Usability of error messages for introductory students

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Introduction to error messages

- In programming, an error is when the computer cannot understand an expression in the code
  - these errors will return an error message
- Here's an example of an error message:

```
print("Hello World";
->java.3: error: unclosed string literal
```

Importance of error messages

- Error messages are important tool for beginner programmers
  - one of the primary interactions between the system and the user
- Unhelpful error messages impose learning difficulties, especially for new programmers
- Error messages with poor usability can lead the user down the wrong path

Goals of an error message

- An error message should:
  - not add confusion
  - be easy to understand
  - help a student locate the issue
- Example:

```
Developing...
```

Analyzing error messages

- Human-computer interaction: study on interfaces between user and programs
- Much of the research presented from an HCI perspective
- We will discuss error messages in terms of usability

Outline

Outline

Compiler errors

- When a compiler fails to compile a program, a user will receive a compiler error message
- For newer programmers, these typically occur from syntax errors
- Example (in Java):

```
int seven = (2 + 5;
error: ')' expected
```

Runtime errors

- A runtime error occurs after a program has compiled
- Usually indication of logical errors in the code
- Cannot be predicted, dependent on the values
- Example:

```
String string = "Hello World";
System.out.print(string.substring(6,12));

java.lang.StringIndexOutOfBoundsException:
String index out of range: 12
```

Statically typed

- All variables and/or objects assigned types
- Type checking done at compile time
  - this means different error messages
- Languages like Java or C++ are statically typed
- The following example would give an error at compile time in statically typed:

```
personName = "Frank"
personName = 7
```

Dynamically typed

- Values are not assigned to types
- Type checking done at runtime
- Languages in Lisp family
- The following example would give an error at runtime in dynamically typed:

```
personName = "Frank"
personName = 7
```

Outline

Overview of study

- Marceau et al. noticed students struggling with error messages in course
- Conducted study on DrRacket error messages in Spring of 2009
- Hoping to use the data to improve students' interactions with DrRacket error messages

Integrated development environments

- An integrated development environment (IDE) is a program for writing and running code
- Some IDEs come packaged with debugging tools and custom error messages

Racket programming language

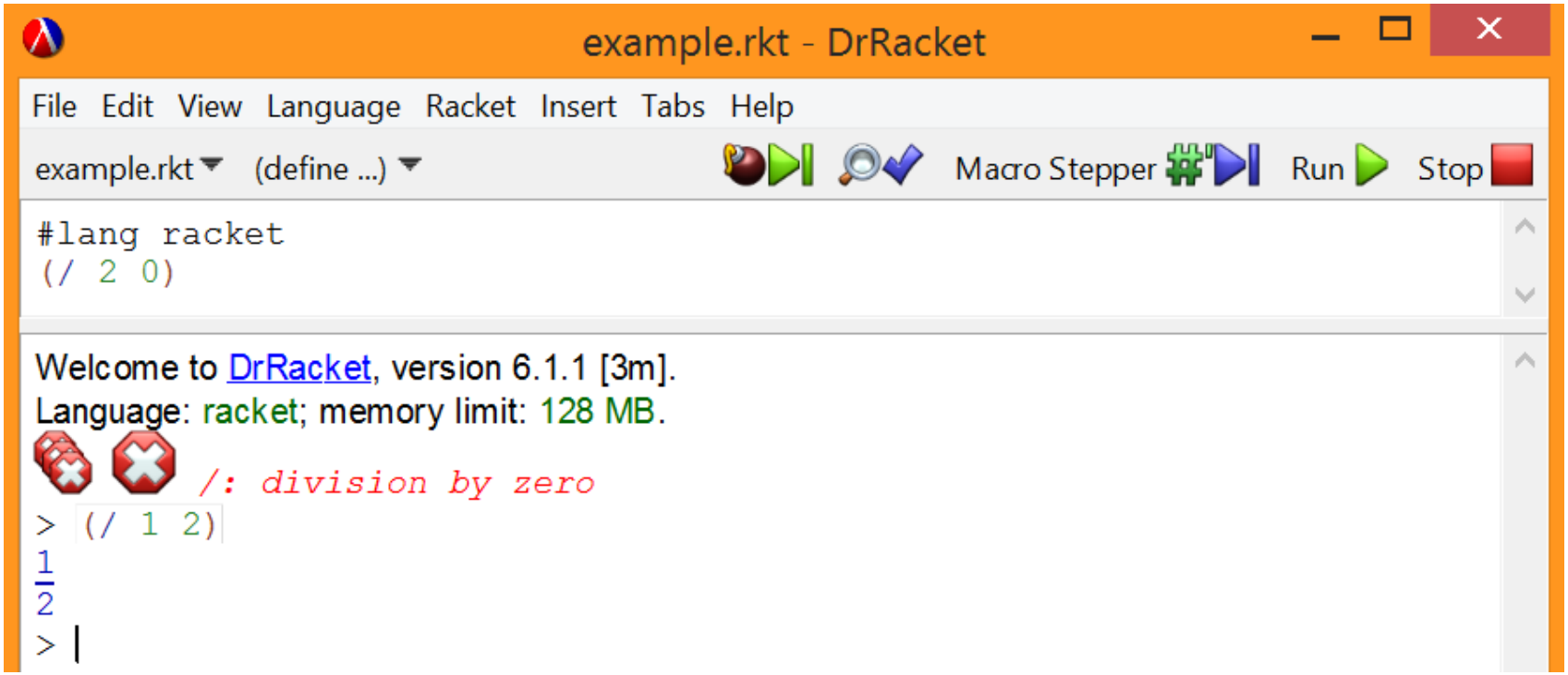
- Programming language useful for teaching in introductory courses
- Member of Lisp languages
- Functional language: computation as a composition of functions and retains immutable data and avoids changing state
- dynamically typed
- Syntax example:

```
(+ 1 2)
-> 3
```

DrRacket

- An IDE for developing programs in Racket
- Geared toward introductory programmers
- DrRacket offers (mostly) user-friendly error messages and libraries to program in various levels

DrRacket interface



Study of DrRacket error messages

- Marceau et al. interested in finding which errors students struggled with
- Configured DrRacket to save a copy of each program a student tried to execute and the error messages received
- Programs taken from a once-per-week lab session

Table of results

Lab Number	#1			#2			#3			#4			#5			#6		
	%error	%bad	#bad	%error	%bad	#bad	%error	%bad	#bad	%error	%bad	#bad	%error	%bad	#bad	%error	%bad	#bad
arg. count	5%	48%	0.22	17%	27%	**0.74**	14%	17%	0.33	13%	20%	0.24	35%	21%	**0.74**	12%	31%	0.36
parens matching	28%	24%	0.58	12%	14%	0.27	17%	0%	0.00	14%	0%	0.00	13%	0%	0.00	10%	15%	0.15
runtime cond	3%	0%	0.00	3%	100%	0.49	4%	20%	0.12	6%	72%	0.40	8%	78%	**0.62**	1%	100%	0.06
runtime type	2%	100%	0.15	8%	73%	**0.91**	16%	40%	**0.93**	8%	22%	0.17	6%	44%	0.26	3%	38%	0.13
syntax cond	14%	51%	0.59	4%	50%	0.31	6%	26%	0.24	10%	28%	0.25	9%	20%	0.17	11%	11%	0.12
syntax define	16%	50%	**0.68**	14%	50%	**1.14**	6%	15%	0.14	7%	24%	0.14	2%	17%	0.03	3%	38%	0.10
syntax func call	14%	64%	**0.74**	14%	17%	0.37	12%	14%	0.26	23%	27%	0.55	4%	29%	0.12	13%	38%	0.48
syntax struct	0%	0%	0.00	8%	32%	0.43	5%	92%	**0.73**	0%	0%	0.00	1%	0%	0.00	0%	0%	0.00
unbound id.	16%	16%	0.21	13%	40%	**0.85**	16%	14%	0.32	16%	0%	0.00	20%	7%	0.14	34%	13%	0.44

KEY:
%error: Percentage of error messages during lab of the given category of errors
%bad: Percentage of error messages that were poorly responded to
#bad: Estimate of the number of errors in the category that each student responded poorly to

Results

- Students struggle with certain errors relative to skill level
- Some errors were not indicator of underlying issue
  - student struggled with these errors
  - suggests issues in error message effectiveness

Student code example

```
(define (label-near? name bias word1 word2)
  (cond
      (and (cond [(string=? name word1)
                  "Name Located"]
                 [(string=? bias word2)
                  "Bias Located"])
           (cond [(string=? name word2)
                  "Name Located"]
                 [(string=? bias word2)
                  "Bias Located"])
      "Mark")
))
```

Overview of study

- Compiler error messages often cryptic and difficult for many programmers
- Traver and his students found compiler errors messages difficult to understand
- Traver conducted study in Fall 2002 at Jaume I University to verify which errors intro students struggle with
  - course used C++ programming language

Intro to C++

- Not designed to be taught in intro course
- Imperative language: uses memory manipulation and state-changing statements to build computation
- statically-typed
- Object-oriented programming (OOP): method of programming around class hierarchy and creating objects
- Syntax example:

```
int a = 2;
a = a + 2;
cout << a;
-> 2
```

Method of study

- GNU g++ compiler was used
- Code gathered from students in lab sessions throughout semester
- Analyzed each message and wrote out the following for each message:
  - why the error occurred
  - possible alternate error message
  - why the error is unhelpful

Example of code analyzed

Offending code:

```
SavingAccount::SavingAccount(){
    float SavingAccount::getInterestRate() {
      return rate;
}
```

Error message:

```
In method 'SavingAccount::SavingAccount()':
declaration of 'float SavingAccount::getInterestRat
outside of class is not definition
```

Example continued

Alternative error message:

```
A function declaration inside a function body is
not possible. Did you forget '}' to close the
body of the previous function definition?
```

Results

- Study makes a good case for compiler error usability
- Hopes that approaches be considered to improve messages
- Helped him understand which errors students students struggled with

Outline

Introduction to recommendations

- Something goes here...

Recommendations

- Something goes here...

recommendations continued

- Something goes here...

conclusions and future work for program

- Something goes here...

Java and syntax errors

- Something goes here...

How they developed the program

- Something goes here...

How they tested the program

- Something goes here...

Results of syntax enhancement

- Something goes here...

Conclusions and future work of program

- Something goes here...

Outline

Results

- Something goes here...

Future work

- Something goes here...

Acknowledgments

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Thank you for your time and attention!

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Questions?

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See my senior seminar paper for additional references.