CLaDS:

A Cloud-Based Virtual Lab for the Delivery of Scalable Hands-on Assignments for Practical Data Science Education

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Demand for Data Science/Analytics

2,350,000 job listings in 2015

Demand for **data scientists and data engineers** is expected to grow by **39%** by 2020

Skill Name	Predicted 2-Year Growth
Data Science	93%
Machine Learning	56%
Tableau	52%
Big Data	50%
Data Visualization	44%

`https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=IML14576USEN`

Academia's Response: Online Masters?

A few examples (non-exhaustive):

- UC Berkeley: **Master of Information and Data Science** (2014)
- UIUC: **Master of Computer Science in Data Science** (Coursera, 2017)
- UMich: **Master of Applied Data Science** (Coursera, coming 2019)
- "a top-tier university": **Master of Data Science** (edX, coming "soon")

Problem: how do we scale an online masters program to a thousand students?

What should **providing computing resources** look like?

Challenges of High-Scalability Data Science Education

Assignments to train the next generation of data scientists must:

1. scale to **large numbers of students**,
2. be able to cover a **broad spectrum** of potential skills,
3. allow for the development of **hands-on experience** with **real data sets**, and
4. **minimize** overall deployment **cost**.

CLaDS: A Cloud-based Lab for Data Science

Related Work

Auto-gradable programming assignments:

- Mike Joy, Nathan Griffiths, and Russell Boyatt. “The boss online submission and assessment system”. In: *Journal on Educational Resources in Computing (JERIC)* 5.3 (2005), p. 2
- Christoph Matthies, Arian Treffer, and Matthias Uflacker. “Prof. CI: Employing continuous integration services and Github workflows to teach test-driven development”. In: *2017 IEEE Frontiers in Education Conference (FIE)*. IEEE. 2017, pp. 1–8
- `www.hackerrank.com`, `www.topcoder.com`

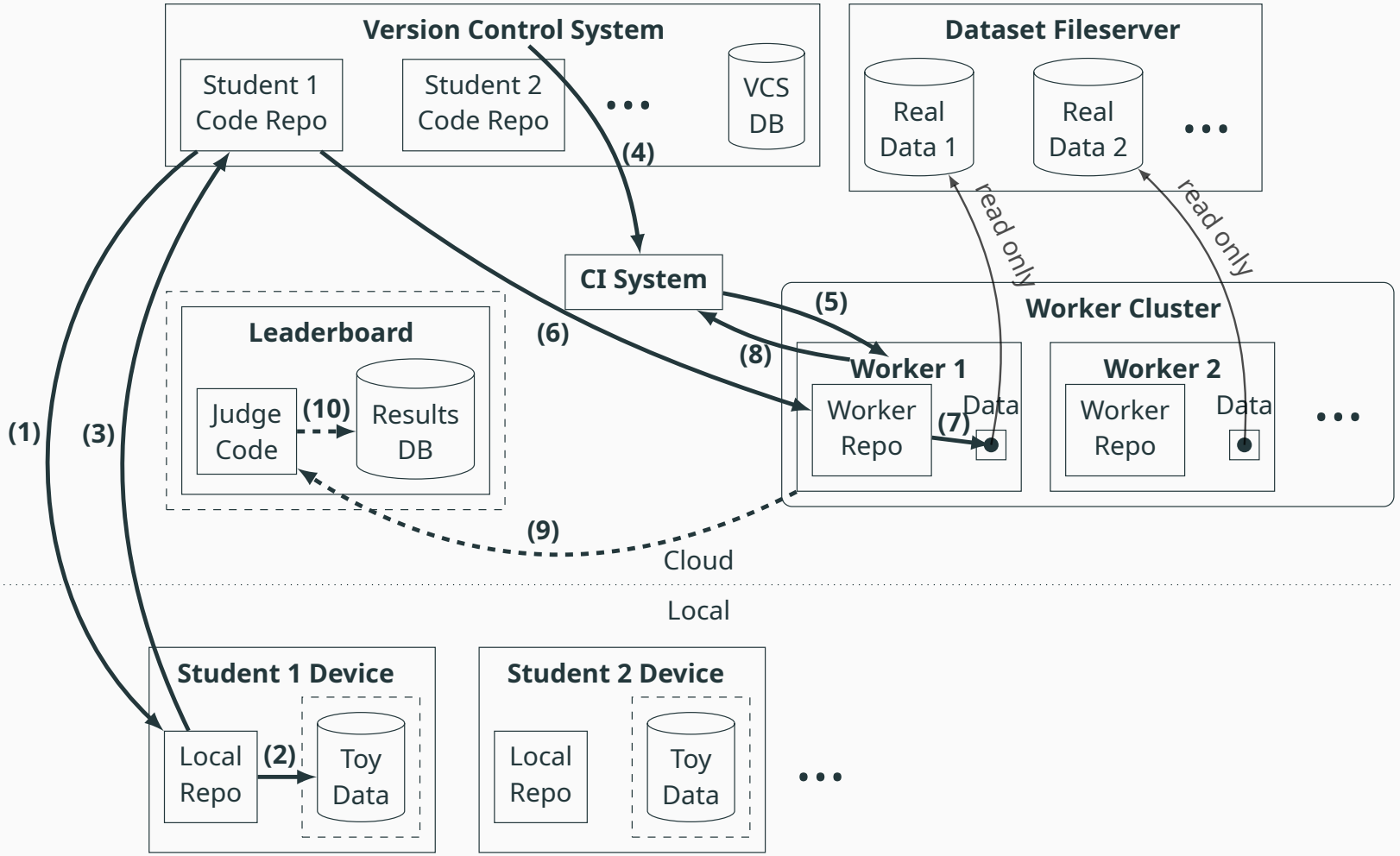
Closest idea: Kaggle (`www.kaggle.com`); key differences:

- complete flexibility (tools, libraries, grading, competition vs. traditional assignments)
- no hard limit on the size of dataset

Domain-specific labs (CLaDS is general):

- Hui Fang et al. “VIRLab: A Web-based Virtual Lab for Learning and Studying Information Retrieval Models”. In: *Proc. SIGIR*. Gold Coast, Queensland, Australia: ACM, 2014, pp. 1249–1250
- Hui Fang and ChengXiang Zhai. “VIRLab: A Platform for Privacy-Preserving Evaluation for Information Retrieval Models”. In: *Proc. PIR@SIGIR*. Gold Cost, Queensland, Australia, 2014, pp. 37–38

System Architecture



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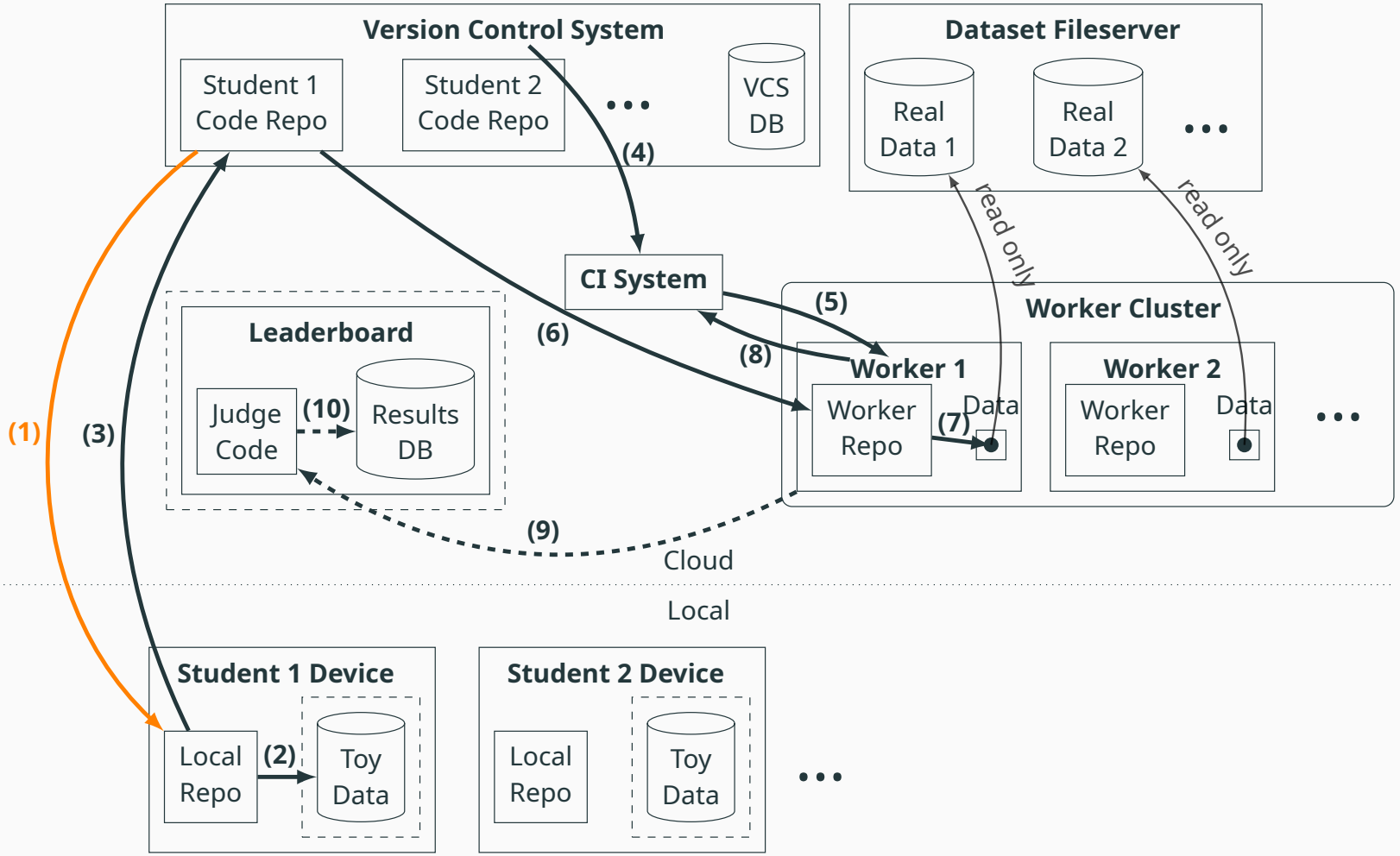

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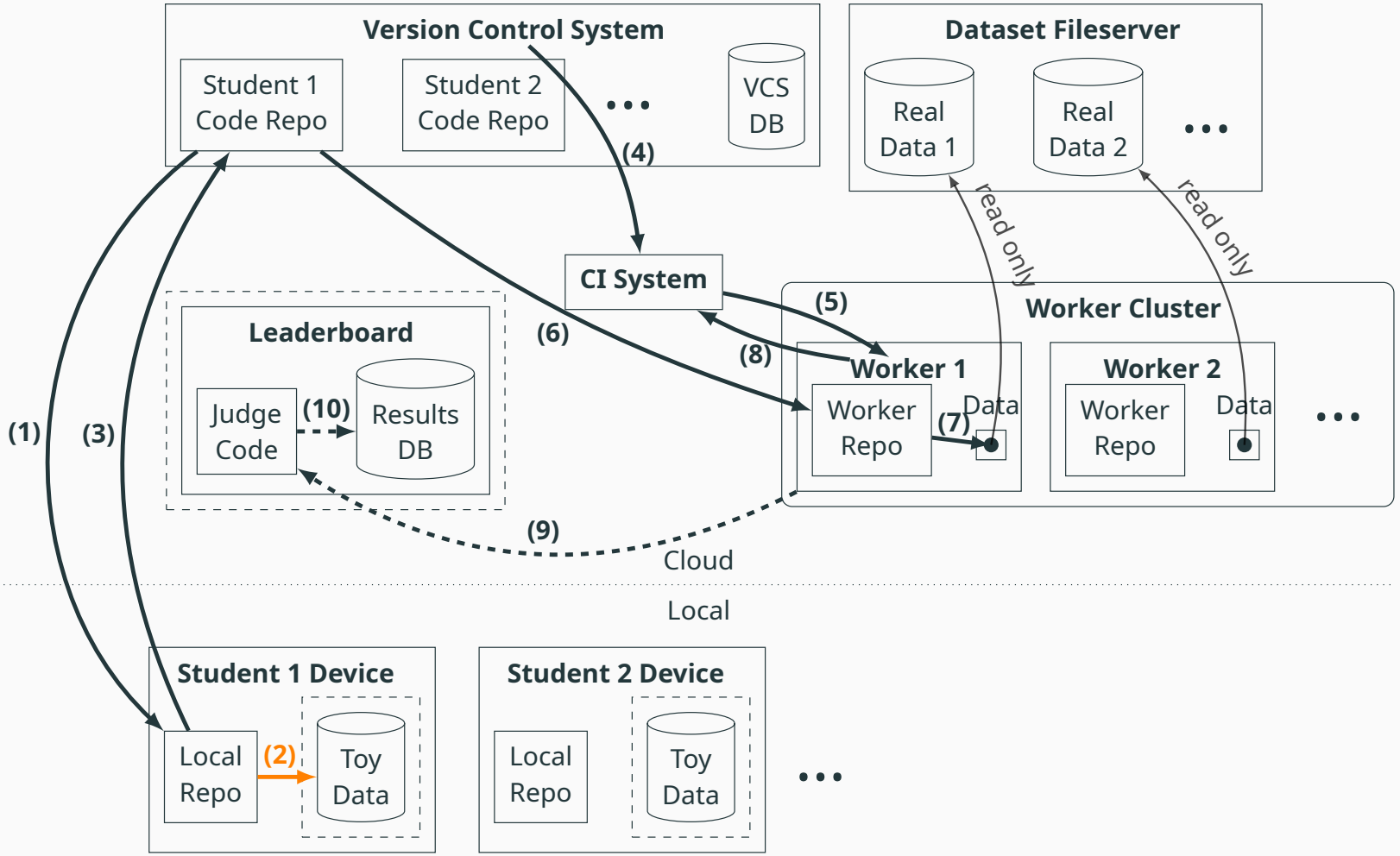

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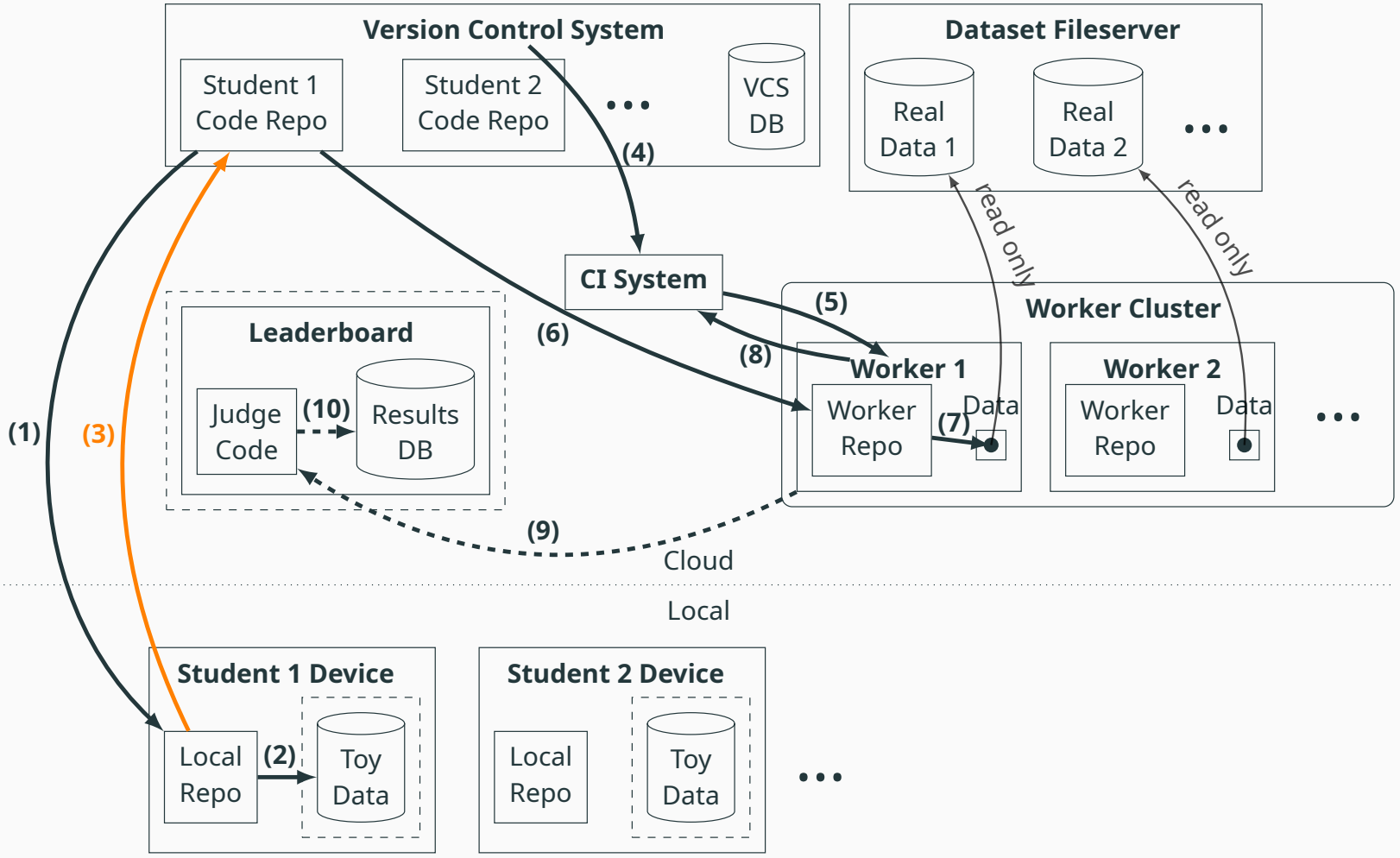

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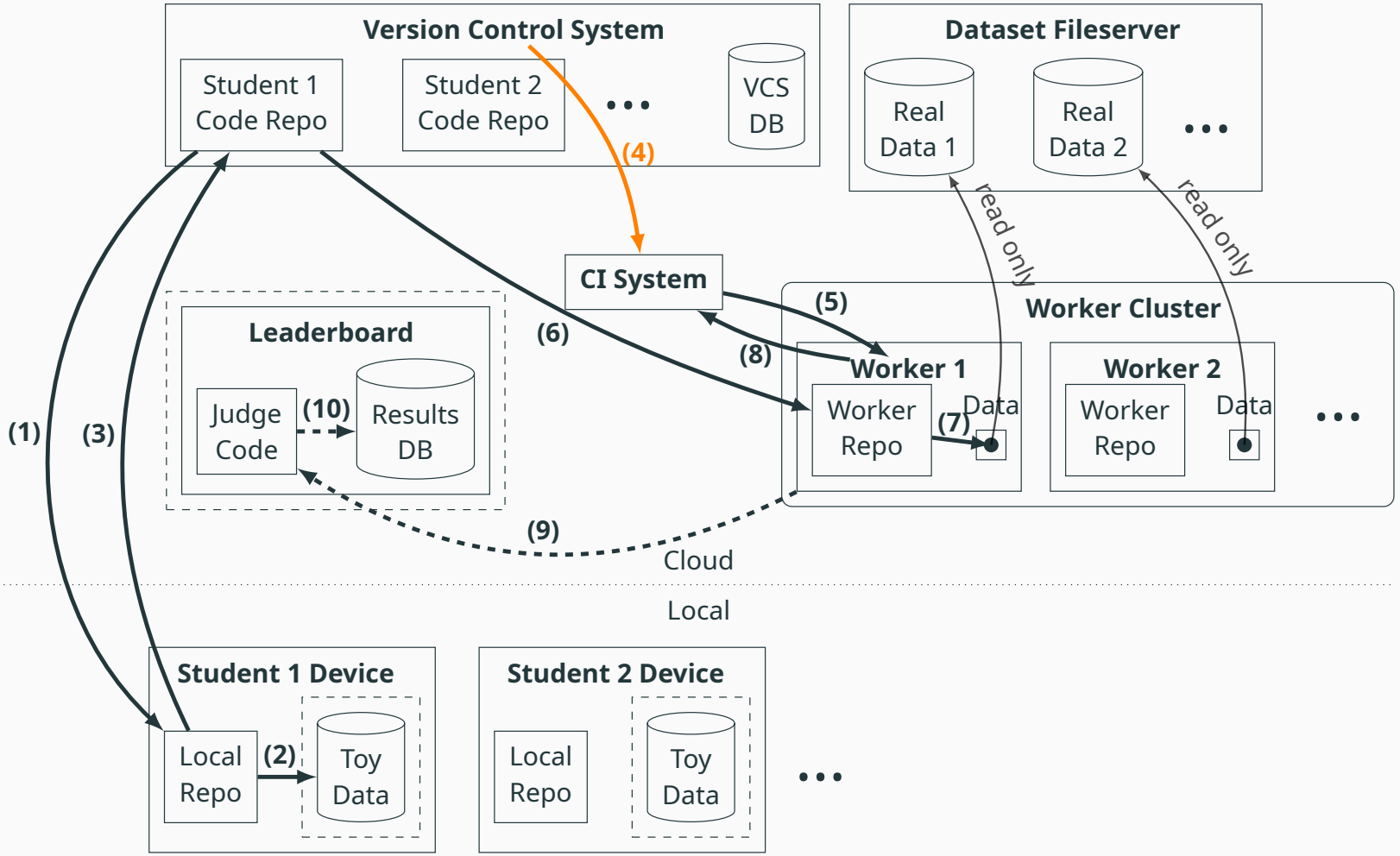

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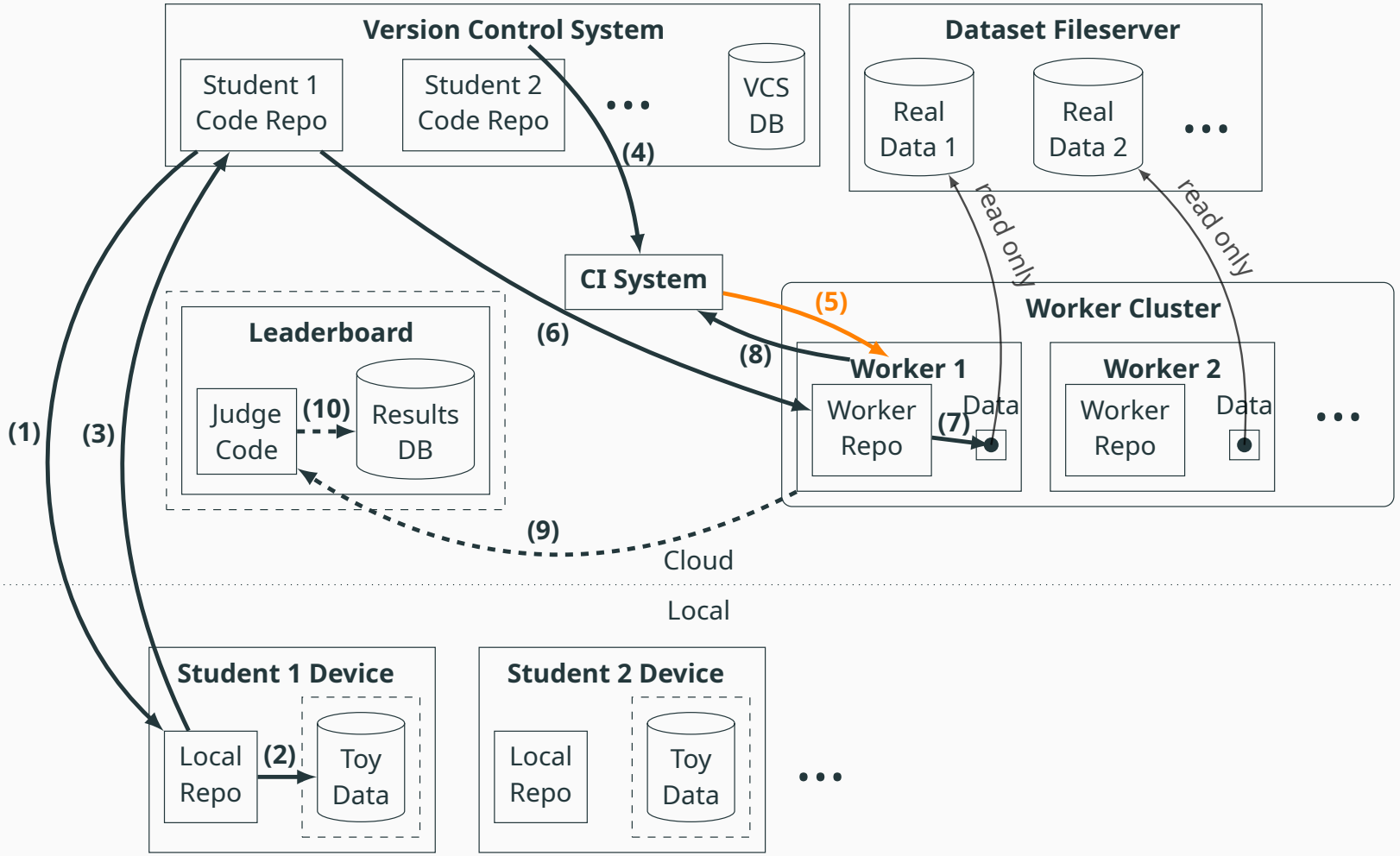

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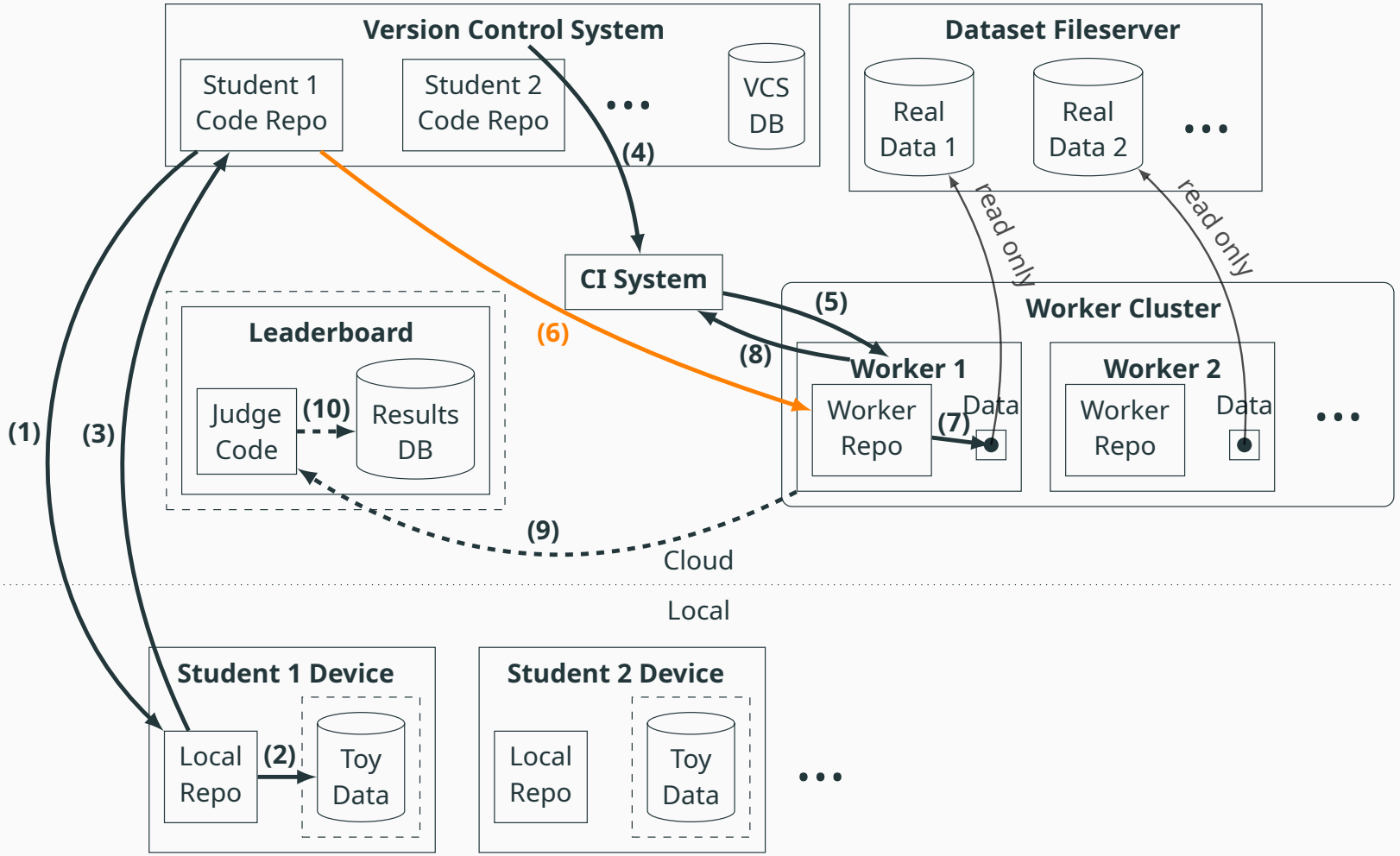

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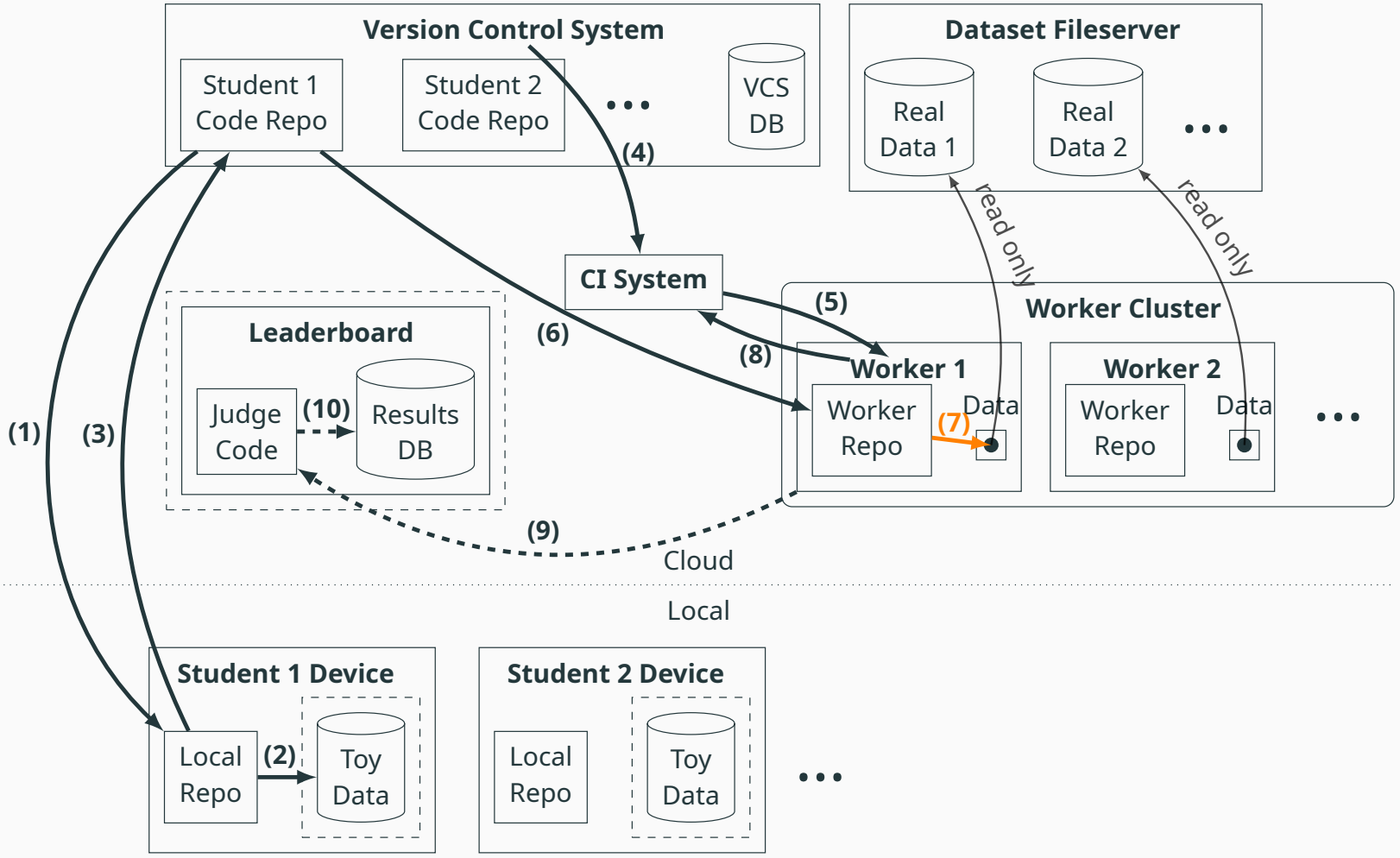

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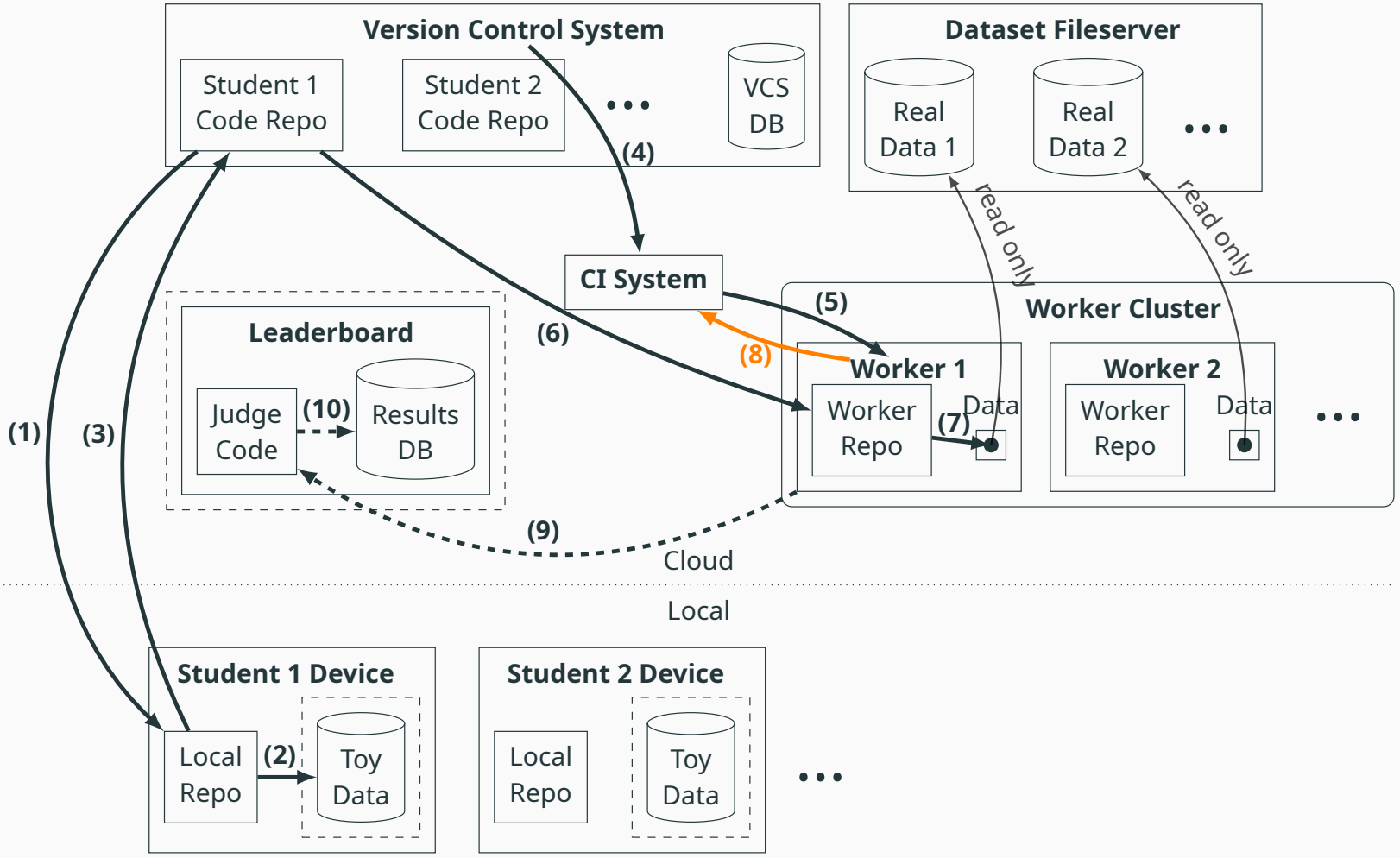

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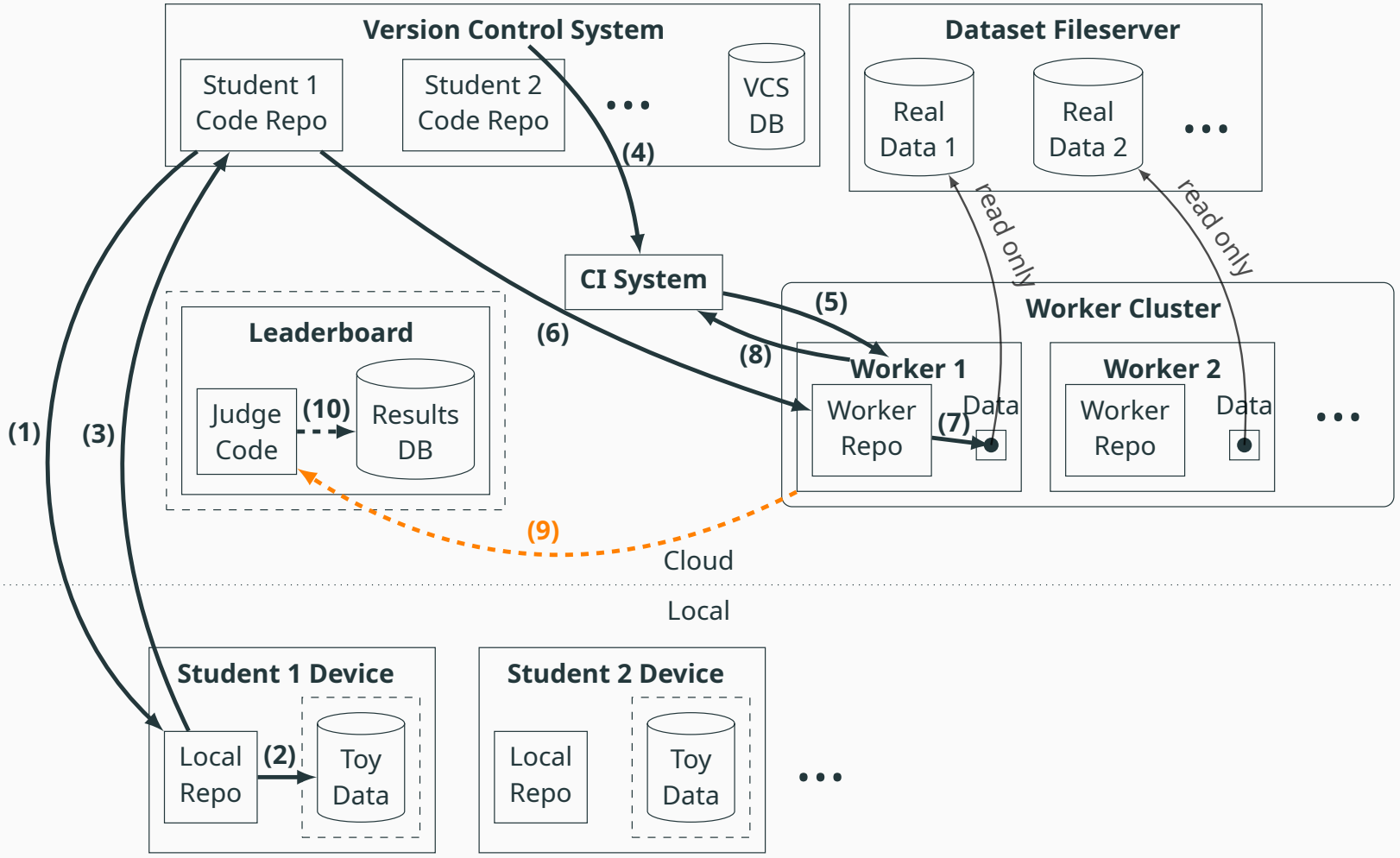

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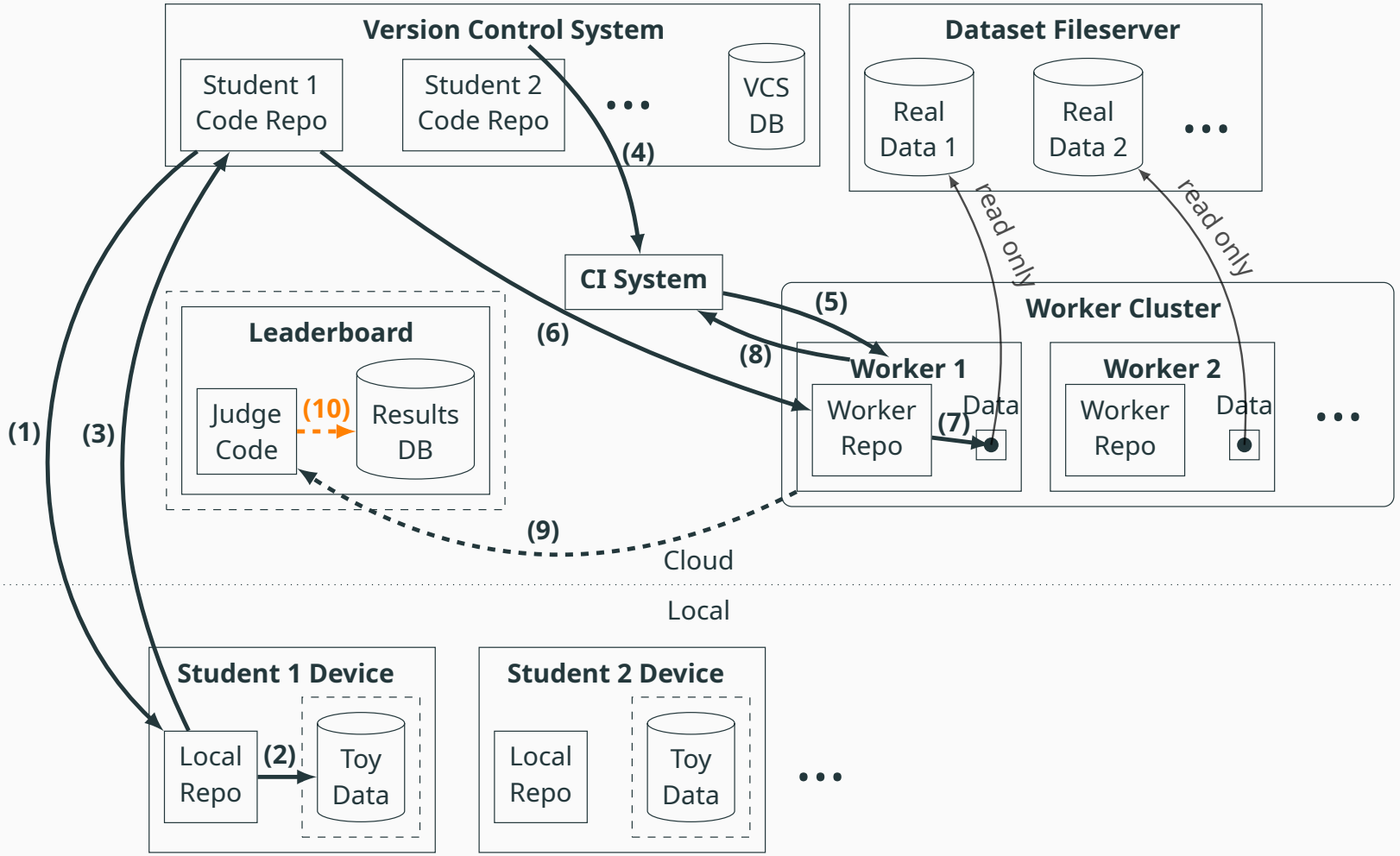


Key Components

What makes it work?

- Auto-scaling worker cluster: computing resources are **demand driven**
- Assignment agnostic: supports a wide variety of **assignment types**
- Workers live “next to” datasets: opens door to **real**(er) **datasets**
- Simpler, event-driven (optional) leaderboards

Software:

- GitLab (VCS; open-core)
- GitLab CI (CI system; open-core)
- Leaderboards (open-source)
- `https://timan-group.github.io/clads/`

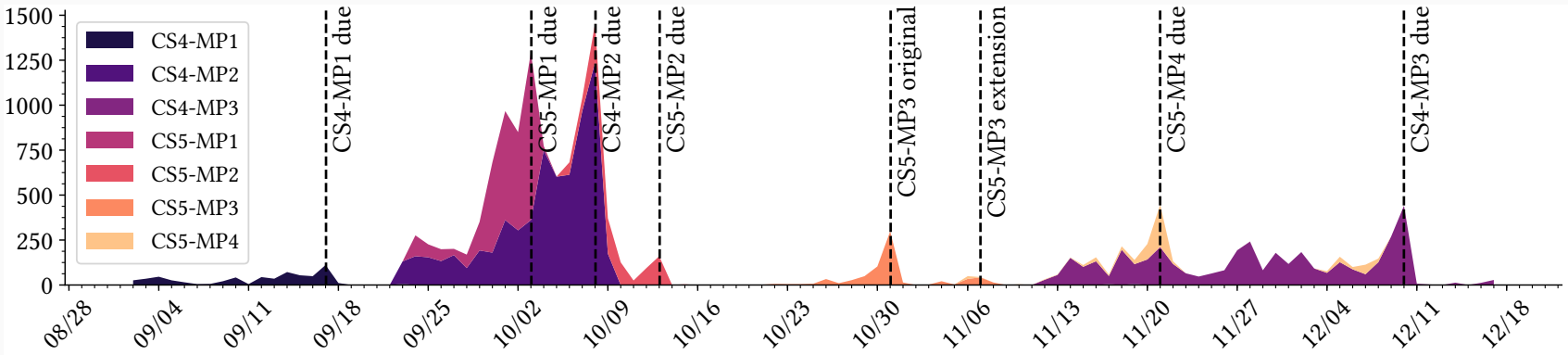
Deployment Experience

Fall 2017:

- CS 410 (online, 136 students)
- CS 510 (on-campus, 91 students)
- **Amortized cost per student: $7.40 USD**

System Utilization

	CS4		CS5	
	Description	Hrs.	Description	Hrs.
MP1	feat. extraction	28.6	smoothing methods	908.8
MP2	retrieval fns.	227.1	word embeddings	79.3
MP3	classification	142.9	topic mdls.	250.9
MP4	-	-	hidden Markov mdls.	29.6



Search Engine Competition: Leaderboard

Search Engine Competition

Rank	Alias	Overall Score		apnews (0.7)		cranfield (0.3)		Updated	Submissions
		Current	Previous	NDCG@10	Previous	NDCG@10	Previous		
1	我跟你讲啊，你们这样子在测试集上调参啊，是不行的！	0.7967	*0.7967*	0.99	*0.99*	0.3455	*0.3455*	2018-02-25 | 19:44:53	18
2	Alpaca_cc	0.4166	*0.4166*	0.438	*0.438*	0.3666	*0.3666*	2018-02-21 | 14:06:00	5
3	gh	0.4134	*0.4209*	0.4338	*0.446*	0.3657	*0.3625*	2018-02-20 | 22:37:32	46
3	Rohan	0.4134	*0.4134*	0.4338	*0.4338*	0.3657	*0.3657*	2018-02-20 | 22:57:41	44
5	oneDayMore	0.3987	*0.3987*	0.4199	*0.4199*	0.3493	*0.3493*	2018-02-21 | 13:26:30	20
6	xingye	0.3986	*0.3986*	0.4207	*0.4207*	0.3471	*0.3471*	2018-02-18 | 21:49:10	34
7	bwj	0.3985	*0.3985*	0.4243	*0.4243*	0.3383	*0.3383*	2018-02-18 | 23:03:30	182
7	BBH	0.3985	*0.3984*	0.4243	*0.4243*	0.3383	*0.3382*	2018-02-18 | 23:48:45	81
9	hrukalive	0.3984	*0.3984*	0.4194	*0.4194*	0.3495	*0.3495*	2018-02-21 | 21:22:01	33
10	Joey	0.3984	*0.3984*	0.4243	*0.4241*	0.3381	*0.3382*	2018-02-18 | 23:04:51	104
11	lily	0.3983	*0.3983*	0.4209	*0.4209*	0.3457	*0.3457*	2018-02-21 | 14:29:47	11
12	ThomasMuller25	0.3979	*0.3978*	0.4177	*0.4177*	0.3516	*0.3515*	2018-02-25 | 23:59:25	96
13	BillyisntBilibili	0.3972	*0.3992*	0.414	*0.4207*	0.358	*0.3492*	2018-02-22 | 21:54:01	32
14	Try one try	0.397	*0.3884*	0.4245	*0.4046*	0.3328	*0.3508*	2018-02-21 | 23:28:07	76

197	cshang	0.3765	*0.3668*	0.3879	*0.3773*	0.35	*0.3424*	2018-02-18 | 22:18:40	4
198	MoNeY_Pro	0.3754	*-inf*	0.386	*-inf*	0.3506	*-inf*	2018-02-16 | 15:50:36	1
198	sliu134	0.3754	*0.3754*	0.386	*0.386*	0.3506	*0.3506*	2018-02-18 | 17:42:27	3
200	Baseline	0.3702	*-inf*	0.3806	*-inf*	0.3461	*-inf*	2017-03-02 | 01:03:25	1
200	Chongye	0.3702	*0.3702*	0.3806	*0.3806*	0.3461	*0.3461*	2018-02-15 | 15:21:31	9
200	Anonymous	0.3702	*0.3702*	0.3806	*0.3806*	0.3461	*0.3461*	2018-02-18 | 23:59:56	3
200	Anonymous	0.3702	*-inf*	0.3806	*-inf*	0.3461	*-inf*	2018-02-18 | 18:43:50	1

Competition Submissions *After Beating Baseline*

Assignment: beat a baseline solution for “A”; compete for extra credit (top X positions in leaderboard).

Table shows **additional effort above and beyond** passing the assignment with a perfect score, even in the 25th percentile.

Assignment	Mean	Std. Dev.	Median	25th %ile
CS4-MP2	20.5	27.6	10.0	5.0
CS4-MP3	21.7	42.3	10.0	3.0

Student Thoughts

- “Professionally speaking, I really feel that I gained a lot, as now I truly understand the essential fundamentals in Text Information Systems areas and, thanks to the hands-on final project, and MPs, can implement some of these principles. I am more than positive that I will utilize the gained knowledge in my workplace in 2018 and make a significant impact.”

- “The system used for the programming assignments to automatically test, evaluate, and rank solutions made the assignments a fun challenge.”

- “The competition style leader board added a fun aspect…”

Takeaways

1. Now possible to perform hands-on data analysis experiments **at scale**

2. **Reproducible research**: archive of methods and their performance alongside public leaderboards for standard tasks

3. Applicable to **more than just classroom learning**—industry training, internal research groups

4. Future of computing resource provisioning for (non-sensitive) engineering work? **Use the cloud for what it's good at!**

Limitations and Future Work

Everything has a limit: just how big can the datasets get?

Everything has a limit: just how many students can we service? (Try MOOC-scale?)

Branch out: ought to be usable by other CS domains—not only data science

Security: how to prevent abuse? Must be addressed for MOOC-scale

Funding: will industry always support this? lab fees? nonprofit org?

Thank you!