Meta: Enabling Programming Languages to Learn from the Crowd

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Stanford HCI
What can programming languages learn from how users write programs?
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Codex (Fast et al., CHI 2014)
Blueprint (Brandt et al., CHI 2011)
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Blueprint (Brandt et al., CHI 2010)
HelpMeOut (Hartmann et al., CHI 2010)
What can programming languages learn from how users write programs?

Meta is a language extension for Python that allows users to share functions and records their behavior.
Meta.search(...)
Meta.search(...)  
MetaFunction.optimize()
Meta.search(...) 

MetaFunction.optimize()

MetaFunction.auto_patch()
Meta.search(...)  

MetaFunction.optimize()  

MetaFunction.auto_patch()  

MetaFunction.get_type()  

MetaFunction.examples()
Meta.search(...)

MetaFunction.optimize()

MetaFunction.auto_patch()

MetaFunction.get_type()

MetaFunction.examples()

MetaFunction.bugs()
DEMO
Documentation (types and examples)

Search (leverage types and examples)

Optimization (make code faster)

Patching (recover from run-time bugs)
System Architecture

CREATING AND LOADING META FUNCTIONS

@meta(...)  
function name  
source code  
imported libraries  

COMMUNITY DB
System Architecture

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@meta(...)
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COMMUNITY DB

meta.load(...)
load libraries
execute source
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meta.load(...)

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COMMUNITY DB

Detect IO by instrumenting core system libraries, no global state
System Architecture

CREATING AND LOADING META FUNCTIONS

@meta(...)

function name
source code
imported libraries

meta.load(...)

load libraries
execute source

COMMUNITY DB

Detect IO by instrumenting core system libraries, no global state
Cache loaded functions locally to speed things up and work outside network
System Architecture

LEVERAGING COMMUNITY RUN-TIME DATA

\texttt{metafunc(...)}

- arguments
- return value
- types of data
- execution time
- run-time exceptions

\rightarrow

COMMUNITY DB
LEVERAGING COMMUNITY RUN-TIME DATA

metafunc(...) arguments
return value
types of data
execution time
run-time exceptions

APIs
get_type()
examples()
optimize()
bugs()
auto_patch()
...

Sample arguments with P(x) = 1/n for better performance
Evaluation

STUDY OF PROFESSIONAL PROGRAMMERS
Evaluation

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7 programmers, machine learning task

746 lines of code, 26% Meta functions

Created 17 Meta functions, loaded 6 unique, executed 15,000 times
Evaluation

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Design concerns: security, privacy, community
Evaluation

PERFORMANCE COST
Evaluation

PERFORMANCE COST

47 ms to load Meta function

133 ms to create Meta function

0.31 ms of overhead to run Meta function

For comparison, sorting a list of 5000 words takes 27 ms

Note: creating and loading Meta functions are fixed costs
Evaluation

EFFECTIVENESS OF COMMUNITY OPTIMIZATION
Evaluation

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44 correct optimizations and 7 incorrect

Median optimized function was 1.45 times faster

1.15-2.91 interquartile range
Evaluation

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is_capitalized('abc') #=> False
str_is_number('abc') #=> False

# with only this datapoint, can conclude functions are equal
is_capitalized('abc') == str_is_number('abc')
Future Work
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How does a system like Meta scale as its community grows to hundreds of thousands of functions?
Future Work

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What other features can we design when programming languages learn from how people code?
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What other features can we design when programming languages learn from how people code?

Is it possible to extend a system like Meta to work beyond pure functions, handling global variables and other kinds of complex state?
Conclusion

Meta envisions a world where an enormous amount of data about how people program is available for analysis, enabling a new class of intelligent programming environments.
Check out www.meta-lang.org/tutorial