Fig. 3. How do developers spend their time?

Program understanding is as expected the dominant activity, but as we see our analysis attributes to it even more importance than what the common knowledge suggests, reaching a value of roughly 70%. This is a strong point in favor of the research

"I know what you did last summer: an investigation of how developers spend their time" Minelli, Mocci and Lanza. ICPC 2015

An Insultingly Shallow Introduction to Cognitive Psychology

Writing code engages memory



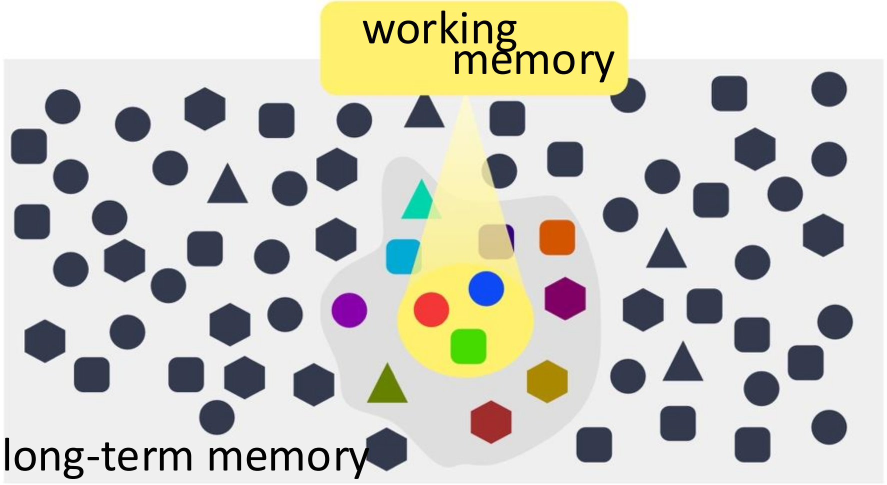
https://en.wikipedia.org/wiki/Atkinson%E2%80%93Shiffrin_memory_model

Short term memory holds "7±2 chunks"

- A chunk might be anything that has meaning
- What counts as a chunk is relative to concepts you already have
- The *number* of chunks in STM is fixed, but chunks might be different size.
- Example:
  - 6, 1, 7, 3, 7, 3, 2, 4, 6, 2 --10 chunks
  - 617-373-2462 -- 3 chunks

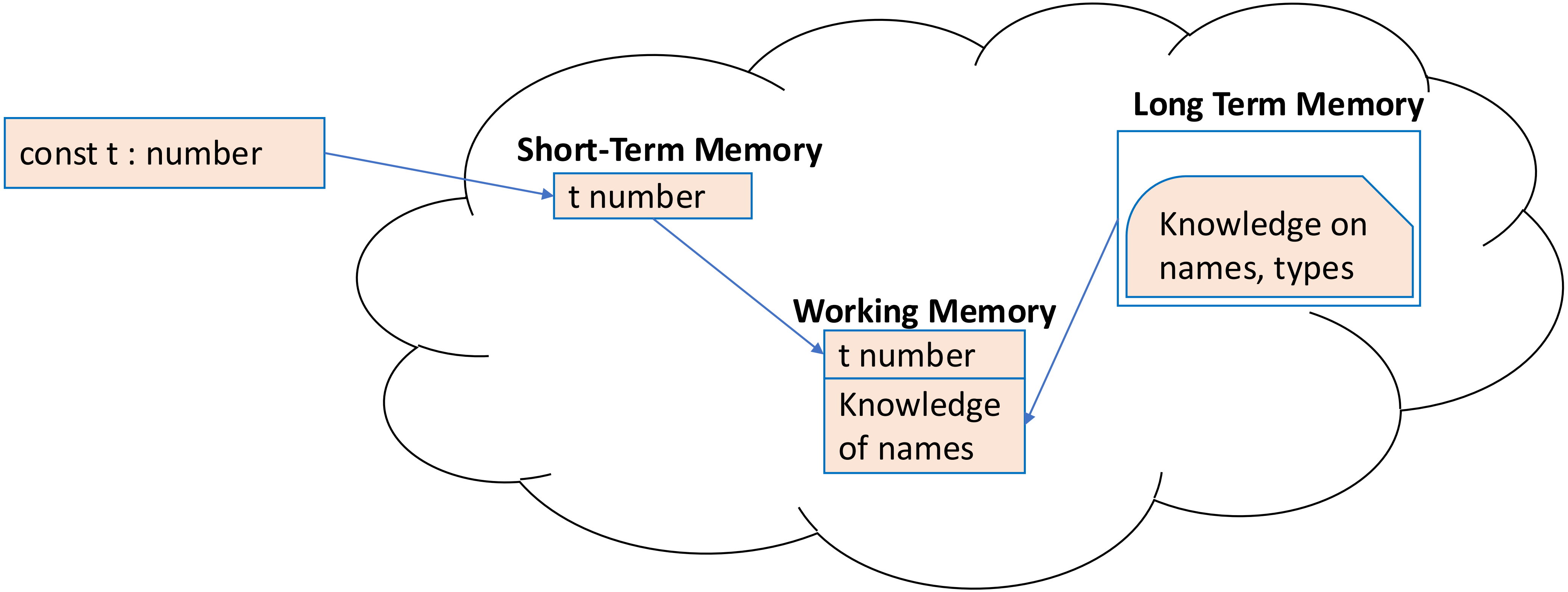
Minimize Your Reader's Cognitive Load

- Understanding code requires a developer to:
  - Access their **long-term memory** (e.g. for language syntax, API documentation)
    - *Long term memory: unlimited capacity, much slower*
  - Access their short-term memory (e.g. for tracking keywords, variable names, etc)
    - *Short-term memory capacity: 7 ± 2 items ("chunks")*
  - Manipulate new thoughts, ideas, etc in working memory



https://en.wikipedia.org/wiki/Working_memory

Cognitive Load Example



https://theelearningcoach.com/learning/what-is-cognitive-load/

Five general-purpose design principles for understandability and maintainability

Five General Principles
1. Use Names and Indentation Wisely
2. Make Your Data Mean Something
3. One Method/One Job
4. Don't Repeat Yourself
5. Identify and Use Good Abstractions

Principle 1. Use names and indentation wisely (consistently)

- Names and indentation are the first thing a reader sees in your code.
- Let's look at each of them

Use Good Names

- The name of a thing is a first clue to the reader about what the thing means.
  - often, it's the only clue ☹
- Use good names for
  - constants
  - variables
  - functions/methods
  - data types
- Good names support chunking

Use Good Names for Variables and Types

```
const t : number
const l : number
```

```
const temp : number
const loc  : number
```

```
const temperature      : Temperature
const sensorLocation   : SensorLocation
```

```
const temperature      : number
const sensorLocation   : number
```

Use Good Names for Functions and Methods

```
function checkLine (line) : boolean
```

```
function lineIsTooLong (line) : boolean
```

Use Good Names for Functions and Methods

- Use noun-like names for functions or methods that return values, e.g.

```
const c = new Circle(initRadius)
const a = c.diameter()
```

- not:

```
const a = c.calculateDiameter()
```

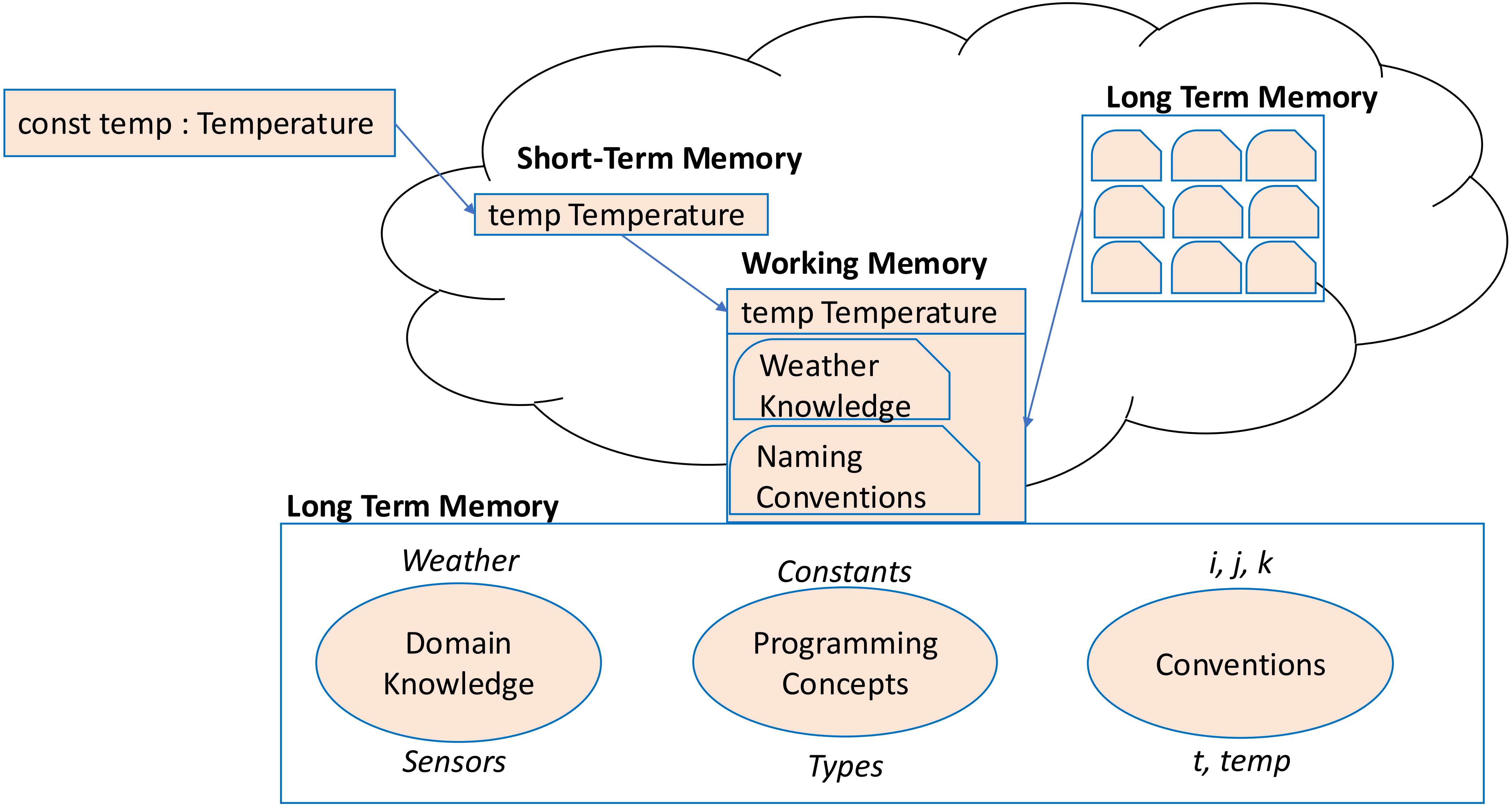
- Reserve verb-like names for functions or methods that perform actions, like

```
table1.addItem(student1,grade1)
```

Use Standard Patterns with Standard Names

- eg addListener, removeListener for Observer pattern
- .instance() for singleton pattern
- use similar names for similar operations
  - don't call it getSomething in one place and fetchSomething in another place.
- functions with similar names should behave similarly
  - if getSomething throws an error on failure then getAnotherThing should also throw an error on failure.

Good Names Draw on Broad Long-Term Memory Knowledge



Standardizing Names is More Important than the Standard Itself

- Using a naming convention *consistently* in a codebase improves understanding
- Consider standardizing:
  - snake_case vs camelCase vs PascalCase
  - Abbreviations in names vs words written out fully
  - Maximum name length
- For this course, we have some naming policies in our style guidelines
- We've covered some of these on the preceding slides.

Use Consistent Indentation to Transmit Structure

```
function foo
    (x: number, y: number,
     shouldIncrement: boolean)
    : number {
    if (shouldIncrement)
      x++;
      x *= 2;
    x += y;
    return x;
  }
```

```
function foo
    (x: number, y: number,
     shouldIncrement: boolean)
    : number {
    if (shouldIncrement) {
      x++;
    }
    x *= 2; // correct indentation
    x +=
    retur
  }
```

Auto-indentation is your friend!
Override it at your peril!

Eslint is your friend!

- Use eslint rules to enforce the coding styles in your shop.
- Many common eslint rules help you avoid errors.
- Others ensure that important information is present in a place where the reader will need it.

Principle 2. Make Your Data Mean Something

- You need to do three things:
  1. Decide what part of the information in the "real world" needs to be represented as data
  2. Decide how that information needs to be represented as data
  3. Document how to interpret the data in your computer as information about the real world

Example: Temperature Sensor

- We want to track the temperature of sensors in different locations
- How should we represent our sensor and its location?
- We need to decide:
  - How to represent sensors (including their temperature)
  - How to represent temperature and locations
  - How to represent a specific sensor, like one in the bathroom

One Way of Representing a Temperature Sensor

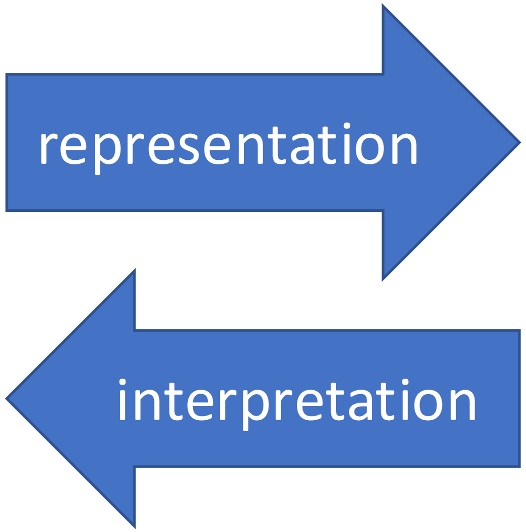
```
type Sensor = {
    location: SensorLocation
    currentTemperature?: Temperature
}

type Temperature = {
    degreesFahrenheit: number
}

type SensorLocation = "Basement" | "Bathroom" | "Kitchen";

let bathroomTemperatureSensor: Sensor = {
    location: "Bathroom"
}
```

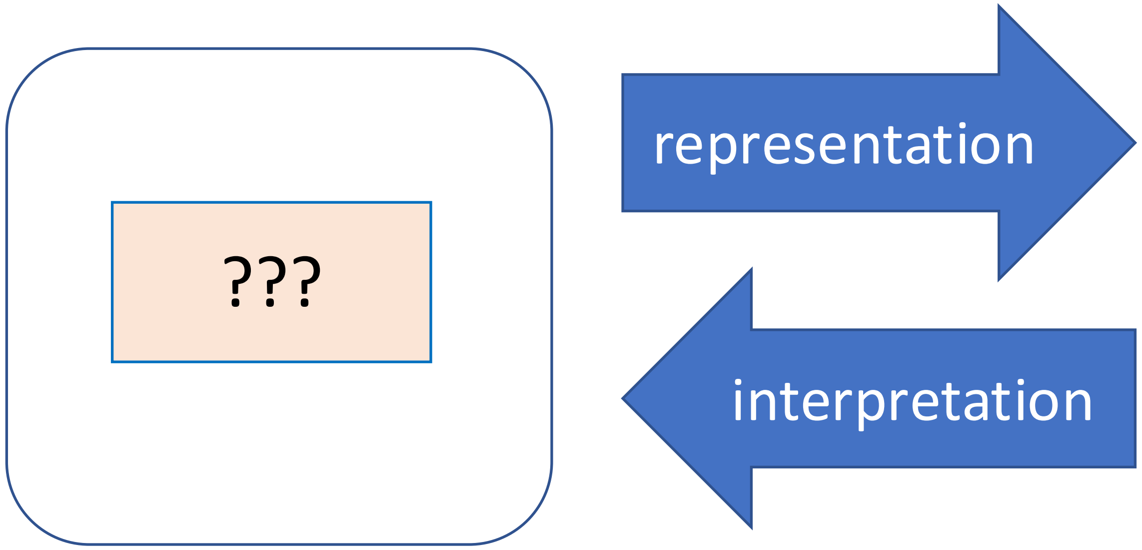
The Big Picture




```
let bathroomTemperatureSensor: Sensor =
{
    location: "Bathroom"
}
```

- How do we know that these are connected?
- Answer: we have to write it down.
- In Typescript, we do that with names, types and comments (or documentation)

Another Example: what does (x,y) mean?




```
export interface BoundingBox {
    x: number;
    y: number;
    width: number;
    height: number;
};
```

- The center?
- Upper-left-hand corner?
- Does y grow in the up or down direction?
- And what about the units? (Pixels? Scaled pixels? Something else?)

Answer: we should have written this down!

Principle 3: One Method/One Job

- Each class, and each method of that class, should have one job, and only one job
- If your method has more than one job, split it into 2 methods. Why?
  - You might want one part but not the other
  - It's easier to test a method that has only one job
- You call both of them if you need to.
  - or write a single method that calls them both
- Same thing for classes.

One Method/One Job Allows for Better In-Memory Chunking

- Recall: we have limited capacity in our short-term memory
- We get to remember "chunks"
- Splitting long methods into smaller ones with good names helps us hold more code in our short-term memory

Principle 4: Don't Repeat Yourself

- If you have some quantity that you use more than once, give it a name and use the name.
- That way you only need to change it in one place!
- And of course you should use a good name
- If you have some task that you do in many places, make it into a procedure.
- If the tasks are slightly different, turn the differences into parameters.

A real example

```
function testequal <T> (testname: string, actualVal: T, correctVal: T) {
    test(testname, () => { expect(actualVal).toBe(correctVal) })
}

describe('tests for countOfLocalMorks', function () {
    testequal('empty crew',countOfLocalMorks(ship1),0)
    testequal('just Mork',countOfLocalMorks(ship2),1)
    testequal('just Mindy',countOfLocalMorks(ship3),0)
    testequal('two Morks',countOfLocalMorks(ship4),2)
    testequal('drone has no Morks',countOfLocalMorks(drone1),0)
})
```

- This is what **test.each** does in Jest

A better example

```
function testLocalMorks(testName: string, ship: Ship, expected: number) {
    test(testName, () => {
        expect(countOfLocalMorks(ship)).toBe(expected)
    })
}

const testData = [
    { testname: 'emptyCrew', ship: ship1, expected: 0 },
    { testname: 'justMork', ship: ship2, expected: 1 },
    { testname: 'justMindy', ship: ship3, expected: 0 },
    { testname: 'twoMorks', ship: ship4, expected: 2 },
    { testname: 'droneNoMorks', ship: drone1, expected: 0 }
]

describe('tests for countOfLocalMorks', () => {
    testData.forEach(({ testname, ship, expected }) => {
        testLocalMorks(testname, ship, expected)
    })
})
```

Principle 5: Identify and Use Good Abstractions

- What's an "abstraction"?
- It's usually something that's hidden in the problem statement
- It's something that is used widely in your program
- It's something where
  - the details or representation might change
  - you use it in ways that don't depend on the representation
- Let's look at a couple of examples.

An abstraction is something that may be used in many places.

- Replace magic numbers with good names

```
const salesPrice = netPrice * 1.06
```

```
const salesTaxRate = 1.06
const salesPrice = netPrice * salesTaxRate
```

Example

- Imagine we are computing income tax in a state where there are four rates:
  - One on incomes less than $10,000
  - One on incomes between $10,000 and $20,000
  - One on incomes between $20,000 and $50,000
  - One on incomes greater than $50,000

You might write something like

```
function grossTax(income: number): number {
    if ((0 <= income) && (income <= 10000)) { return 0 }
    else if ((10000 < income) && (income <= 20000))
    { return 0.10 * (income - 10000) }
    else if ((20000 < income) && (income <= 50000))
    { return 1000 + 0.20 * (income - 20000) }
    else { return 7000 + 0.25 * (income - 50000) }
}
```

- Lots of these details here might change
  - The boundaries of the tax brackets might change
  - The number of brackets might change

"Tax Bracket" might be a good abstraction

- We see there are four of them, but there might be more.
- They are likely to be used in many places
- A tax bracket has a lower bound, an (optional) upper bound, and a rate.
- Each of these may change, but they always represent the same thing

So we can represent a tax bracket like this:

```
// represents a tax bracket for income lower < income <= upper.
// if upper is undefined, then lower < income  (no upper bound)
type TaxBracket = {
    lower: number,
    upper: number | undefined,
    base : number
    rate : number
}

// defines the incomes covered by a bracket
function isInBracket(income:number, bracket:Bracket) : boolean {
    if (bracket.upper == null)
    { return (bracket.lower < income) }
     return ((bracket.lower < income) && (income <= bracket.upper)) }

function taxByBracket(income: number, bracket: Bracket): number {
    return bracket.base + bracket.rate * (income - bracket.lower)
}
```

And we'll also need to represent a tax table

```
// represents a tax table as an array of brackets.
// INVARIANT: ???
type TaxTable = Bracket[]


/** INVARIANT:
 * 1. the brackets are a non-overlapping partition of the positive real numbers
 * 2. the tax associated with the upper bound of a bracket is
 *    the same as the tax associated with the lower bound
 *    of the next higher bracket.
 */

/** NOTE:
 * because the brackets are a non-overlapping partition of the positive real numbers,
 * the brackets need not be sorted by lower bound.
 */
```

And now it's easy to rewrite our function

```
// because the brackets are a non-overlapping partition of the
positive real numbers,
// there will be a unique bracket for each income, so the "as
Bracket" cast is safe. */
function income2bracket(income: number, table: TaxTable): Bracket {
    return table.find(b0 => isInBracket(income, b0)) as Bracket
}

function grossTax2 (income:number, Table: TaxTable ) : number {
    return taxByBracket(income,income2bracket(income,brackets))
}
```

Review: Learning Objectives for this Lesson

- You should now be able to:
  - Describe the purpose of our best practices for code-level design
  - List 5 principles for designing readable code, with examples
  - Identify some violations of the practices and suggest ways to mitigate them