

# MOTIVATION for DATA STRUCTURES



 Here's how big tech companies like Google and Facebook set salaries for software engineers

The crowdsourced data on levels.fyi shows that software engineers get paid extremely well at companies like [Google](#), [Facebook](#), [Amazon](#), [Apple](#), and [Microsoft](#).

Levels.fyi estimates that a Level 3 at Google, or an entry-level engineer who likely just graduated from college, should make \$189,000 in total compensation, or about \$124,000 in salary and \$43,000 in stock compensation. At Facebook, an E3 – an entry-level “software engineer 3” – should make \$166,000 per year total, according to the levels.fyi estimate.

Compensation goes up as level goes up and can even accelerate in an exponential fashion, the website's founders said.

For example, at Google a Level 7, which is considered the top level for the vast majority of engineers, can make \$608,000, according to levels.fyi.

“It differs from company to company, but a bunch of companies have converged on almost the same system where there will be about six levels,” said Osman Ahmed Osman, a former Quora hiring manager who is now writing [a book on technical recruiting](#). Each level has a slightly different job title at each company, but they closely correlate.

“Google and Facebook are examples of companies where things are pretty similar,” he continued.

The companies do have slightly different nomenclature. Apple's levels, for example, are called ICT, for “individual contributor tech.” [Salesforce](#)'s levels are called MTS, for member of technical staff.

Ministry of Education, Singapore

GRADUATE EMPLOYMENT SURVEY										
2,006 full-time graduates from SIT were surveyed in Mar 2022 and the overall response rate obtained was 84.5%.										
SIT: 2021 GES Employment Rates <sup>1</sup> and Salaries of Graduates by Bachelor Degree										
Degree	Proportion of graduates in the Labour Force who were Employed <sup>1</sup>		Basic Monthly Salary <sup>2</sup>		Gross Monthly Salary <sup>2</sup>				75 <sup>th</sup> Percentile	
					Mean	Median	25 <sup>th</sup> Percentile	75 <sup>th</sup> Percentile		
<b>DigPen Institute of Technology</b>										
Bachelor of Arts in Game Design*	100.0%	81.5%	\$3,437	\$3,200	\$3,490	\$3,300	\$3,200	\$3,500		
Bachelor of Fine Arts in Digital Art and Animation	80.0%	63.3%	\$3,081	\$3,200	\$3,125	\$3,200	\$2,885	\$3,500		
Bachelor of Science in Computer Science and Game Design	88.2%	85.3%	\$4,229	\$4,000	\$4,324	\$4,000	\$3,700	\$4,968		
Bachelor of Science in Computer Science in Real-Time Interactive Simulation	95.1%	92.7%	\$4,982	\$4,800	\$4,984	\$4,600	\$4,300	\$5,175		
<b>Singapore Institute of Technology (SIT)</b>										
Bachelor of Accountancy with Honours	97.7%	86.8%	\$3,363	\$3,600	\$3,431	\$3,400	\$3,200	\$3,460		
Bachelor of Engineering with Honours in Information & Communications Technology (Information Security)	100.0%	98.2%	\$4,934	\$4,800	\$5,251	\$4,950	\$4,605	\$5,552		
Bachelor of Engineering with Honours in Information & Communications Technology (Software Engineering)	100.0%	98.0%	\$5,126	\$5,000	\$5,215	\$5,000	\$4,500	\$5,500		
Bachelor of Engineering with Honours in Aircraft Systems Engineering	100.0%	91.7%	\$3,297	\$3,200	\$3,394	\$3,300	\$2,500	\$4,000		
Bachelor of Engineering with Honours in Pharmaceutical Engineering	98.3%	87.9%	\$3,423	\$3,500	\$3,736	\$3,600	\$3,300	\$4,000		
Bachelor of Engineering with Honours in Sustainable Infrastructure Engineering (Building Services)	98.0%	96.1%	\$3,707	\$3,600	\$3,773	\$3,680	\$3,300	\$3,950		
Bachelor of Engineering with Honours in Sustainable Infrastructure Engineering (Land)	96.3%	88.9%	\$3,606	\$3,500	\$3,788	\$3,700	\$3,485	\$4,250		
Bachelor of Engineering with Honours in Telematics (Intelligent Transportation Systems Engineering)	97.5%	85.0%	\$4,086	\$4,000	\$4,146	\$4,000	\$3,850	\$4,500		
Bachelor of Hospitality Business with Honours	96.1%	80.3%	\$3,037	\$3,000	\$3,216	\$3,000	\$2,800	\$3,500		
Bachelor of Science (Diagnostic Radiography)	100.0%	100.0%	\$3,670	\$3,500	\$3,880	\$3,700	\$3,500	\$4,025		
Bachelor of Science (Occupational Therapy)	100.0%	98.3%	\$3,521	\$3,500	\$3,546	\$3,500	\$3,400	\$3,690		
Bachelor of Science (Radiation Therapy)	100.0%	100.0%	\$3,330	\$3,300	\$3,328	\$3,500	\$3,000	\$3,500		
<b>SIT-DigPen Institute of Technology</b>										
Bachelor of Engineering with Honours in Systems Engineering (Electromechanical Systems)	100.0%	95.1%	\$4,086	\$4,000	\$4,402	\$4,370	\$3,700	\$4,900		
<b>SIT-Monash University</b>										
Bachelor of Food Technology with Honours	96.4%	89.1%	\$3,221	\$3,300	\$3,322	\$3,300	\$3,000	\$3,500		
<b>SIT-Newcastle University</b>										
Bachelor of Engineering with Honours in Chemical Engineering	79.2%	66.2%	\$3,466	\$3,300	\$3,836	\$3,700	\$3,350	\$4,200		
Bachelor of Engineering with Honours in Electrical/Electronic Engineering	98.3%	84.5%	\$3,583	\$3,500	\$3,691	\$3,600	\$3,500	\$3,850		
<b>SIT-Trinity College Dublin</b>										
Bachelor of Engineering with Honours in Mechanical Engineering and Manufacturing Engineering	100.0%	90.9%	\$3,198	\$3,100	\$3,819	\$3,750	\$3,400	\$4,250		
Bachelor of Engineering with Honours in Mechanical Design and Manufacturing Engineering	93.4%	90.2%	\$3,646	\$3,600	\$3,787	\$3,650	\$3,600	\$4,000		
Bachelor of Engineering with Honours in Naval Architecture*	100.0%	95.7%	\$3,476	\$3,300	\$3,592	\$3,400	\$3,250	\$3,850		
Bachelor of Engineering with Honours in Occupational Engineering*	82.4%	70.6%	\$3,513	\$3,500	\$3,575	\$3,550	\$3,150	\$3,850		
<b>SIT-University of Glasgow</b>										
Bachelor of Science (Physiotherapy)	97.9%	96.8%	\$3,516	\$3,500	\$3,591	\$3,525	\$3,400	\$3,800		
<b>SIT-University of Liverpool</b>										
Bachelor of Engineering with Honours in Civil Engineering	92.8%	92.8%	\$3,650	\$3,600	\$3,719	\$3,675	\$3,500	\$3,933		
Bachelor of Science with Honours in Nursing	98.3%	86.4%	\$3,493	\$3,350	\$3,697	\$3,700	\$3,350	\$3,990		
<b>Technische Universität München</b>										
Bachelor of Science in Chemical Engineering	95.7%	87.0%	\$3,495	\$3,500	\$3,645	\$3,557	\$3,400	\$3,885		
Bachelor of Science in Electrical Engineering & Information Technology*	81.5%	74.1%	\$3,649	\$3,600	\$3,806	\$3,700	\$3,250	\$4,245		
<b>The Culinary Institute of America</b>										
Bachelor of Business Administration in Food Business Management*	91.9%	67.7%	\$2,647	\$2,500	\$2,817	\$2,700	\$2,500	\$3,100		
<b>The Glasgow School of Art</b>										
Bachelor of Arts with Honours in Communication Design	94.4%	59.3%	\$2,951	\$3,000	\$2,989	\$3,000	\$2,700	\$3,200		
Bachelor of Arts with Honours in Interior Design	94.3%	65.7%	\$2,781	\$3,000	\$2,807	\$3,000	\$2,500	\$3,100		
<b>University of Liverpool</b>										
Bachelor of Arts with Honours in Criminology and Security	95.5%	81.8%	\$3,807	\$3,600	\$4,001	\$3,850	\$3,400	\$4,500		
Source: Graduate Employment Survey jointly conducted by NUS, NTU, SMU, SIT, SUTD and SUSS										

Ministry of Education, Singapore										
GRADUATE EMPLOYMENT SURVEY										
7,430 fresh graduates and 824 follow-up graduates from NUS were surveyed in November 2022 and the overall response rates obtained were 74.8% and 64.4% respectively.										
NUS: 2022 GES Employment Rates <sup>1</sup> and Salaries of Graduates by Bachelor Degree										
Degree	Proportion of graduates in the Labour Force who were Employed <sup>1</sup>		Basic Monthly Salary <sup>2</sup>		Gross Monthly Salary <sup>2</sup>				75 <sup>th</sup> Percentile	
					Mean	Median	25 <sup>th</sup> Percentile	75 <sup>th</sup> Percentile		
<b>Faculty of Arts and Social Sciences</b>										
Bachelor of Arts (General)	88.5%	71.9%	\$3,808	\$3,670	\$3,928	\$3,700	\$3,500	\$4,000		
Bachelor of Arts (Honors)	87.5%	74.4%	\$3,889	\$3,650	\$3,934	\$4,000	\$3,500	\$4,500		
Bachelor of Social Sciences	92.9%	81.1%	\$3,935	\$3,650	\$4,056	\$3,975	\$3,500	\$4,500		
Bachelor of Social Sciences (Honors)	100.0%	100.0%	\$4,331	\$4,200	\$4,331	\$4,200	\$4,200	\$4,500		
Bachelor of Dental Surgery	100.0%	100.0%	\$4,331	\$4,200	\$4,331	\$4,200	\$4,200	\$4,500		
Bachelor of Law*	97.3%	94.6%	\$5,935	\$6,000	\$6,182	\$6,400	\$5,500	\$6,800		
<b>Faculty of Science</b>										
Bachelor of Science**	85.2%	64.0%	\$3,330	\$3,300	\$3,483	\$3,600	\$3,300	\$4,000		
Bachelor of Science (Honors)	90.0%	80.0%	\$4,000	\$3,720	\$4,174	\$3,850	\$3,500	\$4,500		
Bachelor of Science (Honors) (Computational Biology)	74.4%	64.4%	\$4,244	\$4,100	\$4,244	\$4,100	\$4,100	\$4,500		
Bachelor of Science (Pharmacy)*	98.0%	95.1%	\$3,829	\$3,780	\$4,053	\$4,000	\$3,750	\$4,200		
Bachelor of Science (Pharmaceutical Sciences)*	94.1%	76.5%	\$3,789	\$3,700	\$3,808	\$3,700	\$3,400	\$4,100		
Bachelor of Science (Data Science and Analytics)	96.8%	96.8%	\$5,562	\$5,500	\$5,616	\$5,500	\$4,628	\$6,800		
<b>NUS Business School</b>										
Bachelor of Business Administration (Business Administration)	87.9%	74.8%	\$5,564	\$5,500	\$5,626	\$5,500	\$4,000	\$7,000		
Bachelor of Business Administration (Accountancy)*	91.1%	95.7%	\$6,346	\$6,000	\$6,513	\$6,496	\$6,000	\$7,000		
Bachelor of Business Administration (Accountancy) (Honors)	93.3%	93.3%	\$6,404	\$6,300	\$6,500	\$6,800	\$6,400	\$5,500		
Bachelor of Business Administration (Accountancy) (Honors) (Real Estate)	99.0%	95.1%	\$3,924	\$3,800	\$4,062	\$3,850	\$3,600	\$4,400		
<b>School of Computing</b>										
Bachelor of Computing (Computer Science)	96.8%	96.1%	\$6,974	\$6,300	\$7,121	\$6,600	\$5,341	\$7,481		
Bachelor of Computing (Information Security)	94.6%	91.1%	\$5,218	\$5,000	\$5,460	\$5,500	\$4,800	\$6,085		
Bachelor of Computing (Information Systems)	95.3%	93.0%	\$5,515	\$5,300	\$5,672	\$5,500	\$4,800	\$6,290		
Bachelor of Science (Business Analytics)	96.2%	95.2%	\$5,905	\$5,800	\$5,966	\$5,500	\$5,000	\$6,600		
<b>School of Engineering and Engineering Technology</b>										
Bachelor of Engineering (Biomedical Engineering)	92.2%	91.6%	\$4,447	\$4,800	\$4,768	\$4,000	\$3,500	\$5,000		
Bachelor of Engineering (Chemical Engineering)	96.6%	95.5%	\$4,380	\$4,600	\$4,606	\$4,675	\$4,018	\$5,300		
Bachelor of Engineering (Civil Engineering)	93.8%	88.9%	\$3,979	\$3,821	\$3,839	\$4,000	\$3,700	\$4,400		
Bachelor of Engineering (Electrical Engineering)	92.2%	90.7%	\$4,780	\$4,700	\$4,913	\$4,800	\$4,180	\$5,000		
Bachelor of Engineering (Engineering Science)*	100.0%	100.0%	\$4,632	\$4,650	\$4,659	\$4,650	\$4,600	\$5,000		
Bachelor of Engineering (Environmental Engineering)	87.1%	83.9%	\$4,212	\$4,000	\$4,496	\$4,200	\$3,850	\$5,000		
Bachelor of Engineering (Environmental Engineering and Systems Engineering)	92.9%	92.9%	\$5,137	\$5,000	\$5,281	\$5,000	\$3,200	\$5,600		
Bachelor of Engineering (Materials Science and Engineering)	92.9%	87.2%	\$4,384	\$4,360	\$4,599	\$4,500	\$3,850	\$5,000		
Bachelor of Engineering (Mechanical Engineering)	96.2%	91.9%	\$4,024	\$4,000	\$4,780	\$4,625	\$4,000	\$5,000		
Bachelor of Arts (Biochemistry)*	98.0%	92.0%	\$4,360	\$4,300	\$4,481	\$4,400	\$4,000	\$4,500		
Bachelor of Arts (Industrial and Design)	66.7%	43.3%	\$4,328	\$4,500	\$4,420	\$4,500	\$3,500	\$4,500		
Bachelor of Science (Product and Design)	94.6%	92.0%	\$5,612	\$5,300	\$5,870	\$5,955	\$4,375	\$5,800		

Ministry of Education, Singapore

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					Mean	Median	25 <sup>th</sup> Percentile	75 <sup>th</sup> Percentile		
<b>Faculty of Arts &amp; Social Sciences</b>										
Bachelor of Arts	88.5%	76.9%	\$3,808	\$3,670	\$3,928	\$3,700	\$3,500	\$4,000		
Bachelor of Arts (Hons)	87.5%	74.4%	\$3,889	\$3,850	\$4,034	\$4,000	\$3,500	\$4,190		
Bachelor of Social Sciences	92.3%	81.1%	\$3,935	\$3,650	\$4,056	\$3,795	\$3,500	\$4,350		
<b>Faculty of Dentistry</b>										
Bachelor of Dental Surgery	100.0%	100.0%	\$4,331	\$4,200	\$4,331	\$4,200	\$4,200	\$4,400		
<b>Faculty of Law</b>										
Bachelor of Laws	97.3%	94.6%	\$5,935	\$6,000	\$6,182	\$6,400	\$5,500	\$6,800		
<b>Faculty of Science</b>										
Bachelor of Science*	85.2%	63.0%	\$3,630	\$3,500	\$3,823	\$3,600	\$3,500	\$4,000		
Bachelor of Science (Hons)	90.6%	80.1%	\$4,040	\$3,720	\$4,174	\$3,850	\$3,500	\$4,500		
Bachelor of Science (Computational Biology)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		
Bachelor of Science (Pharmaceutical Science)	98.4%	95.1%	\$3,825	\$3,798	\$4,053	\$4,000	\$3,750	\$4,250		
Bachelor of Science (Pharmaceutical Science) (Hons)	94.1%	78.5%	\$3,789	\$3,700	\$3,888	\$3,700	\$3,400	\$4,150		
Bachelor of Science (Data Science and Analytics)	96.8%	96.8%	\$5,552	\$5,500	\$5,616	\$5,500	\$4,628	\$6,100		
<b>Wick Business School</b>										
Bachelor of Business Administration	87.9%	78.8%	\$5,653	\$5,000	\$6,028	\$5,100	\$4,000	\$7,000		
Bachelor of Business Administration (Hons)	97.1%	95.7%	\$5,346	\$4,800	\$5,519	\$4,600	\$4,000	\$5,988		
Bachelor of Business Administration (Accountancy)*	93.3%	93.3%	\$5,494	\$4,800	\$5,560	\$4,800	\$4,400	\$5,500		
Bachelor of Business Administration (Accountancy) (Hons)	99.3%	97.9%	\$4,619	\$4,000	\$4,668	\$4,000	\$3,600	\$5,000		
Bachelor of Science (Real Estate)	95.0%	95.1%	\$3,524	\$3,600	\$3,563	\$3,650	\$3,600	\$4,400		
<b>School of Computing</b>										
Bachelor of Computing (Computer Science)	96.8%	96.1%	\$6,954	\$6,300	\$7,121	\$6,600	\$5,341	\$7,883		
Bachelor of Computing (Information Security)	94.6%	91.1%	\$5,274	\$5,400	\$5,660	\$5,500	\$4,800	\$6,475		
Bachelor of Computing (Information Systems)	95.3%	93.0%	\$5,511	\$5,300	\$5,672	\$5,500	\$4,800	\$6,250		
Bachelor of Science (Business Analytics)	96.2%	95.2%	\$5,845	\$5,500	\$5,966	\$5,500	\$5,000	\$6,600		
<b>School of Design and Engineering</b>										
Bachelor of Engineering (Biomedical Engineering)	97.2%	91.6%	\$4,340	\$3,800	\$4,268	\$4,000	\$3,500	\$5,000		
Bachelor of Engineering (Chemical Engineering)	96.6%	95.5%	\$4,487	\$4,400	\$4,680	\$4,675	\$4,018	\$5,200		
Bachelor of Engineering (Civil Engineering)	95.8%	88.9%	\$5,575	\$5,021	\$5,139	\$4,800	\$3,700	\$4,400		
Bachelor of Engineering (Electrical Engineering)	92.2%	90.7%	\$4,730	\$4,700	\$4,913	\$4,800	\$4,300	\$5,500		
Bachelor of Engineering (Engineering Science)*	100.0%	100.0%	\$4,621	\$4,450	\$4,659	\$4,450	\$4,000	\$5,000		
Bachelor of Engineering (Environmental Engineering)	87.1%	83.9%	\$4,252	\$4,000	\$4,496	\$4,200	\$3,850	\$5,000		
Bachelor of Engineering (Industrial and Systems Engineering)	92.9%	92.9%	\$5,137	\$5,000	\$5,281	\$5,000	\$4,700	\$5,600		
Bachelor of Engineering (Materials Science and Engineering)	92.9%	87.1%	\$4,384	\$4,360	\$4,539	\$4,500	\$3,850	\$5,000		
Bachelor of Engineering (Mechanical Engineering)	96.2%	93.9%	\$4,594	\$4,400	\$4,780	\$4,625	\$4,000	\$5,200		
Bachelor of Arts (Architecture)*	84.0%	82.0%	\$4,380	\$4,300	\$4,482	\$4,400	\$4,000	\$4,800		
Bachelor of Arts (Industrial Design)	66.7%	43.3%	\$4,239	\$4,500	\$4,270	\$4,500	\$3,500	\$4,500		
Bachelor of Science (Project and Facilities Management)	98.4%	92.0%	\$3,612	\$3,500	\$3,670	\$3,555	\$3,375	\$3,855		

# GOOD CODE DESIGN

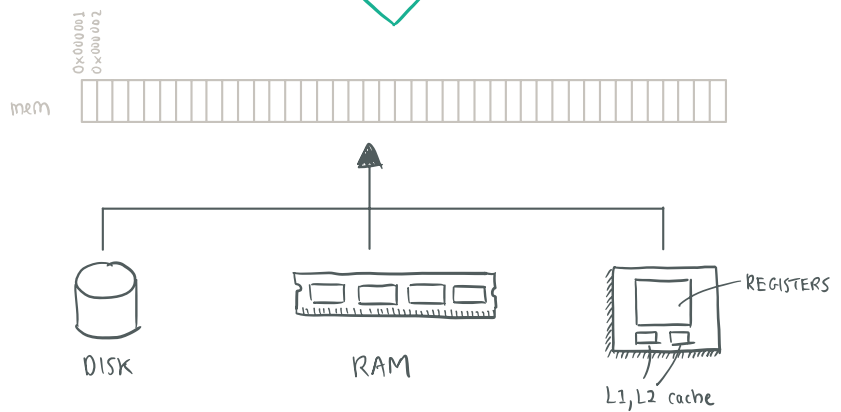
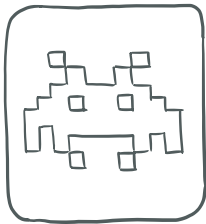


WHERE does **DATA STRUCTURES**

lie in

the **ABSTRACTION**

I like apps to respond  
FAST and use  
LOW memory space



Let's look at operations on an ARRAY data structure...

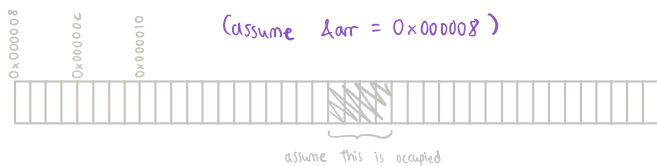
```
int arr[] = {5, 6, 7}
```

abstractly, this is

5	6	7
0	1	2

Q: WHAT does this look like in the mem below?

(assume  $\&arr = 0x000008$ )



① access  $i$ th element...

$$\begin{aligned}\text{arr}[2] &\Rightarrow \text{addr} = \Delta \text{arr} + \text{size of (int)} * 2 \\ &= 0x000008 + 4 \text{ bytes} * 2 \\ &= 0x000010\end{aligned}$$

then return contents at addr

② add an element to the end...

Q: Show the mem after the following operations...

$\text{arr}[3] = 44$

$\text{arr}[4] = 55$

$\text{arr}[5] = 66$

Q: How efficient is this "algorithm"?

Now, let's instead do this with a LINKED LIST...

```
template <typename Item>
class LL {
    struct Node {
        Item data;
        Node* next;
    };
    :
};
```

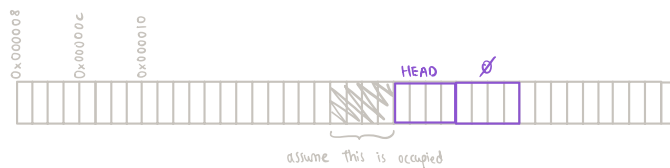
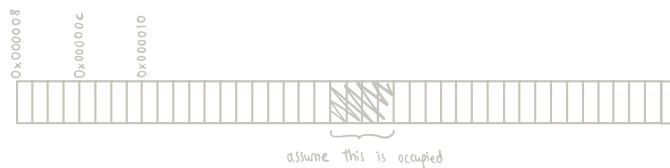
Q: Show the mem after the following operations...

$\text{LL ll}();$

$\text{ll.push}(5);$

$\text{ll.push}(6);$

$\text{ll.push}(7);$



Q: How efficient is accessing the  $i$ th element?

Q: How efficient is adding an element to the end?

Q: How much space do we need to store  $n$  integers in an array vs a linked list?