Automatically Repairing Input Data for Novice Python Programs

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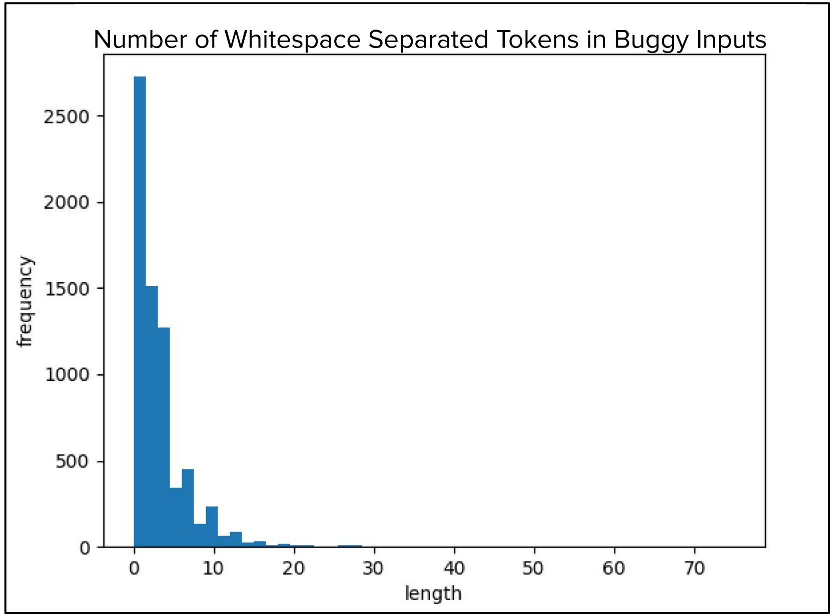
Why Input-Related Bugs

- Access to 4 years of Python Tutor data thanks to Philip Guo
- 33% of python programs contain a call to `input()`
- Found **over 25,000 buggy input / program pairs** where only the input differed in the student's "fixed" version



Example Input-Related Error

In practice, some error messages novices face are fixed by only changing the program's *input*:

Example of Simple Syntactic Mistakes:

Code:

```
x = float(input())
print(x * math.e / 2)
```

Error Causing Input:

```
5,2
```

Student's Fix:

```
3.1
```

Error = Python expects period decimal notation:

```
ValueError: could not convert
string to float: ’5,2’
```

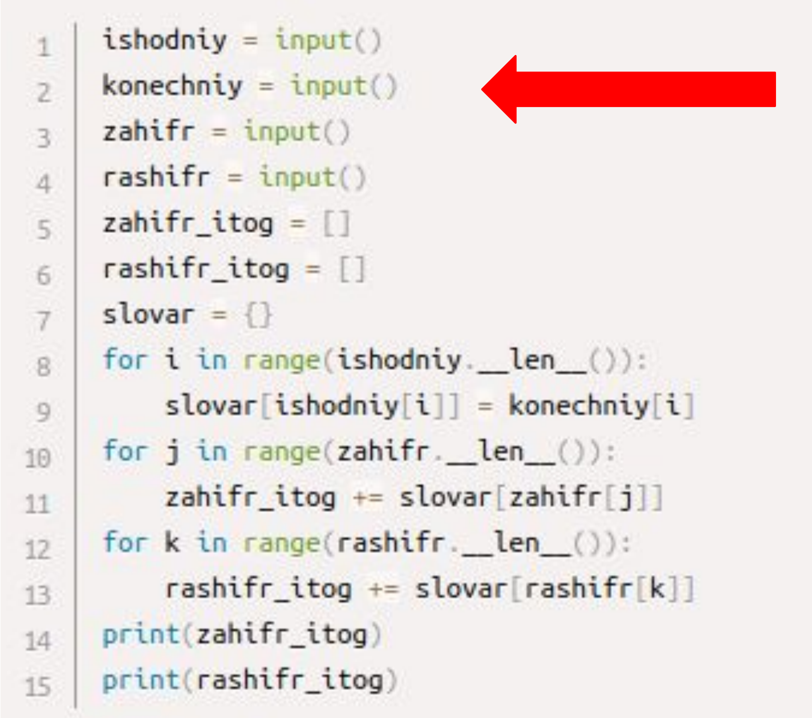
More Complex Buggy Input Data Example

Buggy Input:

```
abcd
*d%#
abacabadaba
#*%*d*%
```

Error:

```
Traceback (most recent call last):
line 13, in <module>
rashifr_itog += slovar[rashifr[k]]
KeyError: '#'
```



```
1  ishodniy = input()
2  konechniy = input()
3  zahifr = input()
4  rashifr = input()
5  zahifr_itog = []
6  rashifr_itog = []
7  slovar = {}
8  for i in range(ishodniy.__len__()):
9      slovar[ishodniy[i]] = konechniy[i]
10 for j in range(zahifr.__len__()):
11     zahifr_itog += slovar[zahifr[j]]
12 for k in range(rashifr.__len__()):
13     rashifr_itog += slovar[rashifr[k]]
14 print(zahifr_itog)
15 print(rashifr_itog)
```

Observations about Input-Related Interpreter Errors

- For syntactic errors, the **error message** is highly correlated to the **eventual student** fix

- For complex errors, fixes are **more diverse**, but we observed that some fix mutations where more common than others. E.g.:
  - Inserting a string literal from the program
  - Inserting a small integer
  - Swapping two lines of inputs
  - Splitting an input line on whitespace

- Student repairs are generative, not just corrective
  - Often requires multiple error messages to be fixed before finding solution

Research Overview

- Found that a significant fraction novices programming bugs involve fixing the input data, not just the code itself

- Developed InFixPy: A **tool to automatically repair input bugs** in novice Python programs

- Ran a **human study** to assess the **quality and helpfulness** of InFixPy generated repairs

InFix Algorithm

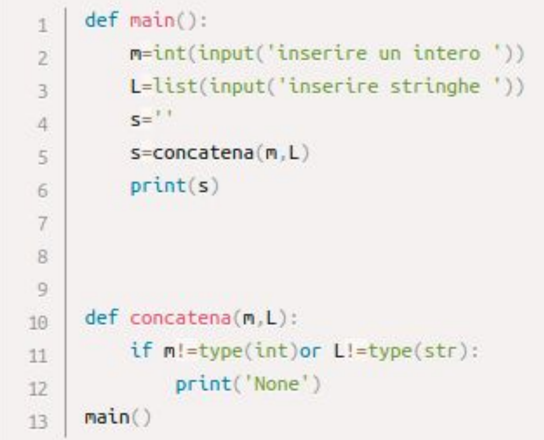
- Iterative search-based algorithm that modifies the student's error-causing input.

- Use **error message templates** to try and repair common syntactic errors

- Apply random **additional mutations** for non-templated error-messages

Example of Algorithm Fix

Python Program



```python
def main():
    m=int(input('inserire un intero '))
    L=list(input('inserire stringhe '))
    s=''
    s=concatena(m,L)
    print(s)



def concatena(m,L):
    if m!=type(int)or L!=type(str):
        print('None')
main()
```

Original Bad Input:

```
ciao
```

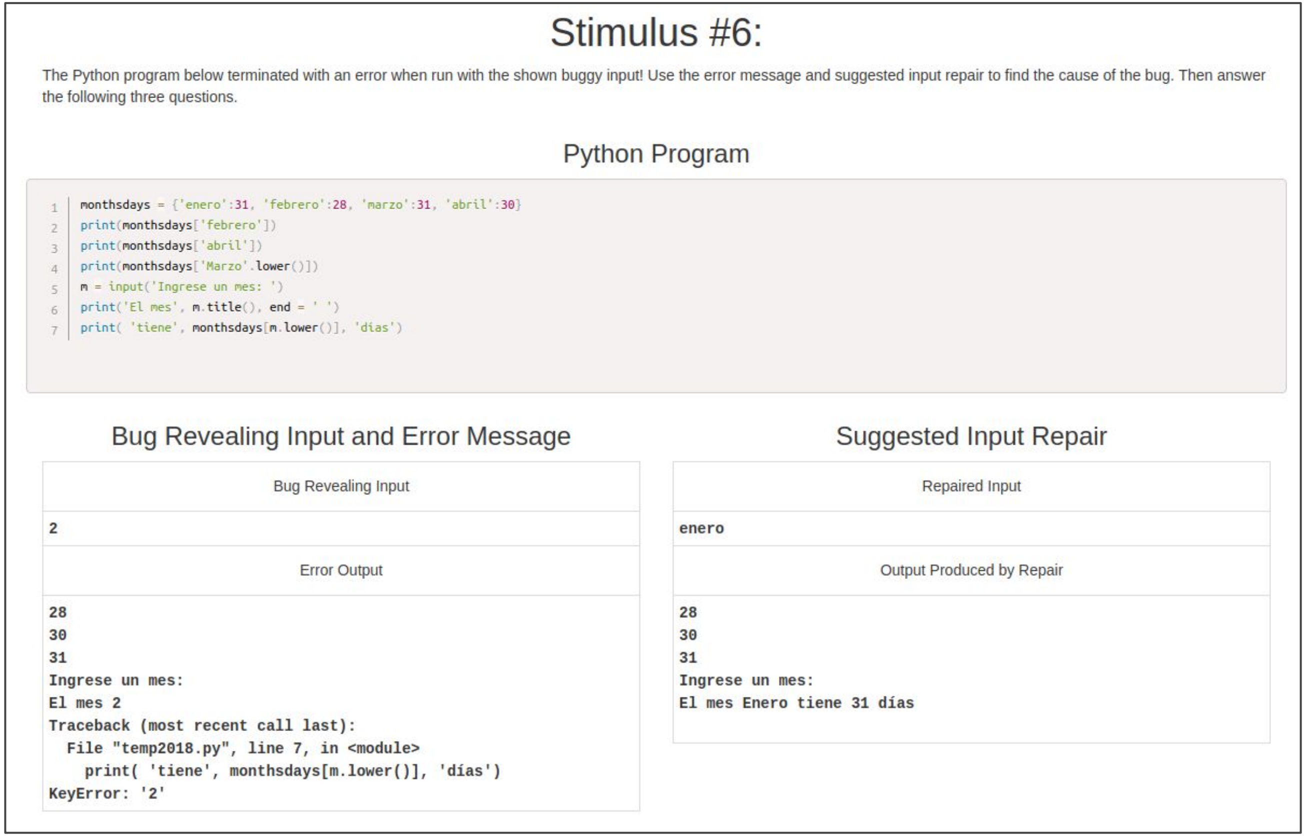
Iteration 1 = ValueError template:

```
-1
```

Iteration 2 = Mutation template :

```
-1
ciao
```

Human Study Evaluating Repair Quality: Sample Stimulus



Stimulus #6:

The Python program below terminated with an error when run with the shown buggy input! Use the error message and suggested input repair to find the cause of the bug. Then answer the following three questions.

Python Program

```
monthsdays = {'enero':31, 'febrero':28, 'marzo':31, 'abril':30}
print(monthsdays['febrero'])
print(monthsdays['abril'])
print(monthsdays['Marzo'.lower()])
m = input('Ingrese un mes: ')
print('El mes', m.title(), end = ' ')
print( 'tiene', monthsdays[m.lower()], 'días')
```

Bug Revealing Input and Error Message

Bug Revealing Input

```
2
```

Error Output

```
28
30
31
Ingrese un mes:
El mes 2
Traceback (most recent call last):
  File "temp2018.py", line 7, in <module>
    print( 'tiene', monthsdays[m.lower()], 'días')
KeyError: '2'
```

Suggested Input Repair

Repaired Input

```
enero
```

Output Produced by Repair

```
28
30
31
Ingrese un mes:
El mes Enero tiene 31 días
```

Evaluation Results

- Empirical results: Can **fix 95%** of 25,000 input-related errors

- Human Study results: 97 participants found the machine repairs of **equal helpfulness** and within **4% the quality** to student made repairs

Questions?