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MEASURING SOFTWARE ENGINEERING

Software Engineering
CS3012

The most complex structures to ever be created were written by software engineers. But even after reshaping the face of the earth using our software we may still not have found a reliable way to measure it.

This report will be exploring the ways in which the software engineering process is measured currently and examining possible directions in which measuring the software engineering process may advance.

Please note that in the following sections I purposefully will not be mentioning any ethical concerns in order to be able to discuss the methods in which the software engineering process can be measured and assessed freely and clearly, without interruptions with my opinions about the method's ethics. I will then be discussing the ethics behind each method in the section titled THE ETHICS.

PERSONAL SOFTWARE PROCESS

Personal Software Process[1] or PSP, developed by Watts Humphrey, is a set of guidelines intended to help software engineers document their software development process and use that data to help them understand what changes to make in order to write software more efficiently. There are many variations of PSP but almost all place a large emphasis on the software engineer trying to predict how long parts of a future project will take them and then comparing their prediction to collected data after the project's completion. The main objectives of PSP, as outlined by Humphrey, are for the software engineer to improve their planning and estimating skills, to make commitments they can keep and to help manage the quality of their projects.

The Personal Software Process relies on the software engineer consistently taking note of every step of their development process. The original PSP, when proposed by Humphrey, was developed before IDEs or always-running syntax checkers in code editors, so this included even documenting all syntax errors. Although there is a minimum of required data, the developer is free to document as much extra data as they please as they themselves will later be processing the data they take using software they write or spreadsheets. If the software engineer has a theory that some external event may have an effect on their productivity, they are free to take note of that event, and when they have enough data collected, analyse it to verify or refute their theory. The problem many software engineers had with PSP is that it is very time consuming as everything had to be recorded manually and the collected data had to be processed manually. It is a more mentally taxing and time consuming task than the alternative of just filling out a premade form or having the data automatically collected.

The data collected using PSP is only useful to the software engineer collecting it if they plan to use the analysis for self-improvement. PSP is not very useful to management. Management cannot use the data to gauge the employee's performance as all of the data is submitted by the employee themselves. That employee might have an agenda to tamper with the data in order to receive a raise or any other reason. Two trivial examples would be the employee reducing the amount syntax errors they made to make themselves look more mindful or recording that it took them longer to write some code than it actually did and then using that undocumented time to check their social media.

Mainly PSP was found to be too burdensome, having way too much overhead for general performance tracking and since is only really used by software engineers in edge cases when they want to analyse something that can't really be tracked automatically. In most other cases PSP is seen as a person whose whole job is to make computers do work efficiently deciding to spend a lot of time doing a job by hand that that the computer is really good at doing by itself more efficiently.

1. W. S. Humphrey, The Personal Software Process, 2000.

DEVELOPMENT PROCESS WATCHERS

Hackystat[1] has been in active development[2] from 2001 to about September 2013. The main idea behind it is for the users to attach 'sensors' in their software development tools and then have those sensors automatically and unobtrusively track their software development process. Hackystat supports over ten development tools including Emacs and Vim.

The most frustrating part about PSP for most software engineers was the cycle of having to constantly interrupt their flow to document some change, then go back to their work. Hackystat watches every change automatically, from switching files in the editor, to writing a new method, to making a single character change. From that it also calculates metrics like testing, commit frequency, development time and churn.

Hackystat was made with group projects in mind, analysing who made what change and who corrected it among countless other things. All of that information is displayed in a table for the management where they can easily compare each team members' performance at a single glance. The management can also, if they are so inclined, see exactly what changes were made at what time and how long it took the developer to make them. This information is collected completely autonomously without any interaction from the developer.

1. csdl.ics.hawaii.edu/research/hackystat/
2. github.com/hackystat

Project (Members)	Coverage	Complexity	Coupling	Churn	Size(LOC)	DevTime	Commit	Build	Test
DueDates-Polu (5)	63.0	1.6	6.9	835.0	3497.0	3.2	21.0	42.0	150.0
duedates-ahinahina (5)	61.0	1.5	7.9	1321.0	3252.0	25.2	59.0	194.0	274.0
duedates-akala (5)	97.0	1.4	8.2	48.0	4616.0	1.9	6.0	5.0	40.0
duedates-omaomao (5)	64.0	1.2	6.2	1566.0	5597.0	22.3	59.0	230.0	507.0
duedates-ulaula (4)	90.0	1.5	7.8	1071.0	5416.0	18.5	47.0	116.0	475.0

Comparing team members in Hackystat. (Image may be found here)

Episode Classification	Episode Actions			
(tdd, 2)	03/31/2006 15:51:21	TestBowlingGame.java	ADD IMPORT	import junit.framework.TestCase
	03/31/2006 15:51:22	TestBowlingGame.java	MOVE CLASS	edu.hawaii.hongbing.game --> TestBowlingGame.java
	03/31/2006 15:51:49	TestBowlingGame.java	ADD METHOD	void testNoPlay()
	03/31/2006 15:52:55	TestBowlingGame.java	TEST EDIT	64sec MI=+1(1), SI=+2(1), TI=+1(1), AI=+1(0), FI=+
	03/31/2006 15:52:55	TestBowlingGame.java	COMPILE	GowlingGame cannot be resolved to a type
	03/31/2006 15:53:06	BowlingGame.java	ADD CLASS	BowlingGame.java
	03/31/2006 15:53:06	TestBowlingGame.java	COMPILE	The method getScore() is undefined for the type Bow
	03/31/2006 15:53:07	BowlingGame.java	BUFFTRANS	FROM TestBowlingGame.java
	03/31/2006 15:53:20	BowlingGame.java	PRODUCTION EDIT	0sec MI=0(0), SI=0(0), FI=+137(137)
	03/31/2006 15:53:34	BowlingGame.java	ADD METHOD	BowlingGame()
	03/31/2006 15:53:37	BowlingGame.java	ADD FIELD	p ublic
	03/31/2006 15:53:39	BowlingGame.java	REMOVE FIELD	ublic
	03/31/2006 15:53:50	BowlingGame.java	PRODUCTION EDIT	3sec MI=+1(1), SI=0(0), FI=+114(251)
	03/31/2006 15:53:55	BowlingGame.java	ADD METHOD	int getScore()
	03/31/2006 15:54:26	BowlingGame.java	PRODUCTION EDIT	21sec MI=+1(2), SI=+1(1), FI=+146(397)
	03/31/2006 15:54:33	TestBowlingGame.java	BUFFTRANS	FROM BowlingGame.java
	03/31/2006 15:54:48	TestBowlingGame.java	UNIT TEST	TEST OK
(tdd, 2)	03/31/2006 15:55:10	TestBowlingGame.java	ADD METHOD	void TestGutterPlay()
	03/31/2006 15:57:05	TestBowlingGame.java	TEST EDIT	104sec MI=+1(2), SI=+3(2), TI=0(1), AI=+1(0), FI=+
	03/31/2006 15:57:05	TestBowlingGame.java	COMPILE	Frame cannot be resolved to a type

Hackystat documents every change made. (Image may be found here)

MINING SOFTWARE REPOSITORIES

These tools focus on analysing the rich data available on the development process from version control repositories, issue tracking systems and the like. Each tool has its strengths, for instance Open Hub[1] focuses on analysing data from open source projects to produce metrics such as these:

Both Cast[2] and Synopsys[3] analyse software for similar stats to Hackystat as well as checking for security risk, graphing project structure among many other things.
The difference between MSRs and Development Process Watchers is that MSRs work with already available data. This means that the software engineer does not need to set anything up at all. They just write their software, test, commit and continue with their day. When they choose to see some metrics, be it when the software is finished or at any other point in the process, they can open up an MSR and get insights into their development process including software security, testing, general data about how much is written a day, languages used and countless other metrics depending on the MSR of their choice.

There is quite a large community of developers who are greatly interested in this topic. There are plenty of competitions that focus on extracting as much interesting useable data as possible out of open source software repositories or from companies that agree to get their repositories mined for the competition. The community has also held 14 annual MSR Conferences[4] so far. In 2018 the 15th Mining Software Repositories Conference will be held in Gothenburg, Sweden.

1. openhub.net
2. castsoftware.com
3. synopsys.com/software-integrity.html
4. 2018.msrconf.org

USING INFORMATION ALREADY AVAILABLE ON EMPLOYEES

It is certain that a lot of useful data about the software engineering process can be extracted by analysing the code, but that is only a part of how the software engineering process can be measured. With the advent of powerful AI we are starting to be able to analyse messy real world data a lot more accurately. Many factors such as the employee's personality, education, past experience, social skills and their dev team's chemistry can help with predicting or evaluating the quality of software systems. In other words we can not only deduce the quality of a piece of software by analysing the code itself but also by analysing the people who wrote it.

The first step would be to analyse as much of each software engineer's code as possible using an MSR or some other in-house tool. Each software engineer would then be assigned a score based on how good their code is. The higher the score, the better the software engineer's code. Let's call this score the Employee's Code Performance Score (ECPS) for the purpose of exploring this subject.

Employers already hold a lot of information on their employees. Combining each software engineer's ECPS with data like past experience, education, past training, earnings, work hours, holidays, cultural background etc. could then be used to find trends between an employee's personal data and how well they perform as an engineer. If the company has a large number of employees quite an accurate model can be created in this way.

This would then allow the company to make statistically valid assumptions about how good a potential future hire is just from reading their CV, before even inviting the job seeker for an

interview. The candidate's expected ECPS could be calculated using their personal details. This expected ECPS may then be used by the company to invite only the highest quality candidates.
Alternatively, a company looking to maximise profits but to also hire candidates of a good enough quality could use each candidate's expected ECPS and calculate the candidate's 'Bad Deal Score' using something like:

```
B = Bad Deal Score
S = Estimated Starting Salary
E = ECPS

B = S/E
```

Candidate's Name	Expected ECPS	Estimated Starting Salary	Bad Deal Score
Alice	85	45,000	529
Bob	12	27,500	2292
Ciara	50	30,000	600
David	75	30,000	400

From the example above, Alice has the highest expected ECPS and the highest starting salary. If the company is looking to hire only the best candidates they would hire her. If the company is looking to maximise profits, they would look at each candidate's Bad Deal Score instead of their expected ECPS and see that hiring David is the best choice, followed by Alice and that hiring Bob is a very bad deal.

This method may also be used by management, depending to their goals (e.g. keep only the best, maximise profits) to help them decide which current employees have more potential in higher up positions or which employees they can think about letting go based on their ECPS or Bad Deal Score.

ECPS may also be used to better gauge code quality. Each line of code an employee writes would be marked with the employee's ECPS score. For instance, if Alice were to write the method `averageSales()`, it would be marked with an ECPS of 85. If David were to write that method it would be marked with an ECPS of 75. This way a method may not only be measured by how well its tests run, but also by the past history of the person who wrote it.

MONITORING EMPLOYEES' BEHAVIOUR

An employee's Internet usage patterns and history can be used to try to estimate how engaged or focused the user was while writing a certain piece of code. Browser data would have to be processed and compared with data from an MSR or a Development Process Watcher. If the employee was checking social media or browsing non code related websites while they were writing an algorithm it could indicate that the employee may have been distracted and the algorithm they wrote may likely be sub-par. These tools have been available for a long time with the most popular being Browse Reporter[1].

One step above that would be tracking everything the employees do on their computers. A popular tool for that, ActivTrak[2], keeps a detailed log of everything an employee does on their computer while also take regular screenshots. The software can deduce at what times the employee was working and at what times they were doing something else on their computer and at what times the computer was left on but nobody was using it. This, similar to data from Browse Reporter can be coupled with MSR or Development Process Watcher data to provide an even more accurate estimation of a piece of software's concentration value, i.e. how tuned in the employee was when writing that piece of software.

ActivTrak is not 100% accurate for the purpose of determining a piece of code's concentration value, though. For example, all an employee must do to have their code marked with a high concentration value is make it look like they were focused at the time of writing that code. Code is only marked as low if ActivTrak notices the user interacting with non-work related programs around the time of writing that code. ActivTrak is quite easy to fool in this case, all the employee would have to do is keep two windows open, say a YouTube video on the left

and documentation for some API on the right. All that needs to be done in order for their code to be flagged with a high concentration value is scroll around a lot to simulate reading on the documentation window while in reality watching YouTube. ActivTrak would record that time as if the employee spent 99% of their time reading documentation and in turn the code written would be marked with a high concentration value.

Tobii[3] along with other eye tracking companies have an answer for that. The most accurate way to tell what the employee is doing on their computer is to know what part of the screen they are looking at. Eye tracking hardware can tell exactly that. It can even tell if a person is reading a line of code while writing it, reading documentation, watching a YouTube video or staring at the same spot while daydreaming. This way it can be known for certain whether the person was focused while writing a piece of code and thus that piece of code can be assigned an accurate concentration value.

Lack of sleep has a large impact on work performance[5]. There is a lot to calculating how well a person has slept so I won't get into it for this report[4]. All we need to know is that fitness trackers that can be purchased on Amazon for as low as £20 are able to accurately track a person's sleep quality during the night.
From data collected on the fitness tracker it is possible to accurately estimate how long an average sleep cycle for that person is. A person needs to sleep for about 5 sleep cycles to feel well slept given that they have a low sleep deficit over the previous 7 days.
Say Alice's average sleep cycle is 93 minutes. This means that she must sleep for about 7 hours and 45 minutes to feel well rested, given that she slept well in the previous week. So for this example Alice's required daily sleep is 7.75 hours.
Using each night's sleep duration, quality and her required daily sleep we can calculate how well rested Alice is feeling at that point in time:

Day	Duration	Quality	Effective Sleep
Mod	7 hours	94%	6.7 hours
Tue	5 hours	72%	3.6 hours
Wed	8 hours	89%	7.1 hours

Over the past 3 days, Alice's total effective sleep was 17.4 hours. She should have slept for 23.25 hours. This means that she is missing 5.85 hours of sleep in order to feel well slept. Over the past 3 days Alice has accumulated a sleep deficit of 25.2%.

Using Alice's sleep deficit and her concentration value at a point in time it is possible to assign a health percentage to every line of code that she writes.

Code health along with an employee's ECPS (from the previous section) can tell with a pretty high accuracy what percentage of an employee's full potential a line of code was written at. To continue with Alice from the previous example, Alice's ECPS is 85. The method `averageSales()` she wrote was given a health percentage of 87% according to this software. The method `averageSales` is therefore rated with a score of 74.
`(74 = 85 * 0.87)`

1. browsereporter.com
2. activtrak.com
3. tobii.com
4. psychologytoday.com/blog/between-you-and-me/201307/your-sleep-cycle-revealed
5. solutionsatwork.brighthorizons.com/~/media/BH/SAW/PDFs/Consulting/2015-HWC-Sleep-Study.ashx

MONITORING EMPLOYEES' SOCIAL INTERACTIONS AND PERSONALITIES

With the help of AI, employers can monitor social channels such as email exchange and Slack messages between team members. Tools such as StatusToday[1] passively monitor the communication between colleagues and display very insightful information for the management in one place. This ranges from social graphs and activeness on the social channel to how influential the employee is in their team, how critical they are in making their team run smoothly and predictions about how likely an employee is to make a mistake that will cost the company.

According to StatusToday, 84% of managers don't know how to accurately measure the engagement and productivity of their team members. Using StatusToday data in combination with the employee's ECPS (from the section titled USING INFROMATION ALREADY AVAILABLE ON EMPLOYEES) management can receive very deep insights about office politics and who writes the best code in order to allow management to clearly see who would be better suited in a different team without making an impact on the current team's productivity, allowing management to rearrange hierarchies more effectively to meet their required goals.

In conjunction with tools like StatusToday, the employee's physical activities can be monitored to analyse their engagement with their work, their office social circles and how all that relates to their software engineering performance. Lighthouse[2] and Google's Nest[3] already offer cameras with human face (and pet) recognition. Speech recognition is also very accurate, in May 2017 Google announced[4] that they have reached a word error rate of 4.9% in their speech recognition software. It is not a push to see both of these technologies combined to create tracking cameras. These cameras may then be set up at strategic places around the office to monitor the employees, identifying them and monitoring their behaviours such as writing code, taking a break etc. These cameras could identify social circles within the company by tracking which employees interact with who. Transcripts of their in person conversations could then be analysed with tools similar to StatusToday to provide similar metrics such as influencers in the team, critical team members etc.

The company may also ask their employees to take personality tests to form teams where each member has compatible personalities. The Big Five[5] traits are seen as the most accurate model of a person's personality at the moment. A lot of information is currently known about how people with different Big Five traits get along.

An engineer's personality data, social tracking data and ECPS data may then be used to create teams of optimal compatibility. Depending on the task, each team could be assigned with a required ratio of influencers, where statistically each team member would get along well enough with each other based on personality data and where each team has a high enough average ECPS.

Depending on the role of the team, each team may have a different mix of developers. For instance Team A, which mainly focuses on high turn-over critical bug fixes, would be assigned with the perfect ratio of influencers to team members, people with a higher ECPS and people who are more compatible with each other. Team Z on the other hand, a team that is working on an add-on that 0.5% of the user base will be using, may be built out of people who didn't make it into the more important teams and thus Team Z would have an imperfect ratio of influencers to team members and a lower average ECPS and compatibility score than Team A.

Upon processing all information from the personalities of each team member and social tracking data that is being dynamically collected at all times each team would then be assigned a dynamic Team Synergy Score. The better the score, the better the team is working together.

Each line of code the team writes could then be scored using something similar to this:

```
L = Line of code's score
E = Author's ECPS
C = Author's concentration
    and tiredness score (from
    previous section)
S = Team Synergy Score

L = E*C*S
```

Scoring each line in this way would allow for software to be measured not only by how well the tests run but also by the quality of the team and the person that wrote it.

1. statustoday.com
2. www.light.house
3. store.nest.com
4. venturebeat.com/2017/05/17/googles-speech-recognition-technology-now-has-a-4-9-word-error-rate/
5. en.wikipedia.org/wiki/Big_Five_personality_traits

THE ETHICS

I've written the previous sections purposefully not mentioning any ethical concerns in order to be able to discuss the methods in which the software engineering process can be measured and assessed freely and clearly, without interruptions with my opinions about the method's ethics.

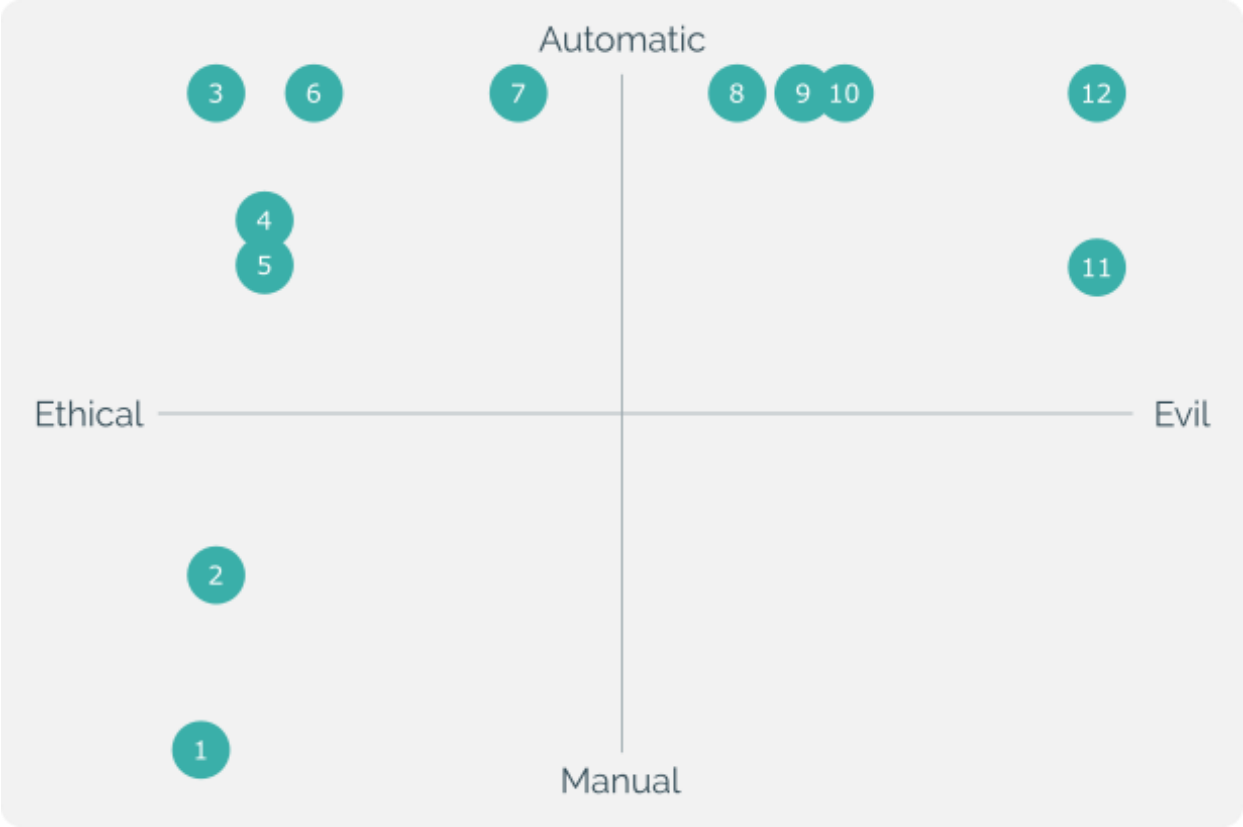
SIDE NOTE

While I discuss ethics, please keep in mind that it is considered ethical, or at least it is not considered completely evil for a company to log a user's every move.

Google Maps has a feature called Timeline. I personally can go back as far as 22 July 2015 and see what I did that day. On that day at 12:03 I walked to my gym and back home at 13:42. Then at 16:47 I drove to and parked at Tesco, walked to four different shops in my town's centre, walked back to Tesco and then drove home at 18:22. Every single day from 22 July 2015 to today is documented this way.

This feature is activated for every person who installs Google Maps by default and the person has to go through a few hoops to deactivate it. (I haven't because I think it's kind of cool.)

Google does not sell that information to advertisers directly (yet?), but it does allow advertisers to target people with different Timeline profiles.



1. PSP: Seems the most ethical to me as all information is submitted completely voluntarily.
2. Building compatible teams using personality tests: This seems ethical to me.
3. MSRs: Rather than focusing on the behaviours of the individual developer as much these generally focus on other metrics from the data generated during the development process. These seem somewhat more ethical than Hackystat to me.
4. The idea of ECPS: The idea of assigning every person a score based

on their performance history, if done correctly and measured accurately to me doesn't seem unethical.

5. Using ECPS to fire employees: Assuming that ECPS is an accurate measurement of an employee's performance I think it is ethical to fire poorly performing employees.
6. Hackystat: Users have had ethical concerns about Hackystat as it constantly watches every change the user makes. It can also be used to focus on the user's coding style rather than just quality of their code.
7. Measuring concentration using Browse Reporter or ActivTrak: This seems moderately unethical to me.
8. Measuring concentration using eye tracking: This seems a lot more unethical than using Browser Reporter or ActivTrak even though it is essentially the same concept.
9. Gauging tiredness using previous sleep data: This seems quite unethical to me. To me this seems like private information that should not be made available to the employer.
10. Using StatusToday to analyse social behaviour: Even though this is a pretty successful product without too much bad PR, it seems quite unethical to me.
11. Using trends between ECPS and personal info to filter job applicants: It is illegal in Ireland to discriminate based on personal details when hiring employees, and even if it wasn't illegal, it is very unethical.
12. Using tracking cameras to analyse social behaviour: This seems very unethical to me.

The graph above as well as the points listed here are my opinion. From the graph it is visible that most of the things discussed are automatic or close to automatic. There are also more ethical things mentioned than unethical. I feel that with technology advancing people accept more and more previously deemed unethical things. In the next, say 5 years, I feel all points will shift to the left slightly.

From looking at the graph the most user friendly point is MSRs as they are completely automatic and also have the least ethical concern.

THE FUTURE

After exploring the ways the software engineering process is measured currently and examining possible directions in which measuring the software engineering process may advance I believe that with the ever improving state of AI there will be more emphasis on previously harder to measure, real world data. I believe software will eventually be rated using additional metrics such as Quality of Authors and Quality of Teams.