



Deverywhere: Develop Software Everywhere - A Template-Based Developing Abstraction

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Preface

This work is a Master's thesis in MTA (Academic College of Tel-Aviv Yafo) as part of the study program M.Sc. in Computer Science. It was carried out during 2014-2015. The idea for this thesis yielded by Dr. Yishai Feldman (IBM Research). This research is in cooperation with Ari Gam who is M.Sc. student in Computer Science from Tel-Aviv University. The readers of this document assumed to have knowledge in Java language, system engineering, and software development tools.

Trondheim, 2012-12-16

(Your signature)

Alex Tilkin

Acknowledgment

I would like to thank Dr. Yishai Feldman, Prof. Shmuel Tyszberowicz and Ari Gam for their great help during the research.

A.T.

Summary and Conclusions

Here you give a summary of your work and your results. This is like a management summary and should be written in a clear and easy language, without many difficult terms and without abbreviations. Everything you present here must be treated in more detail in the main report. You should not give any references to the report in the summary – just explain what you have done and what you have found out. The Summary and Conclusions should be no more than two pages.

You may assume that you have got three minutes to present to the Rector of NTNU what you have done and what you have found out as part of your thesis. (He is an intelligent person, but does not know much about your field of expertise.)

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Chapter 1

Introduction

In the early days of computing, programmers had to work in offices. Personal computers allowed programmers to work at home as well. Laptops further expanded the working environment, and we often see people programming in coffee shops, terminals, trains, and airplanes. With ubiquitous mobile devices becoming increasingly popular, there is an opportunity to allow programmers to work in even more restrictive environments. While such small devices are unlikely to become the preferred working environment, they can be useful in circumstances where urgent action is required and other equipment is unavailable.

This scenario presents two major obstacles: first, the lack of a convenient keyboard; and second, the small screen space, which limits the amount of code that can be shown simultaneously. Some have advocated the creation of new programming languages for mobile platforms, but the cost of adopting a new language, with its related tools and infrastructure, seems to be too great for the benefit of occasionally programming on a mobile device. This applies to the development of mobile and non-mobile applications alike; professional programmers who develop mobile applications still prefer to use large screens and physical keyboards. Instead, we focus on easy ways to use existing languages, such as Java and Java Script, on mobile devices. Our proposed solution, called **Deverywhere**, addresses both challenges, by using templates to make voice and touch input very effective for programming, and for showing much more code in a limited space. Templates, used in context, allow voice input for creating, editing, and navigation; and allow a compact representation of programs that makes maximum use of the given screen space. Both uses require a high degree of configuration, since programmers have differ-

ent preferences regarding the way they want to voice and see programs. The underlying representation is always the original language, so that each programmer can see a tailored view while seamlessly collaborating on the same code with others.

These ideas are also relevant to programming on laptop and desktop systems, for people with disabilities such as repetitive-stress injuries (RSI) that limit keyboard usage, and partial vision loss, which requires the use of very large fonts. For some programmers, no screen is large enough, and so we expect that these programmers will use the compact representation of code even on large displays.

1.1 Background

In-order to create such an IDE we need to investigate several areas. The first one is what are the features that we need in such a developing environment. The second one is how programmers tend to describe the code that they want to insert. And the third one is how we can create a new representation of the code without harming the understanding of it. We need to investigate all those areas in order to design a new environment for developing with a new approach that uses voice and touch gestures.

Several studies have been published that have related to this problem. Part of the studies deal more with research and part deal essentially with application. Susan L. Graham and Andrew Begel from Berkeley University worked on a project named *SPEED*. In their study they developed an add-on that integrates into Eclipse and allows the programmer to insert lines of Java code using speech. Sihan Li, Tao Xie (North Carolina State University) and Nikolai Tillman (Microsoft Research) worked on TouchDevelop. This project provides a simple and clear environment which allows the developer to develop application directly on mobile devices using touch gesture. Dennis Strein and Hans Kratz developed appfour, an IDE that runs on mobile devices. The user can compile applications directly on the the mobile device and run them.

None of the works that are described above provides a comfortable solution for IDE on mobile devices that is fully integrable with stationary computers. None of the works addresses the issue of lack of keyboards and small screen. Our work addresses this issue by providing a comfortable IDE which uses voice, touch and compact representation of the code.

Dictation systems exist today, but their use for programming is extremely limited. Lacking any domain knowledge, they require most of the program to be dictated letter by letter, which is impractical. By building an understanding of program syntax and some semantics into the dictation tool, it is possible to make this process much more efficient.

1.2 Problem Formulation

Programming on mobile devices presents two major obstacles: the lack of a physical keyboard, and the small screen space, which limits the amount of code that can be shown simultaneously. This work addresses both challenges, and offers a method to enable programming on mobile and other devices with limited input and output capabilities. The method uses templates to make voice and touch input very effective for programming, and showing much more code in a limited space. These ideas are also relevant to programming on laptop and desktop systems, for people with disabilities such as repetitive-stress injuries (RSI) that limit keyboard usage, and partial vision loss, which requires the use of very large fonts.

In this work we concentrate on several targets: design of a new representation of the code so it will fit on mobile screens and will be readable as well; Create a set of templates that will allow the programmer to program by dictating the code; And allow the user to configure the representation of the code.

1.3 Literature Survey

In the following list we present the main books and articles that relate to problems that are similar to our area of studying:

- It is shown in Andrew and Susan [2, Chap. 2] that programmers ran into problems of orally expressing their thoughts when they had to dictate a program. This information is very important to us and consequently we designed our experiments based on it.
- It is shown in Andrew and Susan [2, Chap. 3] how spoken Java is processed. They developed several tools for analyzing the semantics and syntax of spoken Java. We are interested in studying the Harmonia tool for our research as well as integrating it in our system.

- Graham [6] provide all the information about how to use the Harmonia tool and how to integrate it in programming tools. It is useful information for our future work.
- It is shown in Feldman [4, Programming By Voice and Touch] the basic ideas and concepts of our work. Basically, this paper is the starting point for this research.

1.4 Objectives

The main objectives are the following:

1. Design the representation of the code in compact mode.
2. Design a concept for configuring language features. It needs to be comfortable and intuitive for the user.
3. Perform a series of experiments with different volunteers. The purposes of those experiments are to understand how programmers pronounce the code that they want to insert. What are the most negligible actions that programmers take?
4. Based on the experiments, define a set of templates that will be used as a tool to identify programmers' commands and transform them into lines of code.
5. Search and investigate existing programming features. The features that we look for are those which are related to the Java and generally to programming. All those features have the potential to be integrated into the system.
6. Build a prototype that proves that developing code on mobile devices is possible.
7. Provide a solid foundation for future works based on this research.

1.5 Limitations

Our study has several limitations which are summarized in the following list:

- This project requires a lot of coding work. Since I'm the only programmer, the implementation will be very limited.

- The analysis part is very long and difficult. It might require a lot of time of the research.
- Not many studies have been done which relate to the field "Developing on Mobile Devices" or "Developing using Voice". Therefore, we don't have many resources that we can learn from which we can learn. Most the work will have to do on our own.
- To implement this system a knowledge of NLP is required. We might need to study this field in order to use tools from it.

1.6 Approach

In this section I provide the scientific approach for each objective (the objectives and the approaches are correlated by the numbers of the times in the list):

1. We will study the most common and major domains of programming features that exist in Java. Afterward we will collect enough programming features covering enough domains and will study other languages to determine how those are features represented there. We will search in related works for new ideas for representations and will have discussions about new ideas. After all those processes are completed we will design a new compact representation.
2. We need to study the most common programming features and collect them into categories. We need to design methods to configure programming features. Thereafter we will have before us the programming features of both groups which will allow us to find the relationship of members from the second group with elements from the first group.
3. We will build a series of experiments which will represent different style of programming. For example, we will utilize object oriented, and algorithmic programming styles. There will be two programmers, the typist and the speaker. The speaker will request from the typer to create a program that is already written in Java. The speaker will dictate the program and the typist will type. After all experiments are accomplished we will compare the source and the reference (dictated program). Furthermore we will analyze the differences between the desired results and the actual results.

4. We will extract all commands that have been dictated during the experiments. We will group them into sets, for each set we will create a template that represents this group.
5. Schedule a series of team meetings. During every meeting the members of the group will suggest programming features that can be integrated into the system. Every feature will be discussed. All features that have been chosen will be saved in an archive.
6. I will build a text file that contains a set of commands. Every command is a simulation of a dictation that the programmer pronounced. I will build a set of rules that know how to handle the commands.

1.7 Structure of the Report

Remark: Write here the structure of the document.

Chapter 2

Experiments

2.1 Introduction

This chapter provides information about experiments that have been performed. The main goal of those experiments is to understand how we pronounce the code that we want to insert. The secondary goal is to create a repository of commands that will be grouped into categories. Based on the repository we will create templates that will help to analyze the pronounced commands.

Every experiment contained two active participants and two passive participants (passive participants are listeners). One of the active participants was the speaker and the other one was the typer. In every experiment the typer gave to the speaker a programming task where he needed to implement a program.

The speaker had to dictate a program and the typer had to type exactly what the speaker dictated. The speaker had to dictate lines of code in such a way so the typer could understand what he meant but not too detailed. For example, if the speaker had to dictate the code in [Figure 2.1](#). He would dictate it like this, *"For each element in elements call to toString"*.

The typer needed to follow dictations of the speaker and to type the code into the text editor (all four participants could see the screen). The typer typed the code in Java. Every one of the participants could participate and provide suggestions for pronouncing the commands. The typer could delete, edit and navigate in the code with no limitations. No time constraints and no limitations on the amount of lines. All experiments have been recorded.

After all experiments have been performed we analyzed them and extracted only the relevant

lines that represent commands. For each experiment we created a table that contained of two columns. The left column contains the commands that have been dictated and the right column represents the code that has been typed.

Remark: The commands that have been inserted into the tables are filtered from irrelevant vowels. For example, the commands *create class ummm look up* (where *ummm* is the vowel) has been converted to *create class look up*

```
foreach(Element element in elements){
    element.toString();
}
```

Figure 2.1: A simple foreach loop where every item in elements activates it's toString method

2.2 Experiment No.1

- Date: 28/Apr/2014.
- Speaker: Alex Tilkin.
- Typist: Ari Gam.
- Description: Implement a small program that contains an interface called *Lookup*. This interface has one method called *find*. It returns *Object* and receives *String*. a class called *SimpleLookup* that implements *Lookup*. It has two private members: *Names* that is an array of *Strings*, and *Values* that is an array of *Objects*. The implemented method *find* iterates over all elements in *Names* and compares every one of them with *Name*. If it finds such element it returns the matched element. In addition a method called *processValues* that receives: *String[] names*, and *Lookup table*. The program presented to the speaker during all the experiment.

Table 2.1 represents the order of the commands that have been dictated (top to bottom). Figure 2.2 represents the code that was presented to the speaker. Figure 2.3 represents the results

of the dictation.

```
interface Lookup {
    Object find(String name);
}

void processValues(String[] names, Lookup table) {
    for (int i = 0; i != names.length; i++) {
        Object value = table.find(names[i]);
        if (value != null)
            processValue(names[i], value);
    }
}

class SimpleLookup implements Lookup {
    private String[] Names;
    private Object[] Values;

    public Object find(String name) {
        for (int i = 0; i < Names.length; i++) {
            if (Names[i].equals(name))
                return Values[i];
        }

        return null;
    }
}
```

Figure 2.2: The original Java code that was presented to the speaker during experiment No. 1

```
interface Lookup{
    Object find(String name){
    }
}

void processValues(String[] names, Lookup table){
    for(int i = 0; i < names.Length(); i++){
        Object value = table.find(names[i]);
        if(value != null){
            processValues(names[i], value);
        }
    }
}

class SimpleLookup implements Lookup{
    private Strings[] names;
    private Object[] values;

    public Object find(String name){
        for (int i = 0; i < name.Length(); i++){
            if (names[i].equals(name)){
                return values[i];
            }
        }

        return null;
    }
}
```

Figure 2.3: The result of dictating the code in [Figure 2.2](#)

The speaker said	The typer typed
Create class LookUp	+Class LookUp
Create a method processValues that returns void and accepts array of strings names and lookupTable	+processValues(names, table)
Create a loop from zero to the length of names	for $0 \leq i < \text{names.length}$
Create value type of object accepts table.find, accepts names at i's index	value \leftarrow table.find(names[i])
If value different from null then	value \neq null ?
call to processValue that accepts name at i's index and value	processValue(name[i], value)
We done with processValues	
Create a class SimpleLookUp implements LookUp	+Class SimpleLookUP : LookUp
Delete the last row	
Create array of strings call it names and make it private	-[] names
Create values type of array of object and make it private	-[] values
Create a method that returns an object call it find accepts name type of string and make it public	+find(name)
Create a loop from zero to the length of names	for $0 \leq i < \text{names.length}$
If names at i's index period equals accept name then	names[i].equals(name) ?
Return values at i's index	\leftarrow values[i]
Exit the for loop	
Return null	null

Table 2.1: This table presents the major commands that have been dictated during experiment No.1

2.3 Experiment No.2

- Date: 28/Apr/2014.

- Speaker: Alex Tilkin.
- Typist: Ari Gam.
- Description: Implement a method called `getInterpolatedValue`. It receives two integers and returns double. The method needs to return the interpolated value based on certain conditions. The program presented to the speaker during all the experiment.

[Table 2.2](#) represents the order of the commands that have been dictated (top to bottom). [Figure 2.5](#) represents the code that was presented to the speaker. [Figure 2.5](#) represents the results of the dictation.

```
public final double getInterpolatedValue(double x, double y){
    if(useBicubic){
        return getBicubicInterpolatedPixel(x, y, this);
    }
    if(x < 0.0 || x >= width-1.0 || y < 0.0 || y >= height-1.0){
        if(x < -1.0 || x >= width || y < -1.0 || y >= height){
            return 0.0;
        }
        else{
            return getInterpolatedEdgeValue(x, y);
        }
    }
    int xBase = (int)x;
    int yBase = (int)y;
    double xFraction = x - xBase;
    if(xFraction < 0.0){
        xFraction = 0.0;
    }
    double lowerLeft = getPixelValue(xBase, yBase);
    double lowerRight = getPixelValue(xBase + 1, yBase);
    double upperAverage = upperLeft + xFraction * (upperRight - upperLeft);
}
```

Figure 2.4: The code that was presented to the speaker during experiment No.2

```
public final double getInterpolatedValue(double x, double y){
    if(useBicubic){
        return getBicubicInterpolatedPixel(x, y, this);
    }
    if(x < 0.0 || x >= width-1.0 || y < 0.0 || y >= height-1.0){
        if(x < -1.0 || x >= width || y < -1.0 || y >= height){
            return 0.0;
        }
        else{
            return getInterpolatedEdgeValue(x, y);
        }
    }
    int xBase = (int)x;
    int yBase = (int)y;
    double xFraction = x - xBase;
    if(xFraction < 0.0){
        xFraction = 0.0;
    }
    double lowerLeft = getPixelValue(xBase, yBase);
    double lowerRight = getPixelValue(xBase + 1, yBase);
    double upperAverage = upperLeft + xFraction * (upperRight - upperLeft);
}
```

Figure 2.5: The result of dictating the code in [Figure 2.3](#)

The speaker said	The typer typed
Create method <code>getInterpolatedValue</code> that accepts arguments <code>x</code> and <code>y</code>	<code>+getInterpolatedValue(x, y)</code>
if <code>useBicubic</code>	<code>useByCubiq?</code>
Change <code>y</code> to <code>i</code> , change <code>q</code> to <code>c</code> , Change capital <code>C</code> to small <code>c</code>	<code>useBicubic?</code>
return a call to <code>getInterpolatedPixel</code> that accepts arguments <code>x</code> , <code>y</code> and <code>this</code>	<code>↵ getBicubicInterpolatedPixel(x, y, this)</code>
We are done with the if	
if <code>x</code> is less than zero dot zero or <code>x</code> is greater or equal to <code>width</code> minus one dot zero or <code>y</code> is less than zero dot zero or <code>y</code> is greater or equal to <code>height</code> minus one dot zero then	<code>x < 0.0 x ≥ width - 1.0 y < 0.0 y ≥ height - 1.0 ?</code>
if <code>x</code> is less than minus one dot zero or <code>x</code> is greater or equal to <code>width</code> or <code>y</code> is less than minus one dot zero or <code>y</code> is greater or equal to <code>height</code> then return zero dot zero	<code>x < -1.0 x ≥ width y < -1.0 y ≥ height ? ↵ 0.0</code>
else return a call to <code>getInterpolatedEdgeValue</code> that accepts parameters <code>x</code> and <code>y</code>	<code>: ↵ getInterpolatedEdgeValue(x, y)</code>
We are done with the outer if	
Assign <code>x</code> to <code>xBase</code>	<code>xBase ← x</code>
Assign <code>y</code> to <code>yBase</code>	<code>yBase ← y</code>
Subtract <code>xBase</code> from <code>x</code> and assign it to <code>xFraction</code>	<code>xFraction ← x - xBase</code>
If <code>xFraction</code> is less than zero period zero then assign zero period zero to <code>xFraction</code>	<code>xFraction < 0.0 ? xFraction ← 0.0</code>
We are done with the if	

Table 2.2: This table presents the major commands that have been dictated during experiment No.2

The speaker said	The typer typed
Assign the returned value from getPixelValue that accepts parameters xBase and yBase to lowerLeft	<code>lowerLeft ← getPixelValue(xBase, yBase)</code>
Assign the returned value from getPixelValue that accepts first parameter xBase plus one and second parameter yBase to lowerRight	<code>lowerRight ← getPixelValue(xBase + 1, yBase)</code>
Assign to upperAverage the calculation of upperLeft plus xFraction times open parenthesis upperRight minus upperLeft close parenthesis	<code>upperAverage = upperLeft + xFraction * (upperRight - upperLeft)</code>
return the calculation of lowerAverage plus yFraction times open parenthesis upperAverage minus lowerAverage	<code>lowerAverage + yFraction * (upperAverage - lowerAverage)</code>

Table 2.3: Processing [Table 2.2](#). This table presents the major commands that have been dictated during experiment No.2

2.4 Experiment No.3

2.4.1 Part A

- Date: 12/May/2014.
- Speaker: Ari Gam.
- Typist: Alex Tilkin.
- Description: Implement the Bubble Sort algorithm . The speaker asked to implement the Bubble Sort algorithm without any assistance. The algorithm had to be implemented in Java. No source code presented to the speaker.

[Table 2.4](#) represents the order of the commands that have been dictated (top to bottom). [Figure 2.6](#) represents the result of the dictation by the speaker in part A.

```
class BubbleSort{
    public void do(){
        for(int i = 0; i < data.length - 1; i++){
            for(int j = 0; j < i; j++){
                if(data[i] > data[j]){
                    int temp = data[j];
                    data[j] = data[i];
                    data[i] = temp;
                }
            }
        }
    }

    private int[] data;

    public BubbleSort(int[] init){
        data = new int[init.length];
        for(int i = 0; i < init.length; i++){
            data[i] = init[i];
        }
    }
}
```

Figure 2.6: The result of the diction of the Bubble Sort algorithm

2.4.2 Part B

- Date: 28/Apr/2014.
- Speaker: Ari Gam.
- Typist: Alex Tilkin.

- Description: After the speaker has completed the implementation of the Bubble Sort algorithm he has been asked to improve it's time complexity by adding additional condition. No source code presented to the speaker.

Table 2.4 represents the order of the commands that have been dictated (top to bottom). Figure 2.7 represents the result of the dictation by the speaker in part B.

```
class BubbleSort{
    public void do(){

        for(int i = 0; i < data.length - 1; i++){
            boolean done = true;
            for(int j = 0; j < i; j++){
                if(data[i] > data[j]){
                    int temp = data[j];
                    data[j] = data[i];
                    data[i] = temp;
                    done = false;
                }
            }
            if(done){
                break;
            }
        }
    }

    private int[] data;

    public BubbleSort(int[] init){
        data = new int[init.length];
        for(int i = 0; i < init.length; i++){
            data[i] = init[i];
        }
    }
}
```

Figure 2.7: The result after the additional condition has been added to the Bubble Sort algorithm

The speaker said	The typer typed
Create class bubble sort	+Class BubbleSort
Public void do with no arguments	+Do
Create array of ints call it data and make it private	-[] data
Create constructor that receives an array of ints and name it init	+BubbleSort([] init)
Copy init to data	data = init.clone
Go to Do method	
Create a loop from zero to the length of data minus one	for $0 \leq i < \text{data.length} - 1$
Create an inner loop from zero to i	for $0 \leq j < i$
If the i element of data bigger than the j element of data then switch between them	data[i] > data[j] ? temp \leftarrow data[i] data[i] \leftarrow data[j] data[j] \leftarrow temp
Here starts part B	
Go to the beginning of Do	
Create a boolean variable done initialized to false	done \leftarrow false
Add to the exit condition of outer loop not done	for $0 \leq i < \text{data.length} - 1$ & done
undo	for $0 \leq i < \text{data.length} - 1$
Move the statement boolean done initialized to false to the first line of the outer loop	
Change the value from false to true	done \leftarrow true
Go to the end of the if	
Initialize done with false	done \leftarrow false

Table 2.4: This table presents the major commands that have been dictated during experiment No.3

2.5 Experiment No.4

- Date: 19/May/2014.
- Speaker: Alex Tilkin.
- Typist: Yishai Feldman.
- Description: A program that simulates TV controller has been presented to the speaker. The program contains the following interfaces: *Command*, and *ElectronicDevice* and the following classes: *TurnOff*, *TurnOn*, *VolumeUp*, *VolumeDown*, *TV*, and *DeviceButton*. the classes *TurnOff*, *TurnOn*, *VolumeUp* and *VolumeDown* implements *Command*. The class *TV* implements *ElectronicDevice*. The whole application is designed based on the Command design pattern. During the whole experiment the code was presented to the speaker.

Figure 2.8 represents the *Command* interface. Figure 2.9 represents the *VolumeDown* class that implements the *Command* interface. Figure 2.10 represents the *VolumeUp* class that implements the *Command* interface. Figure 2.11 represents the *TurnOn* class that implements the *Command* interface. Figure 2.12 represents the *TurnOff* class that implements the *Command* interface. Figure 2.13 represents the *ElectronicDevice* interface. Figure 2.14 represents the *TV* class that implements the *ElectronicDevice* interface. Figure 2.15 is the represents the *DeviceButton* class. This class contains the *main* method.

The following tables represents the order of the major commands that have been dictated (top to bottom) during experiment No.4: Table 2.5, Table 2.6, Table 2.7, Table 2.8.

Remark:In this experiment we present each class only once and not source and dictation result. This is because the source and the dictation results are identical.

```
public interface Command {
    void execute();
}
```

Figure 2.8: The *Command* interface

```
public class VolumeDown implements Command {  
    private TV tv;  
  
    public VolumeDown(TV tv) {  
        this.tv = tv;  
    }  
  
    @Override  
    public void execute() {  
        tv.volumeDown();  
    }  
}
```

Figure 2.9: The *VolumeDown* class that implements the *Command* interface

```
public class VolumeUp implements Command {  
    private TV tv;  
  
    public VolumeUp(TV tv) {  
        this.tv = tv;  
    }  
  
    @Override  
    public void execute() {  
        tv.volumeUp();  
    }  
}
```

Figure 2.10: The *VolumeUp* class that implements the *Command* interface

```
public class TurnOn implements Command {  
    private ElectronicDevice electronicDevice;  
  
    public TurnOn(ElectronicDevice electronicDevice) {  
        this.electronicDevice = electronicDevice;  
    }  
  
    @Override  
    public void execute() {  
        electronicDevice.on();  
    }  
}
```

Figure 2.11: The *TurnOn* class that implements the *Command* interface

```
public class TurnOff implements Command {  
    private ElectronicDevice electronicDevice;  
  
    public TurnOff(ElectronicDevice electronicDevice) {  
        this.electronicDevice = electronicDevice;  
    }  
  
    @Override  
    public void execute() {  
        electronicDevice.off();  
    }  
}
```

Figure 2.12: The *TurnOff* class that implements the *Command* interface


```
public interface ElectronicDevice {  
    void on();  
  
    void off();  
  
    void volumeUp();  
  
    void volumeDown();  
}
```

Figure 2.13: The *ElectronicDevice* interface

```
public class TV implements ElectronicDevice {

    private int volume;

    @Override
    public void on() {
        System.out.println("The TV is on");
    }

    @Override
    public void off() {
        System.out.println("The TV is off");
    }

    @Override
    public void volumeUp() {
        volume++;
        System.out.println("The volume is now " + volume);
    }

    @Override
    public void volumeDown() {
        volume--;
        System.out.println("The volume is now " + volume);
    }
}
```

Figure 2.14: The *TV* class that implements the *ElectronicDevice* interface

```
public class DeviceButton {  
    private Command command;  
  
    public DeviceButton(Command command) {  
        this.command = command;  
    }  
  
    public void press() {  
        command.execute();  
    }  
  
    public static void main(String[] args) {  
        ElectronicDevice tv = new TV();  
        Command turnOffCommand = new TurnOff(tv);  
        Command turnOnCommand = new TurnOn(tv);  
        DeviceButton deviceButtonOn = new DeviceButton(turnOnCommand);  
        DeviceButton deviceButtonOff = new DeviceButton(turnOffCommand);  
        deviceButtonOff.press();  
        deviceButtonOn.press();  
    }  
}
```

Figure 2.15: The *DeviceButton* class that contains the *main* method

The speaker said	The typer typed
Create interface ElectronicDevice	+interface ElectronicDevice
Create method on	+on
Create method off	+off
Create method volumeUp	+volumeUp
Create method volumeDown	+volumeDown
Create class TvRemoteControl	+Class TvRemoteControl
Without RemoteControl	+Class Tv
That implements ElectronicDevice	+Class : ElectronicDevice
Go to on	
Print the TV is on	Print "The TV is on"
Print the TV is off	
Print the TV is off	Print "The TV is off"
Create local field volume	-volume
Go to volumeUp	
Do volume plus plus	volume++
Print the volume is now and concatenate volume	Print "The volume is now" + volume
Add space after now	"The volume is now " + volume
Go to volumeDown	
Do volume minus minus	volume--
Print the volume is now space concatenate volume	Print "The volume is now " + volume
Create interface Command	+interface Command
Create method execute	+execute
Create class TurnTVOn implements Command	+class TurnTvOn : Command

Table 2.5: This table presents the major commands that have been dictated during experiment No.4

The speaker said	The typer typed
Create constructor that accepts TV	+TurnTvOn(tv)
Assign tv to field tv	this.tv ← tv
Go to execute	
Create class VolumeUp implements Command	+class volumeUp : Command
Create constructor that accepts TV	+volumeUp(tv)
Assign tv to field tv	this.tv ← tv
Go to execute	
TV period volumeUp	tv.volumeUp
Create class VolumeDown implements Command	+Class VolumeDown : Command
Create constructor that accepts TV	+volumeDown(tv)
Assign tv to field tv	this.tv ← tv
Go to execute	
TV period volumeDown	tv.volumeDown
Create class DeviceButton	+Class DeviceButton
Create constructor that accepts command	+deviceButton(command)
Assign command to field command	this.command ← command
Create method press	+press
Command period execute	command.execute
The programmer detected mistakes	
Rename TurnTVOn to TurnOn	+Class TurnOn : Command
Change constructor's parameter type to ElectronicDevice	+turnOn(electronicDevice)
Change the type of the field tv to ElectronicDevice	+ElectronicDevice tv
Rename tv to ElectronicDevice	+ElectronicDevice electronicDe- vice
Rename TurnTvOff to TurnOff	+TurnOff : Command

Table 2.6: Processing [Table 2.5](#). This table presents the major commands that have been dictated during experiment No.4

The speaker said	The typer typed
Change constructor's parameter type to ElectronicDevice	+turnOff(electronicDevice)
Change the type of the field tv to ElectronicDevice	+ElectronicDevice tv
Rename tv to ElectronicDevice	+ElectronicDevice electronicDe- vice
Go to volumeUp	
Change constructor's parameter type to ElectronicDevice	+volumeUp(electronicDevice)
Change the type of the field tv to ElectronicDevice	+ElectronicDevice tv
Rename tv to ElectronicDevice	+ElectronicDevice electronicDe- vice
Go to volumeDown	
Change constructor's parameter type to ElectronicDevice	+volumeDown(electronicDevice)
Change the type of the field tv to ElectronicDevice	+ElectronicDevice tv
Rename tv to ElectronicDevice	+ElectronicDevice electronicDe- vice
Create main	+main([]args)
Create ElectronicDevice type of TV	+main([]args)
Create Command type of TurnOff that receives tv and name it turnOffCommand	turnOffCommand ← TurnOff(tv)
Create Command turnOnCommand type of TurnOn and initialize it with TV	turnOnCommand ← TurnOn(tv)
Create DeviceButton that accepts turnOnCommand and assign it to deviceButtonOn	deviceButtonOn ← DeviceBut- ton(turnOnCommand)

Table 2.7: Processing [Table 2.6](#). This table presents the major commands that have been dictated during experiment No.4

The speaker said	The typer typed
Create new DeviceButton, name it deviecButtonOff and initialize it with turnOffCommand	deviceButtoff ← DeviceBut- ton(turnOffCommand)
deviecButtonOff period press	deviceButtoff.press
deviecButtonOn period press	deviceButton.press
Save	
Run	

Table 2.8: Processing [Table 2.7](#). This table presents the major commands that have been dictated during experiment No.4

2.6 Experiment No.5

- Date: 03/07/2014.
- Speaker: Perry Shalom.
- Typist: Alex Tilkin.
- Description: In this experiment the typist has been asked to implement a program that builds a car. The program had to be designed based on the Builder design pattern. The program had one main class *Car* It had to contain three private fields type of String: *wheels*, *engine*, and *body*. A private constructor that accepts all three parameters that initialize the fields. If one of the parameter is null or empty string the constructor should return and not initialize anyone of the fields. The *Car* class had to contain a private static class *CarBuilder*, it had to contain three private fields type of String: *wheels*, *engine*, and *body*. It had to contain a method named *buildCar* that checks if all three fields are initialized and return a new instance of *Car* class. If one of the fields is not initialized then the method will return null. A main method needs to build a car by using the *CarBuilder* class. No source code presented to the speaker.

[Figure 2.16](#) represents the dictation result of experiment No.5. [Figure 2.17](#) represents the compact representation of [Figure 2.16](#). [Table 2.9](#) and [Table 2.10](#) represents the major commands that have been taken during experiments No.5.


```
public class Car{
    private String _wheels;
    private String _engine;
    private String _body;

    private Car(String wheels, String engine, String body){
        if(body == null || engine == null || wheels == null){
            return;
        }
        _wheels = wheels;
        _engine = engine;
        _body = body;
    }

    public static class CarBuilder{
        String Body;
        String Wheels;
        String Engine;
        public Car BuildCar(){
            if(Body != null && Wheels != null && Engine != null){
                return new Car(Wheels, Engine, Body);
            }
            return null;
        }
    }

    public static void main(String[] args){
        Car.CarBuilder carBuilder = new CarBuilder();
        carBuilder.Engine = "honda";
        carBuilder.Wheels = "4";
        carBuilder.Body = "private";
        Car car;
        car = carBuilder.BuildCar();
    }
}
```

```

+Class Car
  -string _wheels
  -string _engine
  -string _body

  -Car(body, engine, wheels)
    _body ← body
    _engine ← engine
    _wheels ← wheels

+static Class CarBuilder
  +string _body
  +string _wheels
  +string _engine

  +Car BuildCar()
    body ≠ null ∧ engine ≠ null ∧ wheels ≠ null ?
      ↪ new Car(body, engine, wheels)
    ↪ null

+static Main(args[])
  carBuilder ← new CarBuilder()
  carBuilder.engine ← "honda"
  carBuilder.wheels ← "4"
  carBuilder.body ← "private"
  car ← CarBuilder.BuildCar

```

Figure 2.17: The result of experiment No.5 in compact representation

The speaker said	The typer typed
Create interface ElectronicDevice	+interface ElectronicDevice
Create class car	+Class Car
Create wheels type of string and make it private	-string _wheels
Create engine type of string and make it private	-string _engine
Create body type of string make it private	-string _body
Create static inner class CarBuilder	+Class CarBuilder
Create method CreateCar that returns Car	+Car <i>CreateCar</i>
Change CreateCar to BuildCar	+Car BuildCar
Create body type of string make it public	+string body
Create wheels type of string and make it public	+string wheels
Create engine type of string and make it public	+string engine
Go to BuildCar	
If wheels and body and engine are not empty strings then	wheels \neq null \wedge body \neq null \wedge engine \neq null ?
Return to Car	
Create a constructor that receives its three fields and initializes them	+Car(body, engine, wheels) _body \leftarrow body _engine \leftarrow engine _wheels \leftarrow wheels
go to the the beginning of the constructor	
If body equals null or engine equals null or wheels equals null then return	body = null \vee wheels = null \vee engine = null ? \leftarrow
Make the constructor of Car private	-Car
Go to the If of BuildCar in CarBuilder	
return a new instance of car with the fields body, engine and wheels	\leftarrow new Car(body, engine, wheels)
Exit the If,	

Table 2.9: This table presents the major commands that have been dictated during experiment No.5

The speaker said	The typer typed
return null	\leftarrow null
Create Main inside Car	<i>main</i>
change the method to static	+Car <i>BuildCar</i>
Undo	+Car BuildCar
Go to the beginning of Main	
Create an instance of CarBuilder	carBuilder \leftarrow new CarBuilder
Initialize engine of carBuilder with honda	carBuilder.engine \leftarrow "honda"
Initialize wheels of carBuilder the string four	carBuilder.wheels \leftarrow "4"
Initialize body of carBuilder the string private	carBuilder.body \leftarrow "private"
Create identifier type of car	car
Call to BuildCar of CarBuilder and put the returned value into car	car \leftarrow CarBuilder.BuildCar

Table 2.10: Proceeding [Table 2.9](#). This table presents the major commands that have been dictated during experiment No.5

Chapter 3

Supported Features

3.1 Introduction

This chapter discusses about the research that has been done to collect information about existing technologies for the Java language. The purpose of this research is to collect information about potential technologies that can be integrated in to Deverywhere system and to increase it's functionality. All features have been discussed by the research group whether they have a potential to be integrated or not. The features that presented in this chapter are only those which have been chosen to be integrated. Note that this research is flexible and the list of features might be changed. This part is important for the research because our architecture and prototype are designed in such way so all the mentioned features can be integrated into it.

Every feature that discussed in this chapter is followed by a numerical value which represents the priority of the feature. the range of the numbers is 1-4 where 1 is the highest priority and 4 is the lowest priority. The meaning of priority is how important that feature to this research.

3.2 List of Features

3.2.1 Programming by Voice (writing)

- Priority: 1

Allow the user to program using his voice.

- In case the system stumbles a case of ambiguity it will present options to the user which he could choose the most appropriate solution.
- The system should distinguish between when the user dictates to it or speaking to someone (this is very complicated feature to implement so it might be postponed to later works).

3.2.2 Navigation by Voice

- Priority: 2

The user could navigate in the code using his voice.

3.2.3 Editing by Voice

- Priority: 3

The user could edit the code by using his voice.

3.2.4 Compact View Mode

- Priority: 1

Provide an easy for understanding, comfortable and compact representation for code. Allow the use of emoticons and other graphical symbols in order to represent language features such as: classes, methods, and variables.

3.2.5 Refactoring

Enable the user to perform refactoring operations on the code with voice commands. Due to it is complicated to support all refactoring features we decided to choose several that will be supported (prioritized list where the first one has the highest priority).

- Rename Element (Variable, Rename, Field etc.) - Changing the name into a new one that better reveals its purpose

- Constructor Using Fields - Create constructor by selecting a couple of fields and and create a constructor that receives those fields as a formal variables that initialize the local fields
- Surround with “try-catch” - Surround a chunk of code with “try-catch” statement
- Move Element (Method or Field) - move to a more appropriate Class or source file
- Push Down - Move fields from derived class to the base class
- Pull Up - Move fields from base class to derived class
- Self-Encapsulate Field - force code to access the field with getter and setter methods (should be hidden) (described in details in the section “Getters and Setters Identification”)
- Change Method Signature

3.2.6 Object Identification

- Priority: 2 (relates to [3.2.2](#))

This is a core feature that has to be implemented in-order to allow other features like: navigation, refactoring and any other feature that requires from the user to point where he want to take the action. Below is a list of several features that provides example where is it needed.

- Refactoring - When a user asks to refactor a certain object he say something lie "change car to truck". in order to change this identifier first the system needs to identify it and then start the process of renaming it.
- Navigation in code - In order to allow navigation in code the system needs to identify the object and its location in order to navigate correctly. For example, one may say “go to a method drive of car” and the cursor will go to the first line of the method “Drive” in the class “Car”.
- Code Selection - user may select pieces of code by telling the system start and end points. For example, "Select the code from line sixteen to line twenty four".

3.2.7 Temporal Abstraction

- Priority: 4

This feature Allows the user to speak in a high level commands and generate code automatically. Due to the complexity to implement the whole feature we chose to concentrate on the section “Sequences as Conventional Interfaces”: Allows the user to speak in loops terminology and presents the code in mathematical sequences representation.

- The user will speak in loops terminology and create Java loops.
- Transform Java loops to mathematical sequences.
- Perform well-known algorithms on collections, for example. "Perform Quick Sort on a collection cars by the field year".

3.2.8 Details on Touch

- Priority: 2

Allow the user to inspect an element in (e.g. a variable) and peek into hidden details (e.g. its type) without losing orientation.

3.2.9 Changing the View Mode

- Priority: 4

Allow a user to change the view mode from compact to explicit and vise versa (explicit means to show the types and the accessibility of each object).

3.2.10 Fish Eye

- Priority: 3

Improve user orientation by displaying a large part of the program on the screen; less-relevant lines will be displayed in small font.

3.2.11 Quick Fix

- Priority: 2

This is the same feature as Eclipse has.

- Package Declaration - (need to run in the background). Add missing package declaration or correct package declaration. Move compilation unit to package that corresponds to the package declaration.
- Imports - (need to run in the background). Remove unused, unresolvable or non-visible import. Invoke 'Organize imports' on problems in imports.
- Types - Create new class, interface, enum, annotation or type variable for references to types that can not be resolved. Change visibility for types that are accessed but not visible. Rename to a similar type for references to types that can not be resolved. Add import statement for types that can not be resolved but exist in the project. Add explicit import statement for ambiguous type references (to import-on-demands for the same type). If the type name is not matching with the compilation unit name either rename the type or rename the compilation unit. Remove unused private types. Add missing type annotation attributes.
- Constructors - Create new constructor for references to constructors that can not be resolved (this, super or new class creation). Reorder, add or remove arguments for constructor references that mismatch parameters. Change method with constructor name to constructor (remove return type). Change visibility for constructors that are accessed but not visible. Remove unused private constructor. Create constructor when super call of the implicit default constructor is undefined, not visible or throws an exception. If type contains unimplemented methods, change type modifier to 'abstract' or add the method to implement.
- Methods - Create new method for references to methods that can not be resolved. Rename to a similar method for references to methods that can not be resolved. Reorder or remove arguments for method references that mismatch parameters. Correct access (visibility,

static) of referenced methods. Remove unused private methods. Correct return type for methods that have a missing return type or where the return type does not match the return statement. Add return statement if missing. For non-abstract methods with no body change to 'abstract' or add body. For an abstract method in a non-abstract type remove abstract modifier of the method or make type abstract. For an abstract/native method with body remove the abstract or native modifier or remove body. Change method access to 'static' if method is invoked inside a constructor invocation (super, this). Change method access to default access to avoid emulated method access. Add 'synchronized' modifier. Override hashCode(). Open the 'Generate hashCode() and equals()' wizard.

- Fields and variables - Correct access (visibility, static) of referenced fields. Create new fields, parameters, local variables or constants for references to variables that can not be resolved. Rename to a variable with similar name for references that can not be resolved. Remove unused private fields. Correct non-static access of static fields. Add 'final' modifier to local variables accessed in outer types. Change field access to default access to avoid emulated method access. Change local variable type to fix a type mismatch. Initialize a variable that has not been initialized. Create getter and setters for invisible or unused fields. Create loop variable to correct an incomplete enhanced 'for' loop by adding the type of the loop variable.
- Exception Handling - Remove unneeded catch block. Remove unneeded exceptions from a multi-catch clause. Handle uncaught exception by surrounding with try/catch or adding catch block to a surrounding try block. Handle uncaught exceptions by surrounding with try/multi-catch or adding exceptions to existing catch clause (1.7 or higher). Handle uncaught exception by adding a throw declaration to the parent method or by generalize an existing throw declaration

3.2.12 Dictation User Experience and Error Correction

- Priority: 1

This feature provides rich user experience for dictation. When the user dictates the system will response not only with textual output but also with suggestions and recommendations for his

work. For example, the user said "create for loop", an ambiguity might happen. The system need to present to the user relevant options and let him decide what does he mean. In addition identical to Eclipse the system will mark compilation error in real time.

3.2.13 Undo, Redo

- Priority: 2

Every step that have been taken during the development process can be reverted.

3.2.14 Templates and Concise commands

- Priority: 1

Allow the user to generate code without explicitly pronounce what needs to be written in the code, e.g., one can say "Create main inside Car" and the program will generate main method inside the class Car. Another example can be, while the cursor is inside the Car class, the user can say "Create a constructor" and the program will generate a constructor with no parameters (no parameters because the user didn't say that he wants parameters inside the constructor)

3.2.15 Save the Program as Regular Source Code

- Priority: 1

Open existing source code file.

3.2.16 Support multiple source files for analyzing

- Priority: 3

Refactoring and displaying definitions.

3.2.17 Search

- Priority: 3

Search and display results.

3.2.18 Source control integration

- Priority: 4

Allow source control programs such as GitHub to integrate the system and control your code.

3.2.19 Stand Alone System

- Priority: 4

The system runs on the mobile device, Internet connectivity is needed only if downloading/uploading source code.

3.2.20 Multi Platform

- Priority: 4

The system runs on major mobile operating systems.

3.2.21 License

- Priority: 2

Open source.

3.2.22 Show Time Complexity of Methods

- Priority: 4

Near every method show it's time complexity. For example, `+print(object)` $O(n)$

3.2.23 Command Variability

- Priority: 3

Sometimes we use different words that have the same meaning (i.e. we say “create a function” when we actually mean “create a method”). In order to provide a convenient environment for programming one can hold a thesaurus (e.g. Wordnet) that will include relations between similar words. This thesaurus can be modified (add, remove, edit), users should be able to define their favorite ways of talking. This includes the choice of words to describe templates, features, and locations. (This may circumvent the need for dictionaries and improve the effectiveness of the process) Both of these assume a fixed set of templates. Ideally, we would also have the following, perhaps for “super users”: Create new templates. This should be as flexible as possible.

3.2.24 Programming Languages Support

- Priority: 4

One may transform the compact code to any language that the transformer will support (e.g. Java, C#). Relevant for variable name conventions, libraries and for explicit mode.

3.2.25 Recommendations System

- Priority: 4

While we work on our program the apprentice will recommend modifications that will improve the code (i.e. instead of writing nested code the apprentice will recommend to write an “if” statement with negative logic and a “return” or “continue” command)

- The recommendations will be presented as a list, the programmer will choose the option by clicking on it or pronounce the option number.

3.2.26 Duplication Handling

- Priority: 2

Once we generate an identifier that already exists the application will handle this and rename the identifier so it will be unique in its scope.

3.2.27 String Construction by Voice

- Priority: 2

String manipulation (e.g. concatenate strings), dictation of characters (e.g. white spaces in hard-coded strings). Simplest that can work.

3.2.28 Real Estate

- Priority: 4

We assume that this technology can be implemented not only on mobile devices but also on even more futuristic devices, e.g., Google Glass.

3.2.29 Auto Identifier Names Generation

- Priority: 1

The application will generate field names based on class name. Note that in compact representation the system might not show class name (i.e. Car car will be displayed as car).

3.2.30 Extension Methods

- Priority: 3

A method added to an object after the original object was compiled. The modified object is often a class, a prototype or a type. Extension methods are permitted by some object-oriented programming languages. There is no syntactic difference between calling an extension method and calling a method declared in the type definition, e.g., one can say "obj.to___", and a list of methods such as: "toFirstUpper", "toString" appears.

3.2.31 Multiple Views

- Priority: 2

This feature allows multiple views in a single language, but without modifying the source code. Davis and Kiczales' registration-based abstractions enables programmers to switch between different views of their program at the press of a button. It is a convenient technique that allows the programmer to view the code in different representations so he will understand the code better and faster. Reference: "How Programming Languages Will Co-evolve with Software Engineering: A Bright Decade Ahead".

3.2.32 Breadcrumbs (Presence in Classes)

- Priority: 3

While we code we create classes and inside them inner classes, methods, properties etc. Sometimes, we might lose our presence due to over encapsulations. In-order to solve this issue we suggest a technique. The technique is to keep the header definition of the outer object on top of the screen while we scroll down in the inner object, e.g.,

```
Class Human
    Class Brain
```

So one can always understand the presence in the code in terms of encapsulation.

3.2.33 Getters and Setters Identification

- Priority: 2

Getter/ Setter technique is a very useful technique but one can't avoid writing explicitly "Set...", "Get...". We assume that the system needs to identify the pattern of whether it is a getter or a setter or not both of them and only print the suffix of the method (ignore the explicit prefix), e.g.,

```
public SetName(string name)
{ _name = name; }
```

Transformed to,

```
person.name(name)
```

One can only call the method Name and based on the template of the call the systems will understand if the user wants to call a setter or a getter. Moreover, instead of writing `person.name(name)` one can write `person.Name ← name`

3.2.34 Omit Declaration Lines

- Priority: 1

Line that contains only object declaration is not a necessary information and can be omitted. The proposal is to emit the lines that contains only object declaration without any binding, e.g., the “Object obj” can be omitted.

3.2.35 Operator Overloading

- Priority: 2

Allow using simple operators instead of using Java libraries for special types, e.g, instead of writing `BigDecimalExtension.operator_plus(x,y)` we will write `e1+e2` (`e1` and `e2` are type of big decimal).

3.2.36 Lambda expression

- Priority: 3

Lambda expressions are a new and important feature included in Java SE 8. They provide a clear and concise way to represent one method interface using an expression. Lambda expressions also improve the Collection libraries making it easier to iterate through, filter, and extract data from a Collection. In addition, new concurrency features improve performance in multi-core environments.

3.2.37 Type Inference

- Priority: 3

You rarely need to write down type signatures anymore, Types Deduction - The application will deduce the type of the identifier based on the right side of the statement.

3.2.38 Source Code on Demand

- Priority: 2

One can see the source code by providing the scope of code that the user wants to see its source code.

3.2.39 Collaboration

- Priority: 4

Collaboration with colleagues.

3.2.40 Native representation

- Priority: 3

Allow mathematical expressions in their native representation, as described in Eisenberg [3].

3.2.41 Inter-procedural Flow

- Priority: 3

A technique that helps the user to understand the flow of the program easily. It presents code blocks connected one to another based on the flow of the program. This technique helps the user to understand the flow a program in a much better way. Inter-procedural Flow is based on Control Flow Graph (CFG) representation technique, using graph notation, of all paths that might be traversed through a program during its execution. Inter-procedural Flow has several applications, we present one that fits our system the most:

- Code Bubbles - This is an application that helps the users to navigate and investigate their code in a novel approach. Link: http://www.andrewbragdon.com/codebubbles_site.asp. Additional link which provides a more detailed description is <http://cs.brown.edu/~spr/codebubbles/>.

3.2.42 Annotations

- Priority: 2

Allow the user to dictate annotations and display annotations in compact form. Allow using tools that are based on annotations:

- JML
- Doxygen

Chapter 4

Compact Representation

4.1 Introduction

Programming languages weren't designed to be presented on small screens, and therefore when you try to present programs on small screens it is difficult to read them. Programming languages are textual, and so require a keyboard in order to edit programs. Standard on-screen keyboards are inconvenient for texting, let alone for programming. In addition, they require one third of the screen which makes the small screen even smaller. Our approach is to use conventional languages such as Java and C++, but allow each programmer to have a tailored compact view that fits a small screen. We believe that we should support programmers better in doing what they already know how to do instead of requiring them to learn a new language and tools only for the purpose of sometimes developing code on mobile phones. Deverywhere is not a new language; it is a way for each programmer to see the code in the way that makes the most sense to him or her. Our solution for small screens is a compact representation of the code, which means focusing on the important information necessary to understand the code.

This chapter discusses how the code can be presented in compact representation. It covers most of the major domains of programming idioms. Every topic that is discussed in this chapter is accompanied with an explanation how it will be configurable by the user and examples of it provided by default.

4.2 Operators

This section discusses how atomic operators will be represented. Every symbol may be modified by the user to any character or icon that s/he wants.

4.2.1 Basic Operators

[Table 4.1](#) provides a set of basic atomic operators that used in almost every line of code.

Operator	Symbol
Plus	+
Minus	-
Multiplication	*
Division	/
Modulo	%
Increment	++
Decrement	--
Null	\perp
Shift	<<; >>; >>>
Relational	<; >; ≤; ≥
Equality	=; ≠
Bitwise AND	&
Bitwise exclusive OR	^
Bitwise inclusive OR	
Logical AND	∧
Logical OR	∨
Ternary	?; :
Assignment	←; +←; -←; *←; /←; %←; &←; ∧←; ∨←; <<←; >>←; >>>←

Table 4.1: This table presents operators and symbols that represent them in compact representation. The symbols are examples for how symbols may be presented. The user may modify to any representation that s/he wants. This idea is discussed in [chapter 5](#). Note: ; is used as a separator between operator symbols.

4.3 Statement Terminators

A statement terminator is used to demarcate the end of an individual statement. For example, a statement terminator in Java is ';' (semicolon) similarly to C, C++ and other programming languages. This character doesn't give any information except where the statement ends. The

programmer will be able to modify the symbol, s/he may decide if it will be displayed or how will it looks like, e.g., `result ← nextNode.data`, this is a line of code that missing statement terminator symbol. It is also possible to modify the style of the terminators or to use an icon.

4.4 Mathematical Expressions

Mathematical expressions are very common in programming. Sometimes they can be very long and complex. Therefore, we would like to represent those expressions in more compact and native way. We can reduce expressions length by changing mathematical expressions representation to native mathematical representation, e.g., $(a - b)/(c - d) \leftarrow \frac{a-b}{c-d}$.

4.5 Boolean expressions

This section discusses compact representation of boolean expressions.

4.5.1 Range

In-order to check if an integer is in a range the programmer needs write to write `0 <= i && i < 10`. We propose to write this expression in a natural representation, it will save space and will be easier for reading. For example, $0 \leq i < 10$.

4.6 Scopes

This section discusses ideas of how the programmer may modify the representation of a scope.

4.6.1 Scope Brackets

The programmer may omit the brackets then the indentation of the code will denote the scope of the code. [Figure 4.1](#) presents a small example of code without scope brackets.

```
age = 10 ?  
  adult ← false  
  isChild ← true
```

Figure 4.1: This is an example of a control block that checks if the age is smaller than 10 then the false is assigned to the identifier *adult* and true is assigned to the identifier *isChild*.

4.6.2 Frame

Figure 4.1 shows that both lines of code related to the condition because they have the same indentation. In-addition it is possible to frame the scope. It may help the programmer to understand scopes better. 4.2 presents how frame can be used to represent scopes.

```
age = 10 ?  
  adult ← false  
  isChild ← true
```

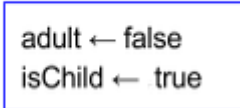


Figure 4.2: This is the same code that presented in Figure 4.1 but a frame is used to represent a scope.

4.6.3 Indentation

It is also possible to reduce the number of spaces.

```
age = 10 ?  
  adult ← false  
  isChild ← true
```

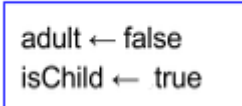


Figure 4.3: This is the same code that presented in Figure 4.2 but with a shorter indentation.

The programmer may modify frame's border color, background color, border width, and border style.

4.6.4 Line Break

Line breaks have an influence on the length and the width of the code. Therefore, we would like to provide several different representations for line breaking.

New Line

Every block of code starts in the same line with the condition key word. [Figure 4.4](#) presents an example of this style.

```
if [condition]
then [code_1]
else [code_2]
[code_3]
```

Figure 4.4: This is a style where every block of code starts in the same line with the condition key word.

2 Columns

In this representation the *then* and the *else* are below the if expression but placed side by side. [Figure 4.5](#) presents an example of this style.

```
if [condition]
then [code_1] else [code_2]
    [code_1]      [code_2]
                [code_2]
```

Figure 4.5: This is a style where the *then* and the *else* are below the if expression but placed side by side.

4.6.5 Fill

This configuration is quite identical to [section 4.6.4](#) but here if one of the code blocks is longer than the other it will catch the whole line. [Figure 4.6](#) presents an example of this style.

```
if [condition]
then [code_1] else [code_2]
      [code_1]      [code_2]
[      code_2      ]
[      code_2      ]
```

Figure 4.6: This is a style where if one of the code blocks is longer than the other it will catch the whole line.

4.7 Accessibilities

The programmer may change the accessibility of classes, and attributes, For instance, they can be presented in the default way, e.g., *public*, *private*, *protected*, *internal* or they can be presented with symbols as show in [Table 4.2](#). Also, it is possible to color the symbols: +, -, ~, ±. Moreover, the programmer may ignore symbols and just color the identifier, e.g., head will stand for private, iterator will stand for public. It is also possible to use icons instead.

Operator	Symbol
Public	+
Private	-
Protected	±
Internal	~

Table 4.2: This table represents possible representations for accessibilities.

4.8 Implementation and Inheritance

Instead of using long terms such as: *Implements*, and *inherits* the programmer may change the text to a more compact representation, e.g., ":" from C++. It is Also possible to use text or icon.

4.9 Types

4.9.1 Style

The programmer may modify the style of types, e.g., change `int` to *int*.

4.9.2 Text Value

The programmer may modify the textual value of types, e.g., change `int` to `integer`.

4.9.3 Omit Types

In-order to save space the programmer may hide types, access level, modifier and show only identifiers. Since types are hidden the programmer may not understand what is the type of the identifier. In-order to avoid ambiguity we suggest a technique that when an object is created the name of the identifier will be the same as the type (but the first letter will be in lowercase), e.g., `private Person _person` will be presented *person* (the Red color denotes that this is a private field and the *italic* denotes that it is static).

4.10 Fields

The programmer may configure that every field that is created will has a specific prefix or postfix, e.g., if the user configured the prefix to be "_" and asked to create the field `car` the system will write `_car`. The programmer may configure that all fields will have a certain style, e.g., `_car`.

4.11 Methods

This section discusses compact representation of methods.

4.11.1 Omit Returned Type

Returned types is important for compilation but also it provides information to the programmer what type is returned from methods. This information may be omitted because it is not needed to be presented. [Figure 4.7](#) shows an example of a method that its returned type is hidden.

```
foo(int a)
    return a
```

Figure 4.7: The returned type (in this case it is int) is omitted.

4.11.2 Omit Types of Formal Parameters

In addition the programmer may omit types of formal parameters of methods. [??](#) shows the same method that is presented in [Figure 4.7](#) but without the type of its formal parameter.

```
foo(a)
    return a
```

Figure 4.8: The type of the formal parameter is omitted.

4.11.3 Omit Parentheses

If a method doesn't has formal parameters it is possible to omit its Parentheses. [??](#) shows a method that doesn't has formal parameters hence its parentheses are omitted.

```
foo
    →📱 "Hello, World!"
```

Figure 4.9: This is method that its parentheses are omitted. The icon of the mobile phone denotes that the text "Hello, world!" will be printed to the console.

4.11.4 Constructors

Constructors are used in every class that is created. There is no need to name the constructors in the name of the classes, we can use symbols or words that will represent it. This section presents ideas that might be used as a representation for constructors.

Different Name

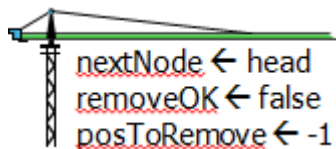
Figure 4.10 presents an example how constructor may be represented with different name other than the name of the class. The programmer may choose any text that make sense to him or her.

```
constructor
  name ← "name"
```

Figure 4.10: This is an example of a constructor that uses the word "constructor" as its symbol.

Icon

Instead of using words the programmer may use an icon that will represent constructors. Figure 4.11 presents an example where an icon of a crane is used to represent constructor.



```
nextNode ← head
removeOK ← false
posToRemove ← -1
```

Figure 4.11: This is an example where the programmer choose to use an icon of a crane to represent constructors.

4.12 Control Blocks

Condition statements are very common in programming. It is important to allow programmers to modify their appearance. This section discusses compact representation of control blocks.

4.12.1 If Statements

Figure 4.12 presents an example how "if" statements may be presented. We use the short version of if statement. It is also allowed to use the short version without the else part(":").

```
[Condition] ?
    [Code]
:
```

Figure 4.12:

4.12.2 Switch

Similar to "if" statements the programmer may change the representation of the switch statements. In Figure 4.13 shows an example of switch that presented in compact representation. Note: The word default may be modified as well.

```
name ?
    "Danny":
        [code]
    "Ben":
        [code]
    "Alex":
        [code]
    default:
        [code]
```

Figure 4.13: This is an example of a switch statement that uses "?" character instead of "switch". In addition breaks are omitted.

4.13 Temporal Abstraction

Temporal abstraction is a technique where the programmer instead of writing loops in imperative programming concept, writes the code in functional programming concept. For instance, [Figure 4.14](#) shows an example of code that checks if a collection contains a certain element.

```
for(int index = 0; index < collection.length; index++){  
    if(collection[index] == element)  
        return true;  
}  
return false;
```

Figure 4.14: This is an example of a for loop that iterates over a collection and looks for an element by comparing instances.

One can see that the code in [Figure 4.14](#) has an index that runs from zero to the length of the collection and checks each element if it is the element that it is looking for. If the element has been identified then *True* is returned. [Figure 4.16](#) presents the same code but in temporal abstraction.

```
return collection.exists(element);
```

Figure 4.15: This is an example of the loop in [Figure 4.14](#) in temporal abstraction representation.

The method "exists" in [Figure 4.15](#) accepts an element and returns *True* if it exists in the collection or *False* if it doesn't. One may notice that the first version is much more longer than the second. This is a very important advantage. This example is simple, [Figure 4.16](#) presents a more complicated example of temporal abstraction.

```
shapes.stream()  
    .filter(s -> s.getColor() == BLUE)  
    .forEach(s -> s.setColor(RED));
```

Figure 4.16: This is an example of code that is written in temporal abstraction technique. The elements that their color is blue are selected and their color is changed to red.

The following list contains methods that will be supported by this system. The signature of those methods is such that accepts two arguments, but we should not be confused since those are "extension methods":

- `drop(java.lang.Iterable<T> iterable, int count)` - Returns a view on this iterable that provides all elements except the first count entries.
- `elementsEqual(java.lang.Iterable<?> iterable, java.lang.Iterable<?> other)` - Determines whether two iterables contain equal elements in the same order.
- `exists(java.lang.Iterable<T> iterable, Functions.Function1<? super T,java.lang.Boolean> predicate)` - Returns true if one or more elements in iterable satisfy the predicate.
- `filter(java.lang.Iterable<?> unfiltered, java.lang.Class<T> type)` - Returns all instances of class type in unfiltered.
- `filter(java.lang.Iterable<T> unfiltered, Functions.Function1<? super T,java.lang.Boolean> predicate)` - Returns the elements of unfiltered that satisfy a predicate.
- `filterNull(java.lang.Iterable<T> unfiltered)` - Returns a new iterable filtering any null references.
- `findFirst(java.lang.Iterable<T> iterable, Functions.Function1<? super T,java.lang.Boolean> predicate)` - Finds the first element in the given iterable that fulfills the predicate.
- `findLast(java.lang.Iterable<T> iterable, Functions.Function1<? super T,java.lang.Boolean> predicate)` - Finds the last element in the given iterable that fulfills the predicate.

- `flatten(java.lang.Iterable<? extends java.lang.Iterable<? extends T>> inputs)` - Combines multiple iterables into a single iterable.
- `fold(java.lang.Iterable<T> iterable, R seed, Functions.Function2<? super R,? super T,? extends R> function)` - Applies the combinator function to all elements of the iterable in turn and uses seed as the start value.
- `forall(java.lang.Iterable<T> iterable, Functions.Function1<? super T,java.lang.Boolean> predicate)` - Returns true if every element in iterable satisfies the predicate.
- `forEach(java.lang.Iterable<T> iterable, Procedures.Procedure1<? super T> procedure)` - Applies procedure for each element of the given iterable.
- `forEach(java.lang.Iterable<T> iterable, Procedures.Procedure2<? super T,? super java.lang.Integer> procedure)` - Applies procedure for each element of the given iterable.
- `head(java.lang.Iterable<T> iterable)` - Returns the first element in the given iterable or null if empty.
- `isEmpty(java.lang.Iterable<?> iterable)` - Determines if the given iterable contains no elements.
- `isEmptyOrNull(java.lang.Iterable<?> iterable)` - Determines if the given iterable is null or contains no elements.
- `join(java.lang.Iterable<?> iterable)` - Returns the concatenated string representation of the elements in the given iterable.
- `join(java.lang.Iterable<?> iterable, java.lang.CharSequence separator)` - Returns the concatenated string representation of the elements in the given iterable.
- `join(java.lang.Iterable<T> iterable, java.lang.CharSequence before, java.lang.CharSequence separator, java.lang.CharSequence after,Functions.Function1<? super T,? extends java.lang.CharSequence> function)` - Returns the concatenated string representation of the elements in the given iterable.

- `join(java.lang.Iterable<T> iterable, java.lang.CharSequence separator, Functions.Function1<? super T,? extends java.lang.CharSequence> function)` - Returns the concatenated string representation of the elements in the given iterable.
- `last(java.lang.Iterable<T> iterable)` - Returns the last element in the given iterable or null if empty.
- `map(java.lang.Iterable<T> original, Functions.Function1<? super T,? extends R> transformation)` - Returns an iterable that performs the given transformation for each element of original when requested.
- `operator_plus(java.lang.Iterable<? extends T> a, java.lang.Iterable<? extends T> b)` - Concatenates two iterables into a single iterable.
- `reduce(java.lang.Iterable<? extends T> iterable, Functions.Function2<? super T,? super T,? extends T> function)` - Applies the combinator function to all elements of the iterable in turn.
- `size(java.lang.Iterable<?> iterable)` - Returns the number of elements in iterable.
- `sort(java.lang.Iterable<T> iterable)` - Creates a sorted list that contains the items of the given iterable.
- `sort(java.lang.Iterable<T> iterable, java.util.Comparator<? super T> comparator)` - Creates a sorted list that contains the items of the given iterable.
- `sortBy(java.lang.Iterable<T> iterable, Functions.Function1<? super T,C> key)` - Creates a sorted list that contains the items of the given iterable.
- `tail(java.lang.Iterable<T> iterable)` - Returns a view on this iterable that contains all the elements except the first.
- `take(java.lang.Iterable<T> iterable, int count)` - Returns a view on this iterable that provides at most the first count entries.

- `toInvertedMap(java.lang.Iterable<? extends K> keys, Functions.Function1<? super K,V> computeValues)` - Returns a map for which the `Map.values()` are computed by the given function, and each key is an element in the given keys.
- `toList(java.lang.Iterable<T> iterable)` - Returns a list that contains all the entries of the given iterable in the same order.
- `toMap(java.lang.Iterable<? extends V> values, Functions.Function1<? super V,K> computeKeys)` - Returns a map for which the `Map.values()` are the given elements in the given order, and each key is the product of invoking a supplied function `computeKeys` on its corresponding value.
- `toSet(java.lang.Iterable<T> iterable)` - Returns a set that contains all the unique entries of the given iterable in the order of their appearance.

4.14 Loops

This section discusses compact representation of loops. We suggest several representations for loops, some of them may look like the for loop.

4.14.1 Temporal Abstraction

Temporal Abstraction is a very useful technique when it comes to loops representation. [section 4.13](#) describes how Temporal Abstraction works and how does it used in our system. Below you can find six modes of representation that supported, every mode provided with description and an example of how the program will look like in this mode. The example that is used is a program that calculates sum of square roots of all positive elements of a collection. [Figure 4.17](#) shows how code looks like with no temporal abstraction.

```

int sum = 0;
for (int i : input) {
    if (i > 0)
        sum += sqrt(i)
}

```

Figure 4.17: This is an example of how the program looks like if Temporal Abstraction is disabled.

[Figure 4.18](#) is an example from Java 8 `java.util.stream` where a sequence of methods called one-by-one and the returned value of the first method activates the next method. We call this type of representation **Program**.

```

input.stream()
    .filter(i → i > 0)
    .mapToInt(i → sqrt(i))
    .sum()

```

Figure 4.18: This is an example of how Temporal Abstraction may be used. In this code all the elements that their value is greater than 0 are selected. Each element is inserted into a map where it's value is the key and the value is it's square. Finally all value are summed. The result of this code is sum of squares of all elements that their values are greater then 0.

Another representation is a lexical representation. The code is represented by a phrase that explains what happens in the line of code. We call this representation **Paragraph of Text**.

```
Sum the square roots of the positive integers of input
```

Figure 4.19: This is an example of how line of code may be represented by a phrase. For example, this phrase explains what happens in [Figure 4.18](#).

Another idea of representing Temporal Abstraction code is by a technique we call **Bullets**. [Figure 4.20](#) shows an example of the code in [Figure 4.18](#) where every action that is taken on the

stream presented in a different bullet. For example, the filtering condition named *Filter* and the criteria is positive, which means take only the positive elements.

```
- Enumerate: input
- Filter:    positive?
- Map:      sqrt
- Accumulate: +, 0
```

Figure 4.20: This is an example of the **Bullets** technique. The original code is presented in [Figure 4.18](#). **Enumerate** is the stream that we want to process. **Filter** is the passing criteria. **Map** is the data structure each element will be inserted and **Accumulate** is the action that will be taken on all the elements in the data structure.

Signal Flow technique is similar to signal-processing concepts. The different parts of the plan are represented as stages, and the computation is represented as a signal that flows through the stages. [Figure 4.21](#) shows an example of the code in [Figure 4.18](#) in **Signal Flow** representation.

<u>Enumerate</u>	→	<u>Filter</u>	→	<u>Map</u>	→	<u>Accumulate</u>
input		positive?		sqrt		+, 0

Figure 4.21: This is an example of the **Signal Flow** technique. The original code is presented in [Figure 4.18](#). The first stage is **Enumerate** that enumerates the input; The second stage is **Filter** that filters the input based on the criteria. The third stage is **Map** that maps the filtered elements; And the last stage is **Accumulate** that accumulates the elements.

The last representation technique is **Spreadsheet**, this is a simple way to represent what the code does by a small example. The idea is yielded from the concept that some people prefer to see an example in order to understand what the code does instead of reading it. [Figure 4.22](#) shows an example of how the code in [Figure 4.18](#) may be presented with **Spreadsheet** technique.

Positive input:	1	7	0	-29	42
sqrt (int):	1	3			6
<hr/>					
0-based Sum:	10				

Figure 4.22: This is an example of the **Spreadsheet** represents the code in [Figure 4.18](#). The first line of is a set of values that may be in a data structure. The second line is the result of the sqrt function. Note that there are no values below the values 0 and -29, this is because the don't pass the criteria (only positive elements). The third row is the result of summing the elements that left. In that case are: 1, 3, and 6. When summing them we will get 10.

4.14.2 Imperative Representation

This section discusses imperative representations for loops. Loops are very common, hence we would like to provide several types of compact representation for them. We call this type of representation Imperative. In computer science terminologies, imperative programming is a programming paradigm that describes computation in terms of statements that change a program state. We decided to call this compact representation imperative because it reminds the imperative programming languages such as: C, C++, and Java.

Loop Icon

The first representation that we suggest is called **Loop Icon**. The idea is to replace the key words that represent loops with \circlearrowleft . By replacing the keywords we save space on one hand but still it is clear to the reader that this is a loop. [Figure 4.23](#) shows an example of a loop without the *for* keyword, Instead \circlearrowleft is placed.

```
 $\circlearrowleft$ (int i = 0; i < n; i++)
    system.out.println(i)
```

Figure 4.23: This is an example where the *for* keyword was replaced with \circlearrowleft .

Loop Watermark

This technique is the most compact representation that we came up with that related to loops representation. We use the background to place the loop symbol, [Figure 4.24](#) shows an example of a loop that uses the **Loop Watermark** representation.

```
toString
  result ← ""
  temp ← head
  i ∈ [1, pos)
    result += temp.data + " "
    temp ← temp.next
  ↓ result
```

Figure 4.24: This is a public method named *toString*, in middle of the method there is a loop that runs from 1 to *pos*, for each iteration it concatenates the value of *temp.data* with space and concatenates it with *result*. The technique that is used in the line $i \in [1, pos)$ is described in [section 4.14.2](#).

Loop Range Representation

The idea for Loop Range technique was taken from mathematics. For example, $i \in [1, pos) \circlearrowleft$ represents that *i* is between 1 and *pos* (not included). It is also very convenient to use this form to iterate over objects in data structures, e.g., a loop over a list of cars may look like this, $item \in cars$. The programmer may iterate only on part of the list. For example, in order to iterate over the first 10 items we will write $item \in cars[0, 10] \circlearrowleft$.

Another way to present loop range is to use the representation that is discussed in [subsection 4.5.1](#). For example, for $0 \leq i < 10$. This is a loop the iterates from *i* to 10.

Loop variables

This technique suggests to present the loop variable and on the background a symbol that shows that this is a loop. For example, [Figure 4.23](#) will be presented like this [Figure 4.25](#).



Figure 4.25: This is an example how a loop like is shown in [Figure 4.23](#) can be presented in Loop Variable mode.

Loop Complexity

Sometimes when a programmer is programming and uses others code he might be interested in the complexity of the code that he uses. Therefore we suggest a representation technique where the programmer may see the complexity instead of the code itself. the code that is shown in [Figure 4.23](#) may be presented as shown in [Figure 4.26](#).



Figure 4.26: This is an example of **Loop Complexity** representation. The complexity of the code in [Figure 4.23](#) is $O(n)$, therefore it is represented with $O(n)$ and a circulation loops that denotes that this is a loop.

Loop Signature

This technique allows the programmer to see only the signature of the loop without the code inside it. For example, the loop

```
for (int i = begin; i < n; i++)
    system.out.println(i)
```


Will be presented as follows:

```
for (int i = begin; i < n; i++)
```

4.15 System Methods

Our motivation is to provide a compact representation to all system methods. System method is a method that has been provided by the developers of the language, e.g., `System.arraycopy()`. Currently it is quite difficult to pinpoint what are going to be the functions that the system will support but the motivation is to denote that this is part of our scope of the work. Gradually we'll add more and more functionality to this section.

Print to Screen (`System.out`)

Instead of writing long lines, e.g., `System.out.println("Hello, World!")`, one may show only `println` "Hello, World!" or use an icon like this:  "Hello, World!".

Memory Copy

Java provides methods that allow copying memory from one data structure to another, e.g., `System.arraycopy()`. This method accepts the source, the target, the initial index of the source, the initial index of the target, and how many items to copy. We suggest the following representation $a[i : \dots] \leftarrow b[i : j]$, which provides more compact view of the code, more readable and understandable code (note: the \dots in the a vector means that the program will use as much as memory as it needs). In this example the system copies all elements from index i to index j from vector b to vector a starting from index i .

Strings Utilities

The class `StringUtils` is a very useful class when it comes to performing operations on strings, e.g., check if string is empty or null; remove substrings, replace substrings, and split a string. The problem with commands is they are very long, e.g., `StringUtils.isEmpty(name)` ($name$ is a string). Instead we would like to give the option to write this line as follows: `name.isEmpty`.

4.16 Layouts

Deverywhere is a system that aims not only for mobile devices but also for personal computers. Compact representation can also be useful to make larger screens more clear and efficient. This section discusses ideas of how code may be presented on large screens.

4.16.1 Tiles

If the user would like to review several methods at the same time he may choose this representation to see them in a grid. In [Figure 4.27](#) 9 methods are displayed simultaneously on the tablet/computer screen. Each method's body is displayed in compact form. [Figure 4.28](#) presents a more clear view of how the methods may be organized.



Figure 4.27: This is an example of Tiles.

method 1	method 2	method 3
[compact body]	[compact body]	[compact body]
method 4	method 5	method 6
[compact body]	[compact body]	[compact body]
method 7	method 8	method 9
[compact body]	[compact body]	[compact body]

Figure 4.28: This is a more clear view of the methods in **??**. The methods are organized in a transparent table.

4.16.2 Breadcrumbs

While we write code we nest methods inside classes; classes inside classes; control blocks inside methods; control blocks inside control blocks etc. Sometimes, we might lose our presence due to over nesting. In-order to solve this issue we suggest a technique where the nesting hierarchy will be presented to the user at top of the screen, e.g., we have a class *Human*, inside this class we have a class *Brain* and inside this class we have a method *think*. [Figure 4.29](#) presents how code may be presented the user if currently he is located in the method *think* (note: there might be code between the three first rows).

```
+class Human
  +class Brain
    +think
      [code]
```

Figure 4.29: This is an example of a method (*think*) inside the class *Brain* inside the class *Human*. In order not to loose the orientation inside the code the titles of encapsulating classes are kept and the code between them is folded. Therefore while the programmer writes code inside the method *think* he knows that he is inside the classes *Brain* and *Human*.

4.16.3 Inter-procedural Flow

A technique that helps the programmer to understand the flow of the program easily. It presents code blocks connected one to another based on the flow of the program. This technique helps the programmer to understand the flow a program in a much better way. Inter-procedural Flow is based on Control Flow Graph (CFG) representation technique, using graph notation, of all paths that might be traversed through a program during its execution.

Code Bubbles

Developers spend significant time reading and navigating code fragments spread across multiple locations. The file-based nature of contemporary IDEs makes it prohibitively difficult to create and maintain a simultaneous view of such fragments. We propose a novel user interface metaphor for code understanding and maintenance based on collections of lightweight, editable fragments called bubbles, which form concurrently visible working sets.

The essential goal of this feature is to make it easier for developers to see many fragments of code (or other information) at once without having to navigate back and forth. Each of these fragments is shown in a bubble.

The following is an example of how will look like compact representation with Code Bubbles. [Figure 4.30](#) is a class which named *Person* who has two private fields: *name* - the name of the person; *partOfTheDay* - which indicates which part of the day it is (morning, noon, afternoon, midnight, night etc.). It has two methods: *greetings* - receives a name of a person and greets him; *getPartOfTheDay* - returns the part of the day.

```
+class Person
  -name
  -partOfDay

  +greetings(name)
    lPartOfDay <- getPartOfDay
    → lPartOfDay + " " + name + " have a nice day"

  +getPartOfDay
    partOfDay
```

Figure 4.30: This is an example of Code Bubbles.

Chapter 5

Representation Configuration

Chapter 6

Programming in Natural Language

6.1 Introduction

Programming languages are textual, and so require a keyboard In order to edit programs. Standard on-screen keyboards are inconvenient for texting, let alone for programming. In addition, they take almost one third of the screen which makes the small screen even smaller. In order to avoid using the inconvenient on-screen keyboard or an external device, we suggest to program by voice. Voice dictation is based on a common set of templates; these templates are individually customizable so that each developer can use the idioms that are most convenient for him or her.

We describe the idea of programming in natural language by writing requirements in order to bridge the gap between the code that the programmer wants to write and a code that is written on the screen. We claim that natural language can serve as the main tool for programming. We do not claim that it is the only tool, the programmer may use other gestures such as touch, on-screen keyboard, or external devices when he needs them.

6.2 Configuration

We suggest that every programmer will dictate his program the way is more convenient to him or her. Every one of us has a different way of describing the things that s/he want to say. Same with code dictation.

For example take the Java loop in [Figure 6.1](#). We would dictate it character by character: "for, open parenthesis, int, space etc.". This is inconvenient and cumbersome. Instead, we would like to forget about the syntax and just describe what you want. One way to say it is: "for i from zero to n". But other programmer may prefer to say "repeat n times" to describe the same loop.

We don't just dictate code from top to bottom; we also need to edit existing code and navigate to specific places in the code. Navigation depends on the context of what is shown on the screen, and on the surrounding code. For example, if the screen contains only one loop, I can say "Go to the loop". Or I could say "Rename the index of the first loop to j" to navigate to the first loop on the screen and change its index variable. This demonstrates that templates used for dictation has named parts, and I can refer to these parts when I issue editing or navigation commands.

```
for(int i = 0; i < n; i++)
```

Figure 6.1: A simple for loop

6.3 Natural Language Processing

In-order to process dictation we suggest two phase process: converting speech to text, and understanding the context of the text. We use speech to text engine for the speech conversion and context free grammar to understand the context.

6.3.1 Speech To Text Engines

We found several speech to text engines that we can use for our solution: Nuance Dragon [\[9\]](#) is a software developer kit (SDK) is used by developers and integrators to add speech recognition capabilities into in-house and commercial applications or workflow applications. This toolkit, which enables everything from free-text dictation to command and control functionality, can be deployed as part of a server- or client-based solution; Kaldi [\[10\]](#) is a toolkit for speech recognition written in C++ and licensed under the Apache License v2.0. Kaldi is intended for use by speech recognition researchers. Google Speech Server V2 [\[7\]](#) is an online free speech to text engine which runs on a server. Mostly used by researchers. We decided to use Google Speech

Server V2 because it is free and easy to use. There are much more speech to text engines but we decided to concentrate on the most known and the one that we choose to use.

6.3.2 Context Free Grammar

A context-free grammar (CFG) is a tuple $G = (T, N, S, R)$, where T is the finite set of terminals of the language, N is the set of non-terminals that represent phrases in a sentence, $S \in N$ is the start variable used to represent a full sentence in the language. R is the set of production rules of the form $N \rightarrow (N \cup T)^*$.

Extended Backus Naur Form

Extended Backus Naur Form is a notation for formally describing syntax how to write entities in language. The metalanguage is based on a suggestion by Niklaus Wirth (Wirth, 1977) that is based on Backus-Naur Form and that contains the most common extensions, i.e:

- Terminal symbols of the language are quoted so that any character, including one used in Extended BNF, can be defined as a terminal symbol of the language being defined.
- [and] indicate optional symbols.
- { and } indicate repetition.
- Each rule has an explicit final character so that there is never any ambiguity about where a rule ends.
- Brackets group items together. It is an obvious convenience to use (and) in their ordinary mathematical sense.

6.3.3 Dictation Parser

We use EBNF to create a set of rules that will validate commands that the programmer dictates. This set of rules can be extended easily by every user that understand EBNF. We use IEEE IEC EBNF [1] as our main reference to learn how to use EBNF. In [8, pages 51-86] Michal Gordon and David Harel claim that formal structured natural language requirements can serve as the

mean and the end to programming the behavior of reactive system using fully executable languages such as live sequence charts (LSC). We adopt this approach and use it to create a set of rules to process user dictation.

Grammar Construction

We now show how our grammar translates controlled natural language. Since we allow a CFG we can increment the grammar with additional rules that allow various ways of generating similar constructs. We can thus increase the set of accepted specifications by augmenting the grammar. However, ambiguity may grow as the grammar grows which would require the user to explicitly disambiguate his intentions in too many cases for the process to be friendly. We shall describe how basic commands such as: creation, navigation, and modification are parsed. The *Dictation Parser* tries to build a parse tree for every dictation that it receives. A valid dictation is a one that the *Dictation Parser* succeeded to create a parse tree for. A number of advanced ideas are not yet supported in the current implementation. Nevertheless, the current grammar allows implementing fully executable systems, and has been tested, among other examples, on the *LinkList* Example, and on the *Command Pattern* Example, see [6.3.4](#).

The set of rules is divided into three main layers: *Top*, *Categories*, and *Common*. The *Top* layer contains rules that have access to all categories. The *Categories* layer contains sub sections that divided to different categories. For example, the *Creation* sub section contains all rules that deal with creation. The *Common* layer knows nothing about any category, it contains all the necessary information for all actions. The *Top* layer and the *Categories* layer have access to the *Common* layer. [Figure 6.4](#) shows how rules divided into layers and sub categories. Note that this division has no effect on the action of rules. It is only to understand the set of rules better.

We now shall explain every sub category inside the *Categories* layer. *Creation* contains all rules that parse any creation dictation. For example, "Create a new class". *Navigation* contains all rules that parse any navigation dictation. For example, "Go to class person". *Modification* contains all rules that parse any modification dictation.

We now discuss two dictations that have the same meaning but expressed differently. It is important to Deverywhere to allow programmers dictate code in their preferred way. Lets assume that the programmer created a class *Car* and now he wants to create an inner class

Wheel. One way to say it is "create a static public class named *wheel* inside class *car*". Figure 6.2 presents the parse tree that is generated for this dictation. This dictation will lead to creating a new static class called *Wheel* inside a class that is called *Car*.

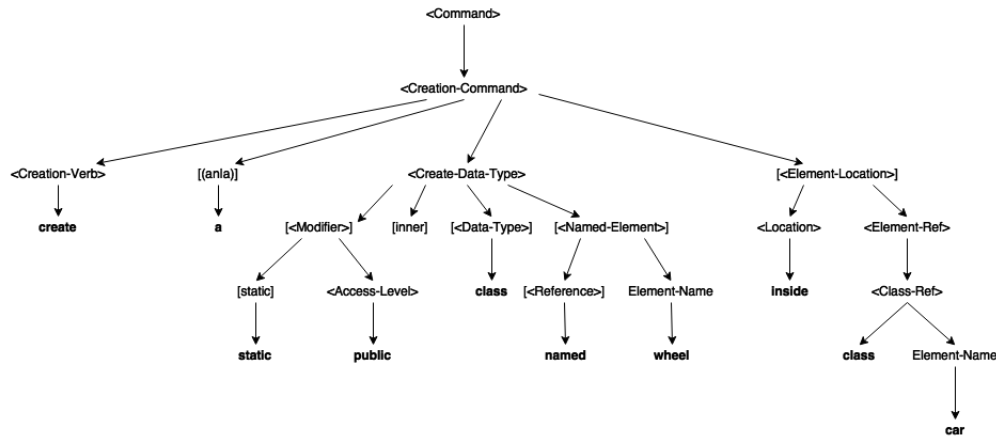


Figure 6.2: The parse tree for the sentence "create a static public class named *wheel* inside class *car*".

Another way to say it is "create an inner class *wheel*". In this case the class that will be create won't be static and the cursor of the IDE shall be placed inside class *Car*, otherwise the class *Wheel* won't be created inside class *Car*. Figure 6.3 presents the parse tree that is generated for this dictation. This dictation will lead to creating a new class called *Wheel* inside a class that is called *Car*.

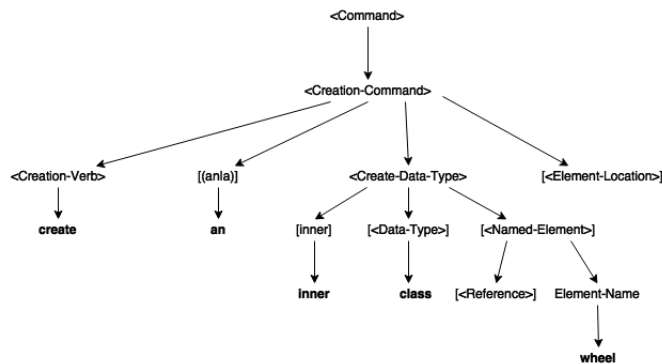


Figure 6.3: The parse tree for the sentence "create an inner class *wheel*".

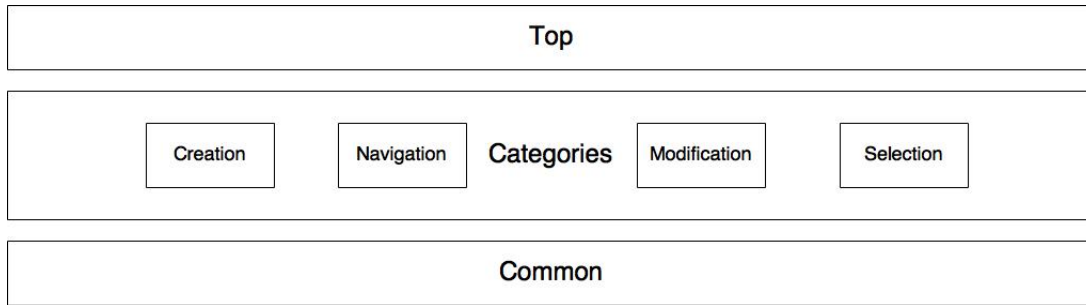


Figure 6.4: This is the architecture of the Dictation Parser rules

Table 6.1

Rule	Description
$\langle \text{Command} \rangle ::= \langle \text{Creation-Command} \rangle \mid \langle \text{Navigation-Command} \rangle \mid \langle \text{Modification-Command} \rangle \mid \langle \text{Selection-Command} \rangle$	bla
$\langle \text{Creation-Command} \rangle ::= \langle \text{Creation-Verb} \rangle \text{ } [(\text{an} \mid \text{a})] (\langle \text{Create-Statement} \rangle \mid \langle \text{Create-Data-Type} \rangle \mid \langle \text{Create-Field} \rangle \mid \langle \text{Create-Method} \rangle \mid \langle \text{Create-Block} \rangle) [\langle \text{Element-Location} \rangle]$	

Table 6.1:

```
for(int i = 0; i < n; i++)
```

Figure 6.5: A simple for loop

6.3.4 Grammar Testing

To test the grammar we provide two programs and their transcripts. The first example is an implementation of a linked list and the second is an example of the Command design pattern.

LinkedList Example

This is an implementation of the data structure linked list. [Figure 6.6-Figure 6.12](#) presents the program that implements Linked List. [Figure 6.3.4](#) lists the dictations that generates this program.

```
public class LinkedList implements Iterable {  
    private Node head;  
    private Node tail;  
    private int size;  
  
    public Iterator iterator(){  
        return new LLIterator();  
    }  
  
    private class Node{  
        public Object data;  
        public Object next;  
  
        public Node(Object data, Object next){  
            this.next = next;  
            this.data = data;  
        }  
  
        public Object getNext(){  
            return next;  
        }  
  
        public Object getData(){  
            return data;  
        }  
  
        public void setNext(Object next){  
            this.next = next;  
        }  
    }  
}
```

Figure 6.6: Implementation of Linked List in Java part 1

```
private class LLIterator implements Iterator{
    private Node nextNode;
    private boolean removeOK;
    private int posToRemove;

    private LLIterator(){
        nextNode = head;
        removeOK = false;
        posToRemove = -1;
    }

    public boolean hasNext(){
        return nextNode != null;
    }

    public Object next(){
        assert hasNext();

        Object result = nextNode.getData();
        nextNode = nextNode.getNext();

        removeOK = true;
        posToRemove++;

        return result;
    }
}
```

Figure 6.7: Implementation of Linked List in Java part 2

```
public void remove(){
    assert removeOK;
    removeOK = false;
    LinkedList.this.remove(posToRemove);
    posToRemove--;
}

}

public void makeEmpty(){
    head = tail = null;
    size = 0;
}

public Object remove(int pos){
    assert pos >= 0 && pos < size;
    Object result;
    if( pos == 0 ){
        result = head.getData();
        head = head.getNext();
        if( size == 1 )
            tail = null;
    }
    else{
        Node temp = head;
        for(int i = 1; i < pos; i++)
            temp = temp.getNext();
        result = temp.getNext().getData();
        temp.setNext( temp.getNext().getNext() );
        if( pos == size - 1 )
            tail = temp;
    }
    size--;
    return result;
}
```

```
public void remove(){
    assert removeOK;
    removeOK = false;
    LinkedList.this.remove(posToRemove);
    posToRemove--;
}

}

public void makeEmpty(){
    head = tail = null;
    size = 0;
}
```

Figure 6.9: Implementation of Linked List in Java part 4


```
public Object remove(int pos){
    assert pos >= 0 && pos < size;
    Object result;
    if( pos == 0 ){
        result = head.getData();
        head = head.getNext();
        if( size == 1 )
            tail = null;
    }
    else{
        Node temp = head;
        for(int i = 1; i < pos; i++)
            temp = temp.getNext();
        result = temp.getNext().getData();
        temp.setNext( temp.getNext().getNext() );
        if( pos == size - 1 )
            tail = temp;
    }
    size--;
    return result;
}
```

Figure 6.10: Implementation of Linked List in Java part 5

```
public Object get(int pos){
    assert pos >= 0 && pos < size;
    Object result;
    if( pos == size - 1 )
        result = tail.getData();
    else{
        Node temp = head;
        for(int i = 0; i < pos; i++)
            temp = temp.getNext();
        result = temp.getData();
    }
    return result;
}

public void insert(int pos, Object obj){
    assert pos >= 0 && pos <= size;
    if(pos == 0)
        addFirst(obj);

    else if( pos == size )
        add(obj);
    else{
        Node temp = head;
        for(int i = 1; i < pos; i++)
            temp = temp.getNext();

        Node newNode = new Node(obj, temp.getNext());
        temp.setNext( newNode );
        size++;
    }
}
```

Figure 6.11: Implementation of Linked List in Java part 6

```
public void add(Object obj){
    Node newNode = new Node(obj, null);
    if( size == 0 )
        head = newNode;
    else
        tail.setNext(newNode);
    tail = newNode;
    size++;
}

public void addFirst(Object obj){
    if(size == 0)
        add(obj);
    else{
        Node newNode = new Node(obj, head);
        head = newNode;
        size++;
    }
}

public String toString(){
    String result = "";
    Node temp = head;
    for(int i = 0; i < size; i++){
        result += temp.getData() + " ";
        temp = temp.getNext();
    }
    return result;
}
```

Figure 6.12: Implementation of Linked List in Java part 7

This is the list of the dictations that generates the program.

- Create class LinkedList that implements Iterable
- Create private field head of type Node
- Create private field tail of type Node
- Create private field size of type int
- Create method iterator that returns Iterator
- Return new LLIterator
- Exit method iterator
- Create inner class Node
- Create field data of type Object
- Make it public
- Create public field next of type Object
- Create constructor that accepts data of type Object and next of type Node
- Assign next to this.next
- Assign data to this.data
- Create method getNext that returns Object
- Return next
- Create method getData that returns Object
- Return data
- Create method setNext that accepts next of type object
- Assign next to this.next

- Exit class Node
- Create inner class LLIterator that implement Iterator
- Create a constructor
- Assign head to field nextNode
- Assign false to field removeOK
- Assign -1 to field posToRemove
- Ceate method hasNext that returns boolean
- Return is nextNode different from null
- Ceate method next that return Object
- Assert hasNext
- Create result of type object and assign nextNode.getData to it
- Call nextNode.getNext and assign it to nextNode
- Assign true to removeOK
- Increase posToRemove
- Return result
- Create method remove
- Assert removeOK
- Assign false to removeOK
- Call LinkedList.this.remove that accepts posToRemove
- Decrease posToRemove
- Exit LLIterator

- Create method makeEmpty
- Assign null to tail and head
- Assign zero to size
- Create method remove that accept pos of type int and returns Object
- Assert is pos more than 0 and pos less than size
- Create result of type Object
- If pos equal to 0 then
- Call head.getData and assign it to result
- Call head.getNext and assign it to head
- If size equal 1 then
- Assign null to tail
- Exit the if
- Else
- Create temp of type Node and assign head to it
- For i from 1 to pos
- Call temp.getNext and assign it to temp
- Exit the loop
- Call temp.getNext.getData and assign it to result
- Call temp.setNext that accepts temp.getNext.getNext
- If pos equal size minus 1 then
- Assign temp to tail

- Exit else
- Decrease size
- return result
- Create method get that accepts pos of type int and returns Object
- Assert is pos more or equal to 0 and less than size
- Create result of type Object
- If pos equal size minus 1 then
- Call tail.getData and assign it to result
- Else
- Create temp of type Node and assign head to it
- For i from 0 to pos
- Call temp.getNext and assign it to temp
- Exit for
- Call temp.getData and assign it to result
- Exit else
- Return result
- Create method insert that accepts pos of type int and obj of type Object
- Assert is pos more or equal to 0 and less than size
- If pos equal to 0 then
- Call addFirst that accepts obj
- Else if pos equal size then

- Call add that accepts obj
- Else
- Assign head to temp of type Node
- For i from 1 to pos
- Call temp.getNext and assign it to temp
- Exit the for loop
- Create new Node that accepts obj and temp.getNext and assign it to newNode of type Node
- Call temp.setNext that accept newNode
- Increase size
- Exit method insert
- Create method add that accepts obj of type Object
- Create new Node that accepts obj and null and assign it to newNode of type Node
- If size equal 0 then
- Assign newNode to head
- Else
- Call tail.setNext that accepts newNode
- Exit
- Assign newNode to tail
- Increase size
- Create method addFirst that accepts obj of type Object

- If size equal 0 then
- Call add that accepts obj
- Else
- Create new Node that accepts obj and head and assign it to newNode of type Node
- Assign newNode to head
- Increase size
- Create method toString that returns String
- Create result of type String and initialize it with an empty string
- Assign head to temp of type Node
- For i from 0 to size
- Result plus equal temp.getData plus space
- Call temp.getNext and assign it to temp
- Exit the loop
- Return result

Car Builder Example

This is an implementation of the Builder design pattern. We created a class of type Car that have properties and contains an inner class of type CarBuilder that has the functionallity to create an instance of Car. In-addition it has main. [Figure 6.13](#)-[Figure 6.14](#) presents the program that implements Linked List. [Figure 6.3.4](#) lists the dictations that generates this program.

```
public class Car
{
    private String _wheels;
    private String _engine;
    private String _body;

    private Car(String wheels, String engine, String body)
    {
        if(body == null || engine == null || wheels == null)return;

        _wheels = wheels;
        _engine = engine;
        _body = body;
    }

    public static class CarBuilder
    {
        String Body;
        String Wheels;
        String Engine;
        public Car BuildCar()
        {
            if(Body != null && Wheels != null && Engine != null)
            {
                return new Car(Wheels, Engine, Body);
            }
            return null;
        }
    }
}
```

Figure 6.13: Implementation of the design pattern Builder that creates a class of type Car part 1

```
public static void main(String[] args)
{
    Car.CarBuilder carBuilder = new CarBuilder();
    carBuilder.Engine = "honda";
    carBuilder.Wheels = "4";
    carBuilder.Body = "private";
    Car car;
    car = carBuilder.BuildCar();
}
}
```

Figure 6.14: Implementation of the design pattern Builder that creates a class of type Car part 2

This is the list of the dictations that generates the program.

- Create class car
- Create field wheel of type string
- Create field engine of type string
- Create field body of type string
- Create private constructor that accept wheels of type string engine of type string and body of type string
- If body equals null or engine equals null or wheels equals null then return
- Assign wheels to field wheels
- Assign engine to field engine
- Assign body to field body
- Create inner class CarBuilder
- Create public field body of type string

- Create public field wheels of type string
- Create public field engine of type string
- Create method buildCar that returns Car
- If body different from null or wheels different from null or engine different from null then return new car that accepts wheels engine and body
- Return null
- Create main inside car
- Create new CarBuilder and assign it to carBuilder of type carBuilder
- Assign honda as string to carBuilder.engine
- Assign 4 as string to carBuilder.engine
- Assign private as string to carBuilder.engine
- Create car of type car
- Call carBuilder.BuildCar and assign it to car

6.4 Implementation

To implement the *Dictation Parser* we reviewed different applications such as: BNFC, BNF Parser Generator, BNF for Java, Antlr 4. We decided to use Antlr 4 because it is can be integrated well in our solution, popular and well-known tool and it is well known to other members of the team. The implementation of the *Dictation Parser* is explained in details in [7.3](#).

Chapter 7

Prototype

7.1 Introduction

This chapter discusses the prototype that provides a proof of concept for this research. Every module of the prototype discussed and described in this chapter. All architecture designs and specifications described in details. Note that not all modules and ideas that discussed here are implemented, this detail will be mentioned for every module.

This prototype presents an ability of programing using speech and represent code in a compact way. It is written in the Java language and uses different third party services and applications. Every service and application that used is discussed and described.

7.2 Speech to Text

This is a module which responsible for the translation from speech to text. The engine that is used for the STT process is Google Speech V2 server. It is shown in Mey [\[7\]](#) how to interact with this server.

7.2.1 Google Speech V2 Server

Google Speech V2 server provides STT service with no charge for everyone who willing to use their service.

Remark: In order to use this service you have to be a chromium user (<https://www.chromium.org/>) because Google's server requires developer's key.

Host

In order to access this service the host that need to be used is <https://www.google.com/speech-api/v2/recognize>.

Request

The request that is need to be sent to Google's server is:

```
curl -X POST \  
--data-binary @'test.flac' \  
--header 'Content-Type: audio/x-flac; rate=44100;' \  
'https://www.google.com/speech-api/v2/recognize?output=json&lang=en-us&key=AIzaSyDT41KV3j_c20seW'
```

Explanation about the curl:

data-binary is a path on your local machine to audio file that you want to translate.

header is the information about encoding of the audio. In this example is flac with a bit rate of 44,100.

uri is the host of the server with concatenation of the output format, language, and developer key. in this example we use json (output=json), english (lang=en-us), and our developer key is AIzaSyDT41KV3j_c2OseWNNt4xv79MD9sj9p2j4.

Response

The response format is JSON. When Google is 100% confident in it's translation, it will return the following object:

```
{  
  "result":  
  [  
    ]  
  ]  
}
```

```
{
  "alternative":
  [
    {
      "transcript": "good morning Google how are you feeling today"
    }
  ],
  "final": true
},
"result_index": 0
}
```

When it's doubtful, it adds a confidence parameter for you. It also seems to add multiple transcripts for some reason.

```
{
  "result":
  [
    {
      "alternative":
      [
        {
          "transcript": "this is a test",
          "confidence": 0.97321892
        },
        {
          "transcript": "this is a test for"
        }
      ],
      "final": true
    }
  ],
}
```

```
    "result_index":0  
  }
```

7.2.2 Speech to Text Library

This library used to bring speech recognition to Processing applications (processing is a programming language, development environment, and online community. Since 2001, Processing has promoted software literacy within the visual arts and visual literacy within technology). Using WebSocket, Google Chrome and Processing, you can get unlimited speech recognition results in your Sketch. As of May 2014, you need a developer API key to use this library. The new API has a limit of 50 requests/day.

This library is an open source with dependency in Processing, hence we had to make modifications so it will fit our needs. Several modifications have been made to this open source:

- The dependency in Processing has been removed so the application could run as a simple Java project.
- A new response parser has been developed because the one that was in use didn't know how to parse the new format of Google Speech V2.
- Auto Speech Recording had memory issues.
- Various redesign modifications.

It is shown in Schulz [11] where to get the source code from and how to use it's API.

7.3 BNF Parser

Appendix A

Publications

This appendix contains all additional products that this research yielded.

A.1 MobileSoft 2015 Conference

Our research group submitted a paper to a mobile research conference and it has been accepted. Details of the conference and the paper provided in the Following list.

- Name: MobileSoft 2015
- Conference Website: <http://mobilesoftconf.org/2015/>
- Location: Italy, Florance
- Dates: May 16-17, 2015
- Paper's Title: Deverywhere: Develop Software Everywhere
- Authors: Yishai A. Feldman, Ari Gam, Alex Tilkin, and Shmuel Tyszberowicz.
- Affiliations: IBM Research, Tel Aviv University, The Academic College Tel Aviv Yaffo.

This conference was the 2nd ACM International Conference on Mobile Software Engineering and Systems Sponsored by ACM SIGSOFT.

Deverywhere: Develop Software Everywhere

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Abstract—Professional programmers use desktop or laptop computers as a preference. However, they sometimes need to continue their work on the go, when they may only have access to mobile devices. Thus, mobile devices can be important but not exclusive development platforms. Therefore, it is necessary to support programming in conventional languages on mobile devices, such as phones and tablets.

Programming on mobile devices presents two major obstacles: the lack of a physical keyboard, and the small screen space, which limits the amount of code that can be shown simultaneously. This paper addresses both challenges, and offers a method to enable programming on mobile and other devices with limited input and output capabilities, by using templates to make voice and touch input very effective for programming, and showing much more code in a limited space. These ideas are also relevant to programming on laptop and desktop systems, for people with disabilities such as repetitive-stress injuries (RSI) that limit keyboard usage, and partial vision loss, which requires the use of very large fonts.

I. INTRODUCTION

In the early days of computing, programmers had to work in offices. Personal computers allowed programmers to work at home as well. Laptops further expanded the working environment, and we often see people programming in coffee shops, terminals, trains, and airplanes. With ubiquitous mobile devices becoming increasingly popular, there is an opportunity to allow programmers to work in even more environments. While such small devices are unlikely to become the preferred working medium, they can be useful in circumstances where urgent action is required and other equipment is unavailable.

This scenario presents two major obstacles: first, the lack of a convenient keyboard; and second, the small screen space, which limits the amount of code that can be shown simultaneously. Some have advocated the creation of new programming languages for mobile platforms,¹ but the cost of adopting a new language, with its related tools and infrastructure, seems to be too great for the benefit of occasionally programming on a mobile device. This applies to the development of mobile and non-mobile applications alike; professional programmers who develop mobile applications still prefer to use large screens and physical keyboards. Instead, we focus on easy ways to use existing languages, such as Java and JavaScript, on mobile devices. Our proposed solution, called *Deverywhere*, addresses both challenges, by using templates to make voice and touch input very effective for programming, and to show much more

code in a limited space. Templates, used in context, allow voice input for program creation, editing, and navigation; and allow a compact representation of programs that makes maximum use of the given screen space. Both uses require a high degree of configuration, since programmers have different preferences regarding the way they want to voice and see programs. The underlying representation is always the original language, so that each programmer can see a tailored view while seamlessly collaborating on the same code with others.

These ideas are also relevant to programming on laptop and desktop systems, for people with disabilities such as repetitive-stress injuries (RSI) that limit keyboard usage, and partial vision loss, which requires the use of very large fonts. For some programmers, no screen is large enough, and so we expect that these programmers will use the compact representation of code even on large displays.

II. PROGRAMMING BY VOICE AND TOUCH

Dictation systems exist today, but their use for programming is extremely limited. Lacking any domain knowledge, they require most of the program to be dictated letter by letter, which is impractical. By building an understanding of program syntax and some semantics into the dictation tool, it is possible to make this process much more efficient. For example, the spoken words “for i from zero to n” can be interpreted as the Java idiom

```
for (int i = 0; i < n; i++) body
```

The current insertion point would be left at the body of the loop. Furthermore, *Deverywhere* will know that this place in the template is called “the body,” so that a further instruction to “edit the body of the for loop” will return to that point. Touch can alternatively be used for the same purpose.

Other locations can also be associated with templates. For example, the template above can define “the loop index” as referring to the variable *i*, so that the developer can later say “rename the loop index to *j*.” The general form of a Java `for` statement can define the “initialization,” “test,” and “update” locations, referring to the three parts inside the parentheses. A conditional template may have three locations, referring to the condition, the consequent, and alternative.

Similarly, an “iterate” template can be defined to generalize the use of iterators that are not accessible through the `Iterable` interface. For example, suppose that `tree` is an element of class `Tree<Element>`, which does not implement `Iterable` but provides an iterator through a

¹See, for example, the “Theme and goals” section of the PROMOTO 2014 Workshop, <http://research.microsoft.com/en-us/events/promoto2014>.

method `inOrderIterator()`. The utterance “iterate on tree in order” will create the following code:

```
Iterator<Element> iterator =
    tree.inOrderIterator();
while (iterator.hasNext()) {
    Element element = iter.next();
    □
}
```

The box represents the current insertion point. In this example, the types of the iterator and the element have been inserted automatically, based on the type of `tree`. Their names have been chosen heuristically, but they can be changed by the developer; they can later be referred to as “the iterator” and “the element,” respectively.

Such templates can be created for language constructs as well as for other types of patterns, such as application frameworks. For instance, we can dictate “event key is shift enter” for the following common Dojo expression that checks the details of a keyboard event:

```
event.keyCode == dojo.keys.ENTER
&& event.shiftKey
```

As part of the template-based input method, developers will be able to specify the kind of syntactic element they are about to enter, such as class, method, variable, or constant. A suitable template will be applied; for example, a constant in Java will automatically be defined as `public static final`. Similarly, a “main method” will open with the already supplied header `public static void main(String[] args)`. The same words (“main method,” “constant X,” etc.) can be used to navigate to the appropriate element. In addition, it should be possible to refer to elements according to their position in the text shown on the screen; for example, “first for loop,” “inner if statement,” “loop on i.” These templates should be recognized regardless of how the code was entered. This implies that Deverywhere should recognize templates from the original language text, without relying on any external annotations.

A convenient way to add templates should be provided, as the number of possible templates is unlimited, and may even be programmer-specific. Each template is associated with utterances to create it, with named locations, and with its compact representation. The utterances form a grammar, which need not be completely unambiguous, since the development environment can offer a choice between alternatives. This, however, should be avoided as much as possible.

The same utterance and compact representation can be associated with more than one code template, in order to support multiple programming languages. One of the significant advantages of this template-based system is its ability to treat multiple languages in a similar way (to the extent that the languages provide similar mechanisms, of course).

Context is crucial to understanding. For example, names in a program are usually limited to a relatively small set, which depends on the current scope; a number of methods can be used to select the correct one efficiently. One way is to start

naming a variable (or class name, method name, etc.) either by spelling or, if it is composed of known words, by sounding them. Once the choice becomes small enough to show it on the screen, completion can be made by sounding the number of the correct choice. Another way is to assign short nicknames to variables and other named elements, then refer to them by their nicknames. The initial definition of a variable cannot be made in this way, as the space of choices is unlimited. If the name is a known word or a series of known words, they can be dictated and Deverywhere can join them in the way appropriate for the programming language and the type of the element; for example, using CamelCase with appropriate capitalization in Java.

Refactoring and other source transformations, as in Eclipse, are a must for Deverywhere, with the appropriate modification of the relevant wizards to work with voice entry. In addition, other capabilities would be useful. For instance, suppose the developer wants to use the result of a method call that is part of an expression in another context. In Eclipse, the developer would have to mark the method call expression, then apply the Extract Local Variable refactoring, then move the generated variable definition upwards if necessary, and finally use it. Instead, in the voice-programming system, the developer will be able to say “use the result of the second call to substring.” This will create the variable at the correct position, and insert a use of the variable at the current insertion point.

Statically-typed languages such as Java are often very verbose, especially in the specification of types. However, type inference methods exist for these languages, and current IDEs use them to identify errors and fix them automatically. The voice-programming system will not require (yet allow) the specification of types at any point, and will try to infer as much information as possible. In the example above, “for i from zero to n,” it is clear that `i` is an `int`, and this need not be mentioned at all. When type inference fails, information about the variable may be limited; for example, the system will not be able to suggest methods for that variable. Therefore, the developer should always have a verbal command that adds a type definition to the variable at the current insertion point. This will add the missing type at the point the variable is defined, but will not change the current view or the current insertion point, so that the developer can continue choosing the method to call without further distractions.

III. PROGRAMMING ON SMALL DISPLAYS

While mobile displays are getting larger, they are still significantly smaller than the displays developers are used to. Even a 7” phone/tablet provides much less screen space for programming than a typical 21” desktop display. The amount of code that developers can see simultaneously has a great effect on their productivity. Special techniques are therefore required in order for programming on small displays to be effective. The templates that are used for voice entry can also be used for display.

There are many ways to show information visually in a compact way; for example, using special symbols, colors,

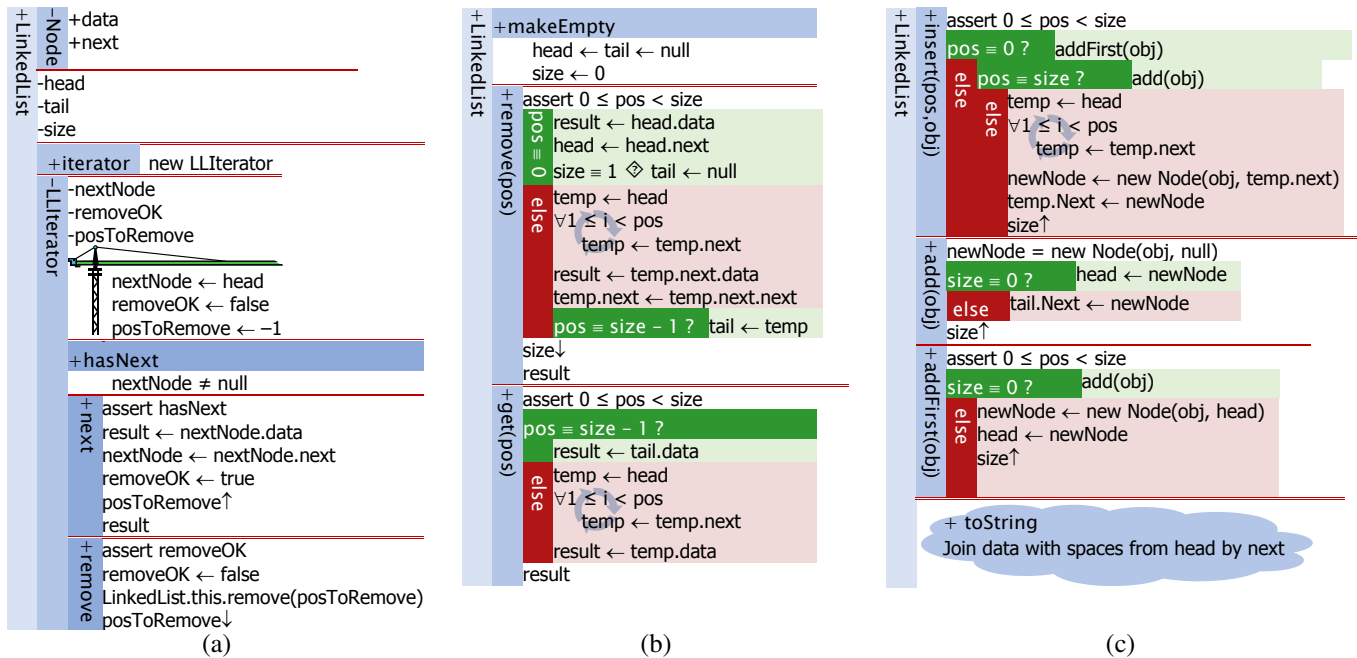


Fig. 1: The `LinkedList` class, as would be shown by Deverywhere.

fonts, backgrounds, borders, and even watermarks. Some information, such as noise words (then, else, end, etc.), types, throws declarations, access levels, and package prefixes, can even be omitted altogether (with an option of showing them selectively, perhaps using a touch gesture).

The example in Figure 1 shows many of these techniques; it may be extreme for some tastes, but, as mentioned above, the way program features are shown in the compact representation must be individually configurable, for the preferences of each developer and also based on screen size. This particular presentation of the program should be thought of as an example of how Deverywhere can be customized rather than as the definitive output format. The figure shows the code separated into three parts, each of which fits the size of a reasonable smartphone.

This code of example is taken from the University of Texas CS307 course of 2011 (<https://www.cs.utexas.edu/~scottm/cs307/javacode/codeSamples/LinkedList.java>), and implements a linked list. It has not been modified in any way except for the presentation, and the intent is for the code kept in the source-control repository to be the same as the original.

This example demonstrates many possible features of compact representations of programs. Names of enclosing classes and methods appear on the bar that also serves for the indentation, unless the bodies are very short. Many language elements are omitted (comments, types, keywords such as `class` and `return`, empty pairs of parentheses, and symbols such as statement terminators and braces); others have been replaced by short notation (+ and - for public and private, the equivalence symbol for ==, arrows for ++ and --, and special

notation for constructors, conditionals, and loops). Background colors are used to show scopes (shades of blue for classes and methods, green for the then and red for the else part of conditionals); the scope of a constructor is denoted by the extent of the crane symbol. Note that class and method names appear at the start of every relevant screen, not just at the beginning of their scopes.

Templates have been used in several places to make code more concise (and perhaps also more readable). Getters and setters have been compressed to look like field reads and writes, as is done in several languages (but not in Java). The common mathematical idiom $0 \leq x < s$ is used instead of the cumbersome notation that uses a conjunction of two inequalities. The same notation is used here for loop bounds, in the (very common) case of a unit increment.

Conditionals are shown here using the same block structure as classes and methods, except for the colors used to denote the different branches. One exception, demonstrating a somewhat more conventional way of representing a conditional, appears inside the `remove` method in part (b). This notation is similar to the three-way conditional expression of Java, but uses a different symbol to denote that it is a statement rather than an expression.

Loops are shown with a circular watermark that denotes the scope, and a special symbol (∇) to indicate the loop control. This is perhaps the most unusual notation we show in this paper; while it may be chosen by few developers, we use it to show the variety of notation that can be used for a compact representation of programs.

The last method, `toString()`, is different from the other parts of this example. In some cases, it is useful to show some

documentation (perhaps, but not necessarily, the Javadoc) instead of the method body. This offers a very concise view that shows the intent without the implementation; this is often very useful.

Other possibilities, not shown in this example, include automatically inlining a value that is only used once provided the resulting expression is not too large; this could have been done (twice) for `newNode` in part (c). Existing Eclipse templates, such as expanding `sysout` to `System.out.println`, can be used in reverse to compact programs that use the expansions of such templates. This can be extended even further; for example, given an analysis that converts imperative idioms to functional ones, such as `LambdaFicator` [6], the view can show the functional form without changing the underlying program.

As can be seen from this example, the representation is sometimes ambiguous. This seems to us to be acceptable, since the meaning will in most cases be obvious from the context. In any case, the developer will always be able to ask to see more details (perhaps by touching locations for which more information is desired).

Program slicing, and especially Fine Slicing [1], is a very effective technique for showing a small part of the code that is relevant to a particular purpose. When browsing code, slicing can be used to prevent the need for a lot of scrolling. The program view would normally consist of a single method, possibly with some context given as a breadcrumbs view. In some cases, it is useful to show enclosing conditionals and loops, but without intervening details; this is a kind of poor-man's slicing that is more easily implemented.

IV. ROADMAP

In order to map the requirements and possibilities of development on limited platforms, we performed several dictation experiments where the speaker tried to dictate a program as naturally as possible, and the writer attempted to understand as literally as possible. In addition, we studied previous work on mobile programming environments [5], [7], compact representations [3], [8], [9] and dictation [2], [4], and abstractions used by various programming languages.

Previous work on mobile programming environments [5], [7] has focused on new languages that are more natural for the mobile environment. In contrast, we believe that such new languages will have very limited use, mostly for small applications. Professional development will continue to be done in more established languages, and a mobile solution for professional programmers should support these languages without requiring changes in the underlying technology.

We found many interesting ideas in Intentional Software [9] and registration-based abstractions [3], [8], which have discussed multiple views of the same underlying program. VoiceCode [4] and Spoken Java [2] focus on voice entry of programs. Deverywhere combines voice input with a compact presentation using the same set of templates.

The results of our study are several lists and relationships. One list contains features that a mobile programming environment can support; in addition to those discussed above, the list includes items such as the automatic application of quick fixes, renaming conflicting elements, extension methods [10], and two-dimensional expressions (as in mathematics). A second list contains features for compact representation; a third lists features for voice input; and a fourth lists configuration modes, such as the use of typographic styles, layouts, frames, and watermarks. We also created a matrix relating input and output options with the various ways each of these can be shown; this will be the basis for the developer-specific customization.

V. CONCLUSION

Deverywhere relies on templates that have information about their structure that supports flexible voice input and various types of compact representations. Customizability is crucial to support different personal styles as well as different sizes and capabilities of programming environments.

Once fully implemented, Deverywhere has the potential to make programming on devices with limited user interfaces, such as mobile phones and tablets, much more convenient than they are now. This will allow developers to work more comfortably in environments in which programming was very difficult.

These techniques can also provide enormous help to developers who have various kinds of disabilities that prevent them from using existing interfaces on laptop and desktop environments effectively. In fact, we conjecture that many developers would enjoy having the benefits of Deverywhere as additions to their normal working environments.

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- [10] Xtend – modernized java. <http://eclipse.org/xtend>.

Appendix B

Acronyms

NLP Natural Language Processing

ASR Automatic Speech Recognition

STT Speech to Text

JSON (JavaScript Object Notation) is a lightweight data-interchange format

API Application Programming Interface

CFG Context Free Grammar

EBNF Extended Backus Naur Form

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