# A Catalog of OO-inspired End-User Smells, and Application to LEGO MINDSTORMS EV3 and Kodu

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## ABSTRACT

Millions of people in the workforce today program, without degrees or professional training in software development. These end-user programmers perform a variety of tasks, from combining web information to building models to support business decisions. Software engineering research into code smells has traditionally focused on professionally used object-oriented programming languages, yet these end-user domains and languages also suffer from code smells.

In this work, we explore recent research in two distinct end-user domains and languages: spreadsheets in Microsoft Excel and web mashups in Yahoo Pipes. Based on existing OO-smells and their applications to these two end-user domains, we distill a catalog of generic end-user smells. We demonstrate the broad applicability of the catalog by mapping the smells to two additional end-user languages not previously targeted by smell detection and refactoring research, both aimed at education: LEGO MINDSTORMS EV3 and Microsoft's Kodu. The results of this application show that OO inspired smells indeed occur in educational end-user languages and are present in 88% and 93% of the EV3 and Kodu programs, respectively. Most commonly we find that programs are plagued with lazy class, duplication, and dead code smells, with duplication smells being present in nearly 2/3 of programs in each language. We conclude the paper by proposing new end-user smells inspired by the educational languages, moving beyond the OO paradigm.

## 1. INTRODUCTION

**TODO: make smell names consistent and emph everywhere** End-user programmers are said to outnumber professional programmers three times over [1]. These end-user programmers perform a wide variety of tasks within their organizations, ranging from creating new web streams to building and maintaining applications in a spreadsheet. When performing these tasks, end-user programmers, including users of educational languages, face many of the challenges of professional developers, such as identifying faults, debugging, or understanding code written by someone else [2].

Also similar to professional development is the longevity of the produced artefacts, the average lifespan of a corporate spreadsheet for example is five years [3]. During this long lifespan, end-user artifacts are modified, often by different people. These properties make them, like source code artifacts, vulnerable to *smells*.

Code smells, at outlined in the taxonomy of Fowler pertained to object-oriented (OO) code, and professional programming languages were the focus for at least the first decade of code smell and refactoring research [4]. Recently, however, smells in end-user programming have also reveived attention in research, most notable structural smells in Yahoo Pipes web mashups [5] and Excel spreadsheets [6]. Experiments in these and other end-user areas have shown that end-user programmers understand smells, and often prefer versions of their code that are non-smelly [7–9].

In this paper we combine the above two end-user smell approaches and observe that many of the OO smells are applicable in both domains: either they have been already studied, or there is clear opportunity to do so. This led us to the introduction of a generically applicable, OO-inspired end-user smells. To demonstrate the broad applicability of the catalog, we applied it to two new end-user domains aimed at education: LEGO MINDSTORMS EV3 and Microsoft's Kodu. The results of the application show that OO inspired smells in our catalog in fact occur in both end-user languages: 88% of the EV3 and 93% of the Kodu programs contained at least one smell. This underlines the power of the code smells concept: they are applicable to visual languages aimed at education, which are quite different from the textual languages aimed at professional developers that the concept was initially designed for.

In EV3 and Kodu, the smells that we most commonly find are small abstractions (lazy class), duplication, and dead code, illustrating commonality across all end-user programming domains. The contributions of this work are as follows:

- Synthesis and catalog of object-oriented-inspired code smells in end-user programs
- Application of the catalog to two additional end-user domains focused on education: LEGO MINDSTORMS EV3 and Kodu
- Identification of future opportunities for domain-specific, non-OO-inspired smell detection in end-user programming domains

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Copyright 200X ACM X-XXXXX-XX-X/XX/XX ...$10.00.

The rest of this paper is organized as follows. Section 2 provides background on the two previously studied domains, Excel spreadsheets and Yahoo Pipes mashups. The synthesized catalog of smells is presented in Section 3. We apply the catalog to LEGO MINDSTORMS EV3 and Kodu in Section 4 by defining each smell in each domain and measuring the presence of smells in corpuses of programs created by both children and the community for each language. We explore opportunities for new, non-OO smells in end-user domains in Section 5, which is followed by related work in Section 6, threats to validity in Section 7 and a conclusion in Section 8.

## 2. BACKGROUND

In this section we briefly introduce the two end-user languages targeted by prior smell research, before presenting the relevant end-user code smells in Section 3.

### 2.1 Excel

Spreadsheets are very commonly used in businesses, from inventory administration to educational applications and from scientific modeling to financial systems. Winston [10] estimates that 90% of all analysts in industry perform calculations in spreadsheets. Microsoft Excel is by far the most used, and therefore most studied, spreadsheet program, but other implementations exists and are similar.

In modern spreadsheet programs, a *cell* can contain a single *formula* which performs a calculation, and a table of cells is bundled in a *worksheet*; an example is shown in Figure 1. A *workbook* consist of a collection of worksheets. Formulas can reference other cells in the same or in different workbooks and worksheets.

### 2.2 Yahoo Pipes

Yahoo Pipes was[1] a popular web mashup language and environment with which RSS feed information could be collected and combined from various sources. Figure 2 shows an example program as it appeared in the Pipes Editor. The boxes represent modules connected by wires and data flows from the data sources at the top (e.g., *fetch feed* modules) to the output at the bottom (i.e., *pipe output*). The wires connect the output of a module with either the input or a field of another module.

Various manipulations of the data are possible along the way, such as concatenating RSS feeds (e.g., *union* modules), sorting or filtering based on various criteria, or truncating the list (e.g., *truncate* modules). Abstraction was possible with *subpipe* modules, which allowed a programmer to insert a different pipe as a subroutine. These subpipes appeared like a standard module but when clicked, opened the abstracted pipe in an editor.

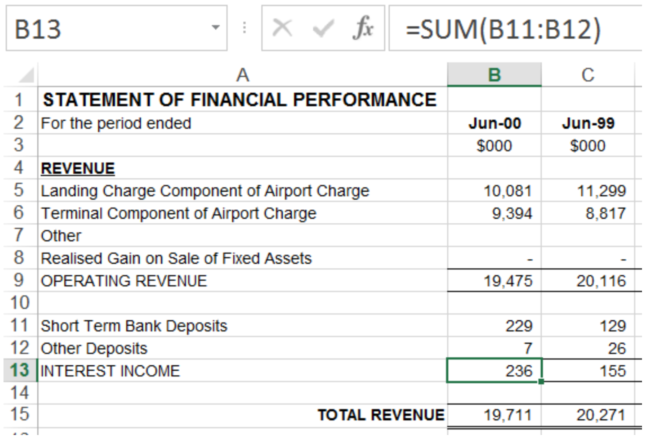
## 3. SMELLS IN END-USER PROGRAMS

Research into end-user language smells has had two approaches, which are not mutually exclusive. The first approach is to take existing smells for OO programming languages, usually those defined by Fowler [11], and transform them to be applicable to the end-user environment [5–9]. The second approach is to define smells tailored to the end-user environment. This can be done by interviewing experienced end-users to see which smells they perceive [9], by looking at user reports like forum or newsgroup posts [9,12], or by analyzing publicly available repositories [5,7,8].

This section provides an overview of different OO-inspired smells that researchers have found to be applicable to end-user artifacts. We catalog the OO smells present in two end-user languages, Excel spreadsheets and Yahoo Pipes mashups, in Table 1, as identified in prior work [5–8]. Overall, we often observe similarities in the code smells studied. Specifically, the *duplicate code*, *lazy class*, and *long method*

[1]We use the past tense as the Yahoo Pipes environment has been discontinued as of September 30, 2015.

**Figure 1: Microsoft Excel 2013 showing a spreadsheet. Columns B and C show the typical mix of data and calculation. The formula of the selected cell B13 is visible right above the spreadsheet.**



B13 | =SUM(B11:B12)

| | A | B | C |
|---|---|---|---|
| 1 | **STATEMENT OF FINANCIAL PERFORMANCE** | | |
| 2 | For the period ended | **Jun-00** | **Jun-99** |
| 3 | | $000 | $000 |
| 4 | **REVENUE** | | |
| 5 | Landing Charge Component of Airport Charge | 10,081 | 11,299 |
| 6 | Terminal Component of Airport Charge | 9,394 | 8,817 |
| 7 | Other | | |
| 8 | Realised Gain on Sale of Fixed Assets | - | - |
| 9 | OPERATING REVENUE | 19,475 | 20,116 |
| 10 | | | |
| 11 | Short Term Bank Deposits | 229 | 129 |
| 12 | Other Deposits | 7 | 26 |
| 13 | INTEREST INCOME | 236 | 155 |
| 14 | | | |
| 15 | **TOTAL REVENUE** | 19,711 | 20,271 |

**Figure 2: Example of a program in Yahoo Pipes. It has five RSS feed data sources, each in a *fetch feed* module, feeding to a *union* module that concatenates the feeds, a *truncate* module that limits the number of items to 15 prior to the final *pipe output*.**

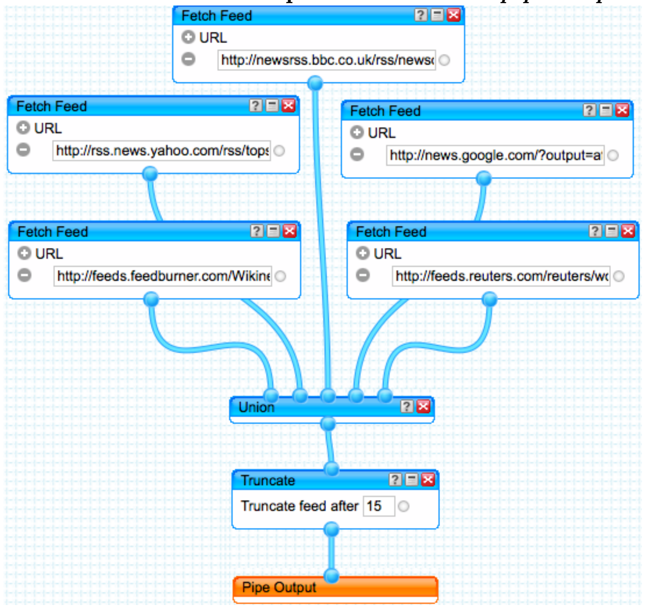

Fetch Feed
URL
http://newsrss.bbc.co.uk/rss/news
Fetch Feed
URL
http://rss.news.yahoo.com/rss/tops
Fetch Feed
URL
http://news.google.com/?output=a
Fetch Feed
URL
http://feeds.feedburner.com/Wikin
Fetch Feed
URL
http://feeds.reuters.com/reuters/w
Union
Truncate
Truncate feed after 15
Pipe Output

Table 1: Catalog of Code Smells in End-User Programs

| OO Smell | Excel | Yahoo Pipes |
|---|---|---|
| Dead Code | | Unnecessary Module [8] |
| Deprecated Interface | | Deprecated Module or Invalid Source [8] |
| Duplicate Code | Duplicated Formulas [7] | Duplicate Modules, Duplicate String or Isomorphic Paths [8] |
| Feature Envy | Feature Envy [6] | |
| Inappropriate Intimacy | Inappropriate Intimacy [6] | |
| Lazy class or Middle Man | Middle Man [6] | Unnecessary Abstraction [8] |
| Long Method | Multiple Operations [7] | Noisy Module : Duplicate Field [8] |
| Many Parameters | Multiple References [7] | |
| Message Chain | Long Calculation Chain [7] | |
| No-op | | Unnecessary Module [8] |
| Unused Field | | Noisy Module : Empty Field [8] |

smells have been studied in both languages. Next, we briefly explore some of the studied smells in these two domains.

## 3.1 Excel

Hermans *et al.* [6, 7] analogize a workbook to a program, a worksheet to a class inside that program and a cell to a method and use this to adapt nine of Fowler's smells [11] to the spreadsheet domain. An example of this is the *long method* smell, which translates to the *multiple operations* smell, since formulas with a large number of operations suffer from similar problems as long methods in terms of understandability and similarly the *many parameters* smell applies to spreadsheet formulas that refer to a large number of other cells or ranges.

The above two smells occur at the formula level, but smells at the worksheet level occur too. For example, the *feature envy* smell occurs where a given formula mainly uses cells located on a different worksheet, such as:

```
=('Required Funds'!B9/'Required Funds'!C9/12) +
('Required Funds'!B10/'Required Funds'!C10/12)
+ ('Required Funds'!B11/'Required Funds'!C11/12)
```

This formula occurs in the clienttemplate.xlsx spreadsheet stemming from the EUSES corpus [13]. As this formula refers to cells from the `Required Funds` worksheet, it would be a better fit. Similarly, two worksheets can have formulas that refer to each other heavily, introducing the *inappropriate intimacy* smell. The *message chain* smell occurs within spreadsheets if long chains of connecting formulas are constructed. This hampers understandability, as the entire chain of formulas has to be traced. In a study on the above mentioned EUSES corpus, 42% of spreadsheets were found to be smelly [7].

## 3.2 Yahoo Pipes

Stolee and Elbaum [5, 8] treat a Yahoo Pipes mashup as a class and each module as a method. Fields in a module are treated as parameters. Using this analogy, several OO smells can be mapped to this language. The most common smell, appearing in nearly one-third of the 8,000 pipes studied, was *duplicate strings*, an instance of Fowler's *duplicate code* smell. A similar smell, *duplicate modules*, impacted nearly one-quarter of the pipes studied.

*Dead code* can appear in Yahoo Pipes when a module is not connected to the rest of the pipe. A *deprecate module* occurs when a program uses a module that has been deprecated in the API. A *lazy class* or *no-op* smell occurs when data flows through an entire pipe or a module, respectively, but is not manipulated. The *unused field* smell occurs when blank fields are left in modules, specifically when those blanks are supposed to contain data sources. Considering the smells in Table 1, 81% of over 8,000 programs were found to be smelly [5, 8].

## 3.3 Summary

In both the Excel and the Yahoo! Pipes work, OO inspired smells were applied to end-user languages. Some of the smells have been already studied in both domains, while others have not. However, the absence of an entry in Table 1 does not mean the absence of the smell in that language, it simply means such smells have not been studied. While measuring the occurrence of these smells falls outside the scope of the current work, we speculate that some of these unstudied smells may be applicable. For example, *many parameters* is not discussed in previous work on Yahoo Pipes, but could apply when a pipe module receives many field values via wire from other modules. Similarly, *no-op* could occur in Excel in a formula like `SUM(A1+A2+A3)`. Here, the `SUM` function does not add anything, it is only sums one value: the result of the addition.

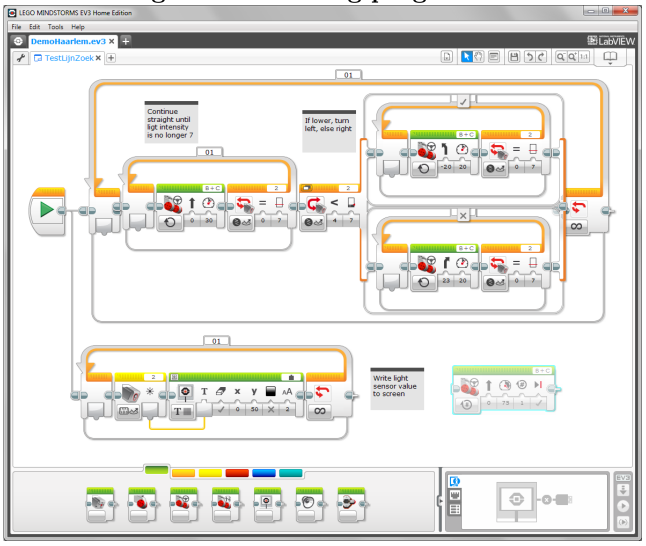
## 4. APPLICATION

In Section 3, we cataloged OO-inspired end-user smells from previous work. In order to demonstrate the applicability of our catalog, we apply it to two new domains: LEGO MINDSTORMS EV3 software (EV3 for short) and Kodu.

## 4.1 LEGO MINDSTORMS EV3

EV3 is the third iteration of the LEGO MINDSTORMS robotics line. It consists of a number of sensors, four motors

**Figure 3: The interface of LEGO MINDSTORMS EV3 showing a line following program.**


LEGO MINDSTORMS EV3 Home Edition
File Edit Tools Help
DemoHaarlem.ev3
LabVIEW
TestLijnZoek
Continue straight until ligt intensity is no longer 7
If lower, turn left, else right
Write light sensor value to screen

and an ARM 9 “intelligent brick”. The robotics kit comes with a control software package, which allows for visual programming of the brick, based on LabView[2]. The software supports several basic constructs common to programming, including loops and conditionals, as well as more advanced features like parallel execution. Figure 3 shows the user interface of the EV3 software with a program that makes a robot follow a black line by steering left if the sensor value is below the threshold of 7 and right if the value is above, and in parallel writes the sensor value to the screen. This program demonstrates some of the basic EV3 programming concepts including parallel execution, loops and switches. Blocks have to be connected to the ‘Play button’ on the left with wires to be executed, the block on the lower right is not connected and thus colored gray to indicate this to the user.

In addition to the programming concepts described above, users have the possibility to define ‘MY BLOCKS’ which are basically subroutines. MY BLOCKS may have up to 9 different input and one output parameter. MY BLOCKS cannot be programmed from scratch; they can only be created by selecting blocks in an existing program and clicking ‘my block builder’. This puts the selected blocks in a new MY BLOCK and replaces the blocks with a call to the newly created MY BLOCK, an abstraction action very functionally similar to ‘extract method’ present in most modern IDEs.

### *4.1.1 Smells in LEGO MINDSTORMS EV3*

In this subsection we describe how the smells in our OO-inspired catalog apply to EV3 programs. As common in the other approaches, we define a loose mapping of OO concepts to the end-user language in question, to be able to translate the smells. In EV3 programming, MY BLOCKS consist of a number of blocks, can be called multiple times, and use input and output. As such they resemble methods in source code, modules in Yahoo Pipes and worksheets in spreadsheets. Based on this translation, we investigate whether and how each of the smells in our catalog apply to EV3 programs.

**Dead Code:** It is possible for programming blocks to be disconnected, but the interface clearly indicates this as explained above. However, unused MY BLOCKS can be present in the project without a warning being issued. This is smelly as it makes the program unnecessarily large.

**Deprecated Interface:** This is a smell that does not apply, as, to date, there is only one version of the EV3 software and no blocks have been deprecated.

**Duplicate Code:** When the same, or very similar combinations of blocks occur, the program suffers from the duplicate code smell.

**Feature envy:** While all defined variables within EV3 programs are global, they can be written in a certain MY BLOCK but read in a different one. If, in a given MY BLOCK many variables are read that have been written somewhere else, this is be an occurrence of the feature envy smell.

**Inappropriate Intimacy:** Variables can be read in one MY BLOCK but written somewhere else. If there are two MY BLOCKS sharing multiple variables this way, it might be better to combine them.

**Lazy Class:** If a MY BLOCK is very small, for example, consisting of just one block, they do not add a lot of value, while impacting understandability, as a user has to navigate to the MY BLOCK to see what its functionality is.

**Long method:** If a MY BLOCK grows very large, it will no longer be easy to understand, counteracting the added value of the abstraction.

**Many Parameters:** MY BLOCKS can have 9 different parameters, which could be considered too much for easy understandability, especially since parameters need to be connected with wires, potentially leading to visual clutter.

**Message Chain:** Since MY BLOCKS can have both input and output parameters, they can form a message chain, in which values are continuously passed until they are used, while they could have been passed directly, outside of the MY BLOCKS.

**No-op:** It is possible to combine blocks in such a fashion that they do not actually contribute to the functionality of the program. For example, if a user stops the same motor twice, the second stop will be a no-op.

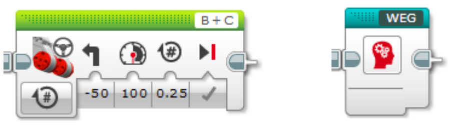
**Unused Field:** As explained above, MY BLOCKS can define parameters. However, the user is not forced to use them, hence it is possible to define parameters but not use them.

[2]`http://www.ni.com/labview/`

**Table 2: Size in terms of the different number of blocks used in the seventeen LEGO MINDSTORMS EV3 programs, and the smells they exhibit**

| Name | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | L11 | L12 | L13 | L14 | L15 | L16 | L17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Action | 8 | 6 | 5 | 7 | 16 | 8 | 10 | 16 | 10 | 1 | 2 | 1 | 7 | 15 | 2 | 2 | 78 |
| Flow Control | 3 | 5 | 4 | 4 | 4 | 3 | 7 | 11 | 2 | 2 | 1 | 4 | 11 | 2 | 0 | 0 | 25 |
| Sensor | 1 | 0 | 0 | 2 | 1 | 0 | 8 | 10 | 4 | 1 | 0 | 1 | 0 | 4 | 2 | 0 | 0 |
| Data Operations | 1 | 0 | 2 | 5 | 0 | 0 | 4 | 4 | 1 | 0 | 0 | 2 | 0 | 7 | 1 | 1 | 0 |
| Advanced | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MyBlock Call | 2 | 0 | 2 | 2 | 3 | 4 | 3 | 5 | 0 | 1 | 0 | 1 | 0 | 3 | 1 | 4 | 27 |
| Comment | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 6 | 6 | 0 | 15 | 0 | 0 | 7 | 13 |
| Variables | 0 | 0 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 |
| MyBlocks | 3 | 0 | 3 | 2 | 3 | 2 | 2 | 4 | 0 | 1 | 0 | 1 | 0 | 4 | 1 | 3 | 6 |
| Total Blocks | 20 | 11 | 17 | 26 | 28 | 18 | 35 | 50 | 17 | 12 | 9 | 10 | 33 | 54 | 7 | 17 | 149 |
| Dead Code | ✓ |  | ✓ | ✓ |  |  | ✓ | ✓ |  |  |  |  |  | ✓ |  |  | ✓ |
| Deprecated |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Duplicate Code |  |  |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  | ✓ |  |  | ✓ | ✓ |
| Feature Envy | ✓ |  | ✓ | ✓ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Inappropriate Intimacy |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Lazy Class | ✓ |  | ✓ | ✓ |  | ✓ |  |  |  |  |  |  |  |  |  |  |  |
| Long method |  |  |  |  | ✓ |  |  |  |  | ✓ |  |  |  | ✓ |  |  | ✓ |
| Many Parameters |  |  |  |  |  |  |  |  |  |  |  | ✓ |  |  |  |  |  |
| Message Chain |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| No-op |  |  | ✓ |  |  |  |  |  |  |  |  |  |  | ✓ |  |  |  |
| Unused Field |  |  |  | ✓ |  |  |  |  |  |  |  |  |  | ✓ |  |  |  |
| Total Smells | 3 | 0 | 4 | 5 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 4 | 0 | 1 | 3 |

**Figure 4: Two blocks representing the same functionality, one in a regular block and one using a call to a my block.**



### 4.1.2 *Study setup*

To determine if EV3 programs suffer from OO-inspired smells, we gathered 17 programs from two data sources. The first source is a robotics club run by one of the authors, where kids aged 8 to 13 program robots every week. The programs collected were designed to participate in two robot competitions: A sumo wresting game in which robot have to push each other out of a ring[3], and a search and rescue game in which robots have to detect a soda can[4]. To obtain a more diverse set of EV3 programs, we also solicited members of the EV3 programming group on Facebook to share their programs with us[5]. Nine programs come from this second source.

After collection, the programs were analyzed by one of the authors. Table 2 shows an overview of the EV3 programs from the Sumo (L1...L5), RoboCup (L6...L8) and Facebook (L9...L17) programs and the smells found in them.

The EV3 programming interface divides the programming blocks into 6 categories, indicated in the colored tabs in Figure 3. The number of blocks in each of the categories for the programs are listed in the first 6 rows in Table 2. Furthermore we have counted the number of comment blocks: special blocks that do not perform any action but are used to document programs, the number of variables: blocks that store a value that can be retrieved later, and the number of MY BLOCKS created in the program. The *Total Blocks* column provides an indication of program size.

To count the number of instances of the *long method*, a smell was counted when the MY BLOCK had 10 or more blocks, as this is typically the size that all blocks would not fit on the screen anymore. For the *lazy class* we defined smelly as three blocks or fewer. For the *many parameters* smell, the use of four or more input values as typically in the programs one or two were used.

### 4.1.3 *Findings*

When investigating the programs, we found that they indeed can suffer from OO-inspired smells.

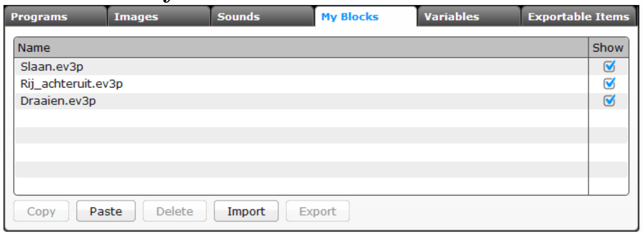
On average, the programs from children's robotics club had 2.5 smells each and the programs from the community received through Facebook had 1.4 smells each, though the people submitting through Facebook most likely sent in nicely polished programs. Furthermore, the community programs were generally smaller (a median of 17 versus 23 total blocks) exhibiting more reuse as they more often used call to MY BLOCKS. There are only three smells that do not occur in any of the programs: *deprecated interface* (not applicable), *inappropriate intimacy* and *message chain*.

Next, we discuss the three most common smells within the EV3 programs.

*Duplicate Code.*

[3]http://www.sugobot.com/
[4]http://rcj.robocup.org/rescue.html
[5]https://www.facebook.com/groups/legomindstorms/permalink/527560164058881/

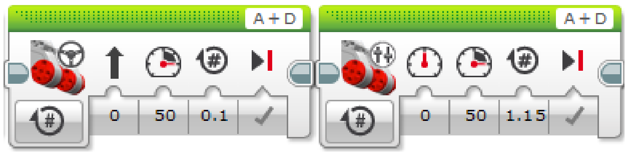
**Figure 5: The project properties screen for the Sumo program 1, showing the three my blocks, but not indicating the my block 'draaien' is currently not called anywhere.**


Programs | Images | Sounds | My Blocks | Variables | Exportable Items

| Name | Show |
|---|---|
| Slaan.ev3p | ✓ |
| Rij_achteruit.ev3p | ✓ |
| Draaien.ev3p | ✓ |

Copy | Paste | Delete | Import | Export

**Figure 6: The duplication smell in two subsequent motor blocks. Since both have the same power and direction, they could have been merged.**



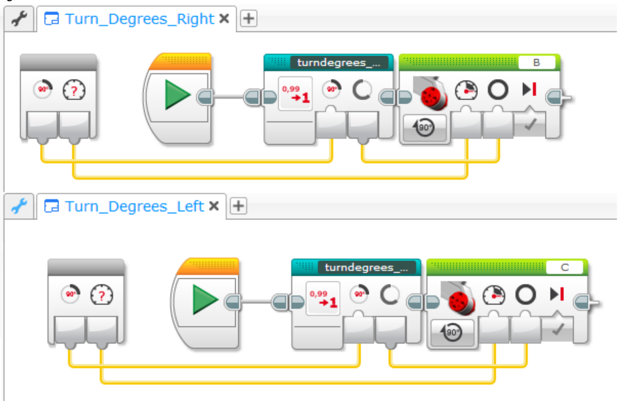
The most common smell we found in the programs is the *duplicate code* smell, which 65% of the programs suffer from. Duplication comes in various forms. Some of the programs use two motor blocks in a row, which could have been merged. For example, consider the two blocks from program L17, shown in Figure 6. This might have been challenging for the users to detect, as they use two slight variations of the motor block, but the two behave exactly the same in this case. Hence, one block moving forward 1.25 would have sufficed. Other programs exhibit duplication at a high level, such as the two MY BLOCKS in program L16, depicted in Figure 7. Here, the two MY BLOCKS perform the exact same operation, but on a different motor. By connecting the name of the motor to a parameter, like angle and speed already are, the same functionality could have been implemented with one MY BLOCK.

### *Dead Code.*

The second most common smell is *dead code*. In 41% of the programs we found MY BLOCKS that no longer connected to one of programs. This can pose a problem, firstly, for understandability, but also poses a practical program as the EV3 environment compiles and transfers all programs and MY BLOCKS to the physical brick, so dead code takes up unnecessary space on the brick. The *dead code* smells is more common in the robotics class programs than in the programs we received via Facebook. This is to be expected, as users felt confident enough to share their programs, so probably they either programs before sharing them, or selected 'clean' programs to share.

Looking at the EV3 programming interface, it is not that surprising that users forget about disconnected MY BLOCKS. The interface does not help users in understanding what MY BLOCKS are used. If we look at the project properties screen, shown in Figure 5, one can see that there is no information about which MY BLOCK is used, and where. Even worse,

**Figure 7: The duplication smell in two different but very similar my blocks. By parameterizing the motor name, this could have been implemented with 1 my block.**



users can delete MY BLOCKS that are still being called, without a warning being issued about this. After removal of a MY BLOCK in use, the program no longer compiles.

### *Lazy Class.*

A *lazy class*, which we count as MY BLOCKS containing three or fewer blocks, are also relatively common, occurring in four of the programs. However, we only find this smell in the programs from the robotics club and not in the programs received via Facebook. Many 'lazy MY BLOCKS' were relatively small, consisting of two or three blocks, or even one in some cases. In general, small abstraction are considered smelly, as understanding the abstraction requires inspecting it, which might not be worth it for small classes, methods or MY BLOCKS. However, for EV3 this smell might not be as smelly as in other languages, as the programming interface does not allow regular blocks to be named, but it does allow this for MY BLOCKS. So by making a MY BLOCK, users can express the intent of a coherent set of blocks, even if this set consist of just one block.

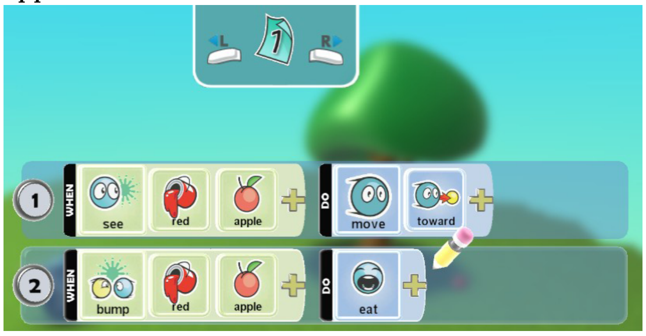
As an example, consider the two blocks from program L6, shown in Figure 4. The left block is regular block controlling a motor, while the right one is a call to a MY BLOCK with the same functionality. The first one just expresses what the robot must do, but the second one expresses the intent ('weg' meaning flee). Using the MY BLOCK here serves as an alternative for adding comment blocks. While small MY BLOCKS still add overhead, as the user need to navigate to the block to understand it, the trade off might be different for EV3 than in other languages.

### *4.1.4 Summary*

To summarize, smells indeed occur in the EV3 programs. Smells are found in 88% of the programs, with *duplicate code*, *dead code* and *lazy class* (small abstractions) observed most often. Hence we conclude that smells from OO are applicable to this end-user language, though for the *lazy class* smell, the impact might be different in the context of EV3.

## 4.2 Kodu

**Figure 8: The interface of Kodu showing programming behavior for a bot that moves towards a red apple and then eats it.**



**TODO: this part does not really explain how variables work, you mention them, but I find it a bit hard to know how they work/look like.** Microsoft Research's Kodu is a visual programming language [14] and environment that allows users to create, play, and share their own video games. It is available for download on the Xbox and PC and is heavily inspired by robotics, as illustrated by the context of programming in it and its language.

Users create a world (e.g., land, water, clouds), add characters and objects, and then can program each character or object (e.g., a kodu robot character, a turtle character, an apple object, a tree object; we use character and object interchangeably) individually. The programming defines how to interact with the world, treating each character or object as an autonomous agent. Each object has 12 pages that can be programmed, analogous to methods in an OO language, where the current page defines the current behavior of the object. The object's behavior can change by switching between pages to modify state and control flow. Each page contains a set of rules, and each rule is in the form of a condition and an action, which form a `when - do` clause. The `when` is defined by a sensor (e.g., see, hear, gamepad input) and filters (e.g., apple, gamepad A button). The `do` is defined by an actuator (e.g., movement, shoot) and modifiers (e.g., missile, toward). All the rules on a page are evaluated in a single frame, from top to bottom. Despite its unique language, Kodu can be used to express many basic concepts in computer science, such as variables, boolean logic and conditional control flow [15].

Figure 8 shows a page and two rules in Kodu. For the first rule, the condition is, `when see red apple`, and the action is, `move toward it`. The action defines the behavior of this particular character when it sees a red apple, that is, it moves toward it. Since the condition identifies an object (i.e., apple), it becomes the default selector, even though it is not explicitly specified. The second rule has a similar condition with a different sensor, `bump`. The action of the second rule, `eat`, indicates that the character should eat any red apple it bumps. The programming in Figure 8 applies to the first page in this character's programming, as indicated by the number one at the top of the screen. The first page is the start page.

To form more complex boolean logic, rules can also be indented to create complex `when` clauses, where both conditions need to be true for the action to occur. Alternatively, indenting a rule and removing the `when` means that multiple `do` clauses occur for the same trigger condition.

### 4.2.1 Smells in Kodu

We describe how the smells in our OO-inspired catalog apply to Kodu programs using a loose mapping of the OO concepts. We consider pages of programming as analogous to methods or classes, similar to how modules are treated in Yahoo Pipes, worksheets in spreadsheets and MY BLOCKS in LEGO MINDSTORMS EV3.

**Dead Code:** If there exists a page with programming such that there is no explicit path of control flow from Page 1 to it, it is unreachable and therefore dead.

**Deprecated Interface:** Some language features may exist in early versions of Kodu but not be available in future versions. As none of these features were ever deployed, this smell is not possible.

**Duplicate Code:** Two pages for the same character with exactly the same set of rules, or two identical rules on a page constitute duplicate code. Alternatively, two rules on the same page with the same *when* clauses (i.e., sensor and filter) but different actions could be consolidated using the indent feature and thus are smelly.

**Feature envy:** All global variables, such as game scores, can be read and written by any character. If a certain character reads variables that have been written by another character, this could be an instance of the feature envy smell.

**Inappropriate Intimacy:** A character has four local properties that describe its state: color, glow color, expressions (angry, crazy, happy) **TODO: this are just 3, not 4** If one character frequently checks the properties of another character, this could constitute inappropriate intimacy.

**Lazy Class:** If a character has no programming, it could be an instance of the lazy smell.

**Long method:** A page with many, many rules may be difficult to understand. Some programming could potentially move to other characters.

**Many Parameters:** A game can have 37 different global scores. Games that use many of these could be unnecessarily smelly.

**Message Chain:** It is possible for a character to create a chain of switches between pages without any logic on the page other than the jump. This would create a long and unnecessary message chain.

**No-op:** Jumping to a page with no logic is the logical equivalent of a null pointer. While no error would be raised, the character would no longer have any behavior and would be stuck. Alternatively, rules with *when* clauses but no *do* clauses do not perform any actions.

**Unused Field:** A global variable that is written to but not read is an instance of the the unused field smell.

**Table 3: Size in terms of the different number of characters and rules used in the 17 Kodu programs, and the smells they exhibit**

| Name | K1 | K2 | K3 | K4 | K5 | K6 | K7 | K8 | K9 | K10 | K11 | K12 | K13 | K14 | K15 | K16 | K17 | K18 | K19 | K20 | K21 | K22 | K23 | K24 | K25 | K26 | K27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Characters | 6 | 17 | 39 | 21 | 62 | 60 | 85 | 26 | 26 | 60 | 42 | 45 | 57 | 36 | 5 | 15 | 28 | 28 | 10 | 2 | 16 | 18 | 76 | 75 | 63 | 4 | 76 |
| Pages | 11 | 7 | 26 | 19 | 18 | 47 | 82 | 19 | 10 | 60 | 41 | 31 | 10 | 9 | 6 | 7 | 7 | 34 | 16 | 2 | 39 | 18 | 9 | 50 | 90 | 8 | 78 |
| Rules | 21 | 17 | 60 | 28 | 31 | 96 | 93 | 29 | 20 | 120 | 58 | 63 | 22 | 35 | 14 | 18 | 23 | 114 | 54 | 3 | 113 | 27 | 30 | 122 | 144 | 32 | 372 |
| HCI Actors | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 1 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 37 | 0 | 2 |
| Dead Code | | | | | | | | | | | | | ✓ | | | | | | | | | | | ✓ | ✓ | | |
| Deprecated | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Duplicate Code | | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Feature Envy | | | ✓ | | | | | | | ✓ | | | | | | | | | ✓ | | | | | ✓ | ✓ | | ✓ |
| Inapprop. Int. | | | | | | | | | | | | | | | | ✓ | | | | | | | | | | | |
| Lazy Class | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| Long method | | | | | | ✓ | | | | | | ✓ | ✓ | | | | | ✓ | ✓ | | | | | ✓ | | | ✓ |
| Many Params | | | | | | | | | | | | | | | | | | | | | | | | | | | ✓ |
| Message Chain | | | | | | | | | | | | | | | | | | | | | | | | ✓ | | | |
| No-op | | ✓ | | | | | | | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | ✓ | | | | ✓ | ✓ | | ✓ |
| Unused Field | | | ✓ | | | | | | ✓ | | | ✓ | | | ✓ | | | ✓ | | | | | | | ✓ | | ✓ |
| Total Smells | 0 | 2 | 4 | 1 | 1 | 3 | 2 | 2 | 3 | 2 | 1 | 5 | 5 | 3 | 2 | 3 | 2 | 4 | 4 | 3 | 2 | 1 | 1 | 7 | 6 | 0 | 7 |

### 4.2.2 *Study Setup*

To determine if Kodu programs indeed suffer from the above defined smells, we have gathered programs from two data sources. For the first data source, we ran a workshop at the Microsoft FUSE lab that introduced children to Kodu Game Lab in a series of three 3-hour sessions. To recruit participants, we advertised the Kodu workshop using a mailing list of parents interested in Kodu. Children between the ages of 9 and 12 volunteered to participate, with parental consent. We collected 17 programs created during the workshop for analysis. For the second data source, we randomly sampled 10 programs from the public Xbox Live community. No demographic information was collected about the users.

The programs were analyzed by one of the authors. Table 3 presents the 17 programs created by children (K1 . . . K17), 10 programs created by the Xbox Live community (K18 . . . K27), and the smells found in each. The *Characters* row defines how many characters and actors are in the program, *Pages* defines how many pages of programming are used by the characters, *Rules* counts all the rules on all the pages, and *HCI Actors* counts the number of actors in the program that are controllable by the Xbox controller, mouse, or keyboard. To count the number of instances of the *long method*, a smell was counted when the page had 10 or more rules. For the *many parameters* smell, the use of four or more game scores. These thresholds were determined by the authors as 10 rules cannot be viewed on a screen screen without scrolling and only a couple games used more than three game scores.

### 4.2.3 *Findings*

On average, the programs from children had 2.3 smells each and the programs from the community had 3.5 smells each, though we note that the programs from the community tend to be larger (e.g., an average of 101 rules vs. 42 rules). Next, we discuss the three most common smells found in the Kodu programs, appearing in 40% or more of the sample. The remaining smells appear in 25% or fewer programs.

### 4.2.4 *Lazy class*

The lazy class smell was the most common, appearing in 79% of the Kodu programs. This smell is intended to capture when a character is placed in the world but has no programming, and thus no behavior. In some cases, this may not be a smell at all, such as when characters are used as decorations in the world (e.g., trees and rocks). In others, it could be similar to an object that is created but that has no behavior.

### 4.2.5 *Duplicate Code*

This smell was present in 61% of the programs. All instances were that of duplicate `when` clauses within a page, and there were no instances of identical rules on a page or identical pages within the same character. The prevalence of this feature **TODO: what feature? did you mean smell?** shows a missed opportunity for consolidating the code.

### 4.2.6 *No-op*

The next most-common smell is the no-op, present in 41% of the programs. All instances of this smell were rules without `do` clauses, rather than jumping to pages without logic. This is probably the product of the rapid cycling between testing and developing observed in Kodu development [15]; since the clauses have no actionable logic, keeping them in the code does not impact the semantics of the program. We note that none of the rules following these clauses were indented to create a conditional conjunction.

### 4.2.7 *Summary*

To summarize, smells indeed occur in the Kodu programs. Smells are found in 93% of the programs, with *lazy class*, *duplicate code*, and *no-op* (small abstractions) appearing most often. Hence we conclude that smells from OO are applicable to this end-user language.

## 4.3 Summary

Table 4 summarizes the frequencies of occurrence of the various smells in the EV3 and Kodu programs. Overall, 88% of the EV3 and 93% of the Kodu programs contained at least one smell. Coupled with the 81% of Yahoo Pipes

**Table 4: Summary of Smells Across EV3 and Kodu Programs**

| | EV3 | Kodu |
|---|---|---|
| Dead Code | 41% | 11% |
| Deprecated Interfaces | 0% | 0% |
| Duplicate Code | 65% | 61% |
| Feature Envy | 18% | 22% |
| Inappropriate Intimacy | 0% | 4% |
| Lazy Class | 24% | 79% |
| Long method | 24% | 25% |
| Many Parameters | 6% | 4% |
| Message Chain | 0% | 4% |
| No-op | 12% | 41% |
| Unused Field | 12% | 25% |
| Any smell | 88% | 93% |

programs [8] and 42% of Excel programs [7] that were previously found to be smelly, this provides further evidence of the prevalence of smells in end-user programs.

As with code written by other end-user programmers [8], *duplicate code* is prevalent in EV3 and Kodu programs, affecting over 60% of the samples in both languages. The other two smells that were studied in Excel and Yahoo Pipes, *lazy class* and *long method*, are present in at least 24% of the studied EV3 and Kodu programs, illustrating commonality across all end-user programming domains.

*Dead code* is more frequently found in EV3 and *lazy class* smells are more common in Kodu. The *no-op* smell is present in 41% of the Kodu programs, which is similar in spirit to the 41% of EV3 programs with *dead code*. *Feature envy* was also prevalent across both languages, appearing in 18% and 22% of the EV3 and Kodu programs, respectively. We observe that the occurring smells seem to be anti-patterns that occur in programming in general, independent of the programming language.

## 5. BEYOND OO SMELLS

The end-user programming environments offer many opportunities to define smells based on user behavior or unique elements of the domain. Here, we explore opportunities for new smells in end-user domains that extend beyond the OO-inspired smells in Section 3.

### 5.1 End-User Programming Smells

Many smells beyond the OO language exist in several of the domains studied.

#### *5.1.1 Layout smells*

The EV3 and Yahoo Pipes languages are visual and involve connecting boxes with wires, making it easy to create an unwieldily structure. EV3 is especially problematic as it lacks an auto-layouting function.

A special case where this happens is when a user creates a MY BLOCK. Remember that MY BLOCKS can only be created with an 'extract method' operation. If this operation is called, all selected are moved to the newly created MY BLOCK, and are replaced by one block that is a call to this new MY BLOCK. Other than that, the layout remains unchanged. So if a big MY BLOCK is created, the program will now have a big gap, making the program harder to read **TODO: if room show example**. This, and other layout smells too are unique to visual languages and can impede understandability.

#### *5.1.2 Lack of Comments smell*

The lack of comments in a program can make it difficult to understand. Kodu and Yahoo Pipes both suffer form a lack of comments in the programming language and development environment, often making it difficult to understand another's work or maintain old code.

#### *5.1.3 Programming Organization smell*

Communities of programmers often have standards for how to structure program code. These *population-based* smells were first introduced for Yahoo Pipes [8] and can be uncovered by exploring programs written by the community. In Kodu, often the rules that map a character's behavior to user input from a gamepad, keyboard or mouse are at the top of a page and the remaining logic is at the bottom. Deviating from this structure can lead to programs that are more difficult to understand when shared.

### 5.2 Domain-Specific Smells

Each end-user domain has unique characteristics that create opportunities for defining domain-specific smells. In Yahoo Pipes, prior work has explored the presence of broken or deprecated data sources as a smell unique to the domain [8]. In Excel, prior work defined referring to an empty cells are smelly [22]. Here, we explore smells in EV3 and Kodu that are unique to their languages and environments.

#### *5.2.1 EV3*

The LEGO MINDSTORMS EV3 programming language differs significantly from the other end-user domains, as EV3 programmers work with both software and hardware. While programming, users need to configure motor blocks to the right port, for example the blocks in Figure 6 are controlling motors A and D. This means that, when a user has the wrong mental model of what motor is connected to what port, the program will not function as wanted. It appears users run into this issue too, as some of the programs we saw comment blocks where the mapping was described, in an effort to ensure proper mapping **TODO: if room add example**.

Hence a smell unique to the EV3 domain is a wrong mapping between the robot in reality and the motor and sensor blocks.

#### *5.2.2 Kodu*

The Kodu environment involves designing games, programming games, and playing games. This, paired with the unique event-driven language, creates unique opportunities for domain-specific Kodu smells.

*Conflicting Outcomes smell.*

The event-driven language in Kodu allows a user to write conflicting outcomes for the same trigger, that is, with the same `when` clause, to write conflicting `do` clauses. For example, consider the following two Kodu rules:

```
(1) When hear turtle : do score 1 red
(2) When hear turtle : do unscore 1 red
```

The *do* clauses are in conflict, both scoring and unscoring the red score by 1, and hence the outcome is the same. Flagging conflicting rules during development would help alert users to this smell.

### *Single Input Device smell.*

Games in Kodu can be programmed and played using an Xbox controller or a keyboard and mouse. Many games are programed assuming a particular device for input, such as an Xbox. However, when playing a game in a different environment, that device may not be available, and thus the game is not portable. This smell could be mitigated by adding analogous rules for other input devices, such as mapping the gamepad trigger switches to the keyboard shift keys or mapping the right stick to movement.

### *Lost Character smell.*

The *lazy class* smell is related to a non-programmed character or object. However, there is also a design smell that can manifest when a programmed object cannot be easily found in the world, and thus there is program behavior that is difficult to change. Resolving this smell could involve physically moving the characters or objects to be more accessible, adding a color or speech bubble above them as a marker, or by adding an environment feature that maintains a list of programmed and non-programmed characters that can be accessed.

## 6. RELATED WORK

Related to the current research are efforts on code smells within traditional languages, starting with the work of Fowler [11]. His book gives an overview of code smells and corresponding refactorings. Recent efforts focused on the automatic identification of code smells by means of metrics. Marinescu [16] for instance, uses metrics to identify *suspect* classes, those classes that might have design flaws. Lanza and Marinescu [17] explain this methodology in more detail. Alves *et al.* [18] focus on a strategy to obtain thresholds for metrics from a benchmark. Olbrich *et al.* furthermore investigates the changes in smells over time, and discusses their impact [19].

Within end-user programming, this paper builds upon two lines of related work. First, the work of Stolee and Elbaum that studied smells [8] and refactorings [5]. They designed a number of smells by transforming known OO smells to the domain of Yahoo Pipes. The second direction is the work by Hermans *et al.* that also took OO smells as an inspiration from a number of smells [6, 7]. Subsequently they described corresponding refactorings [20] and a tool that applies refactorings [21]. This final work builds upon previous work by Badame and Dig that described the first spreadsheet refactoring tool RefBook [12].

In end-user programming environments, user input and logic are often more closely linked than they are in general purpose languages, and as such analyzing the input data as opposed to the logic can also be used as a means of *smell detection*. This is a direction that has been applied to spreadsheets. Cunha et. al [22] for example look at anomalies in the data and define these as smells. Examples of this are *Standard Deviation* which occurs if one assumes a normal distribution for a column in numeric values and the column contains values which fall outside two standard deviations. In more recent work, Barowy et. Al [23] take a more formalized approach which they label "Data Debugging". Their solution uses statistical analysis to find values with an unusually high impact on the calculated results in a spreadsheet, as such values are likely either very important or erroneous.

In addition two above described work on Yahoo Pipes and spreadsheets, there is previous smells work on other end-user environments too, like performance smells in LabView, a visual language for system-design [9, 24].

Research related to EV3 and Kodu predominantly explores language design [?, ?, ?, 15] and educational benefits [?, ?, ?, ?]. There is some, albeit limited, work on detecting code smells in educational languages. Chatley and Timbul describe Kenya, a simple programming language for educational purposes, which they have integrated into the Eclipse environment [25]. They built features that allow the detection of 'bad style' in programs to be detected and reported as code is written, concentrating on encouraging students to program like they were taught in class. This work might indicate that smell detection can be useful for education, but the authors did notevaluate the usefulness of this approach.

## 7. THREATS TO VALIDITY

The threats to validity of this work inherit the threats to validity of the original studies [3, 5–8, 12, 21, 26] on end-user refactoring in spreadsheets and Yahoo Pipes.

Three domains studied in this paper are dataflow languages, and the smells and refactorings may not generalize to other end-user programming domains (e.g., Scratch is OO-based). However, we mitigate this threat by analyzing Kodu, an event-driven language, and show that the smells are also applicable in that context. This provides more evidence of the generality of these smells.

We have defined OO smells in two languages, EV3 and Kodu, yet we have not evaluated whether these smells matter to the end users. Future work is needed to determine the impact of these smell on users of the languages.

In Kodu, the presence of the *lazy class* smell may be intentional and simply represent a design decision (i.e., a rock is not programmed because it's there purely for aesthetics). Evaluating these smells with actual users will help tease out when code is smelly and when it is actually designed intentionally.

We have sampled programs from two sources for each EV3 and Kodu, yet these programs may not be representative of what children and community members create. A larger-scale analysis is necessary to generalize these findings to the populations of EV3 and Kodu programs.

## 8. CONCLUSION

This paper presents an overview of the work in smell detection for end-user programming languages. More specifically, it synthesizes work on Yahoo Pipes and Excel into a catalog of generally applicable smells in end-user languages. To demonstrate the applicability of the catalog, we apply it to two new domains: LEGO MINDSTORMS EV3 and Kodu, two visual languages aimed at programming education. The results show that indeed many of the catalog's smells apply in the new domains, and *lazy class* (small abstractions), *duplicate code* and *dead code* occur frequently in these educational languages too, while being of a quite different character than the textual languages aimed at professional developers that the smells were originally defined for. This shows the applicability of these smells, and also warrants further research into issues end-users encounter while programming. The contributions of this paper are:

- A catalog of object-oriented-inspired code smells in end-user programs (Section 3)
- Application of the catalog to two new end-user domains focused on education (Section 4)
- Identification of future opportunities for smell detection in end-user programming domains, both within and beyond the OO paradigm (Section 5)

The current work also gives rise to more research, for example, exploring the impact of code smells on children who use the educational languages or designing user-friendly refactoring tools for visual languages.

In the end, we observe that the applicability of smells, originally created to detect weaknesses in source code, to other domains shows how powerful the concept is. Furthermore, studying the smells in a fresh context provides new insight on how to use smells in software engineering **TODO: do we show this insight on how to use smells in SE?** and even suggests new types of smells.

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