Workshop on Reasoning and Planning for LLMs

ICLR International Conference On Learning Representations

ErrorRadar: Benchmarking Complex Mathematical Reasoning of Multimodal Large Language Models Via Error Detection

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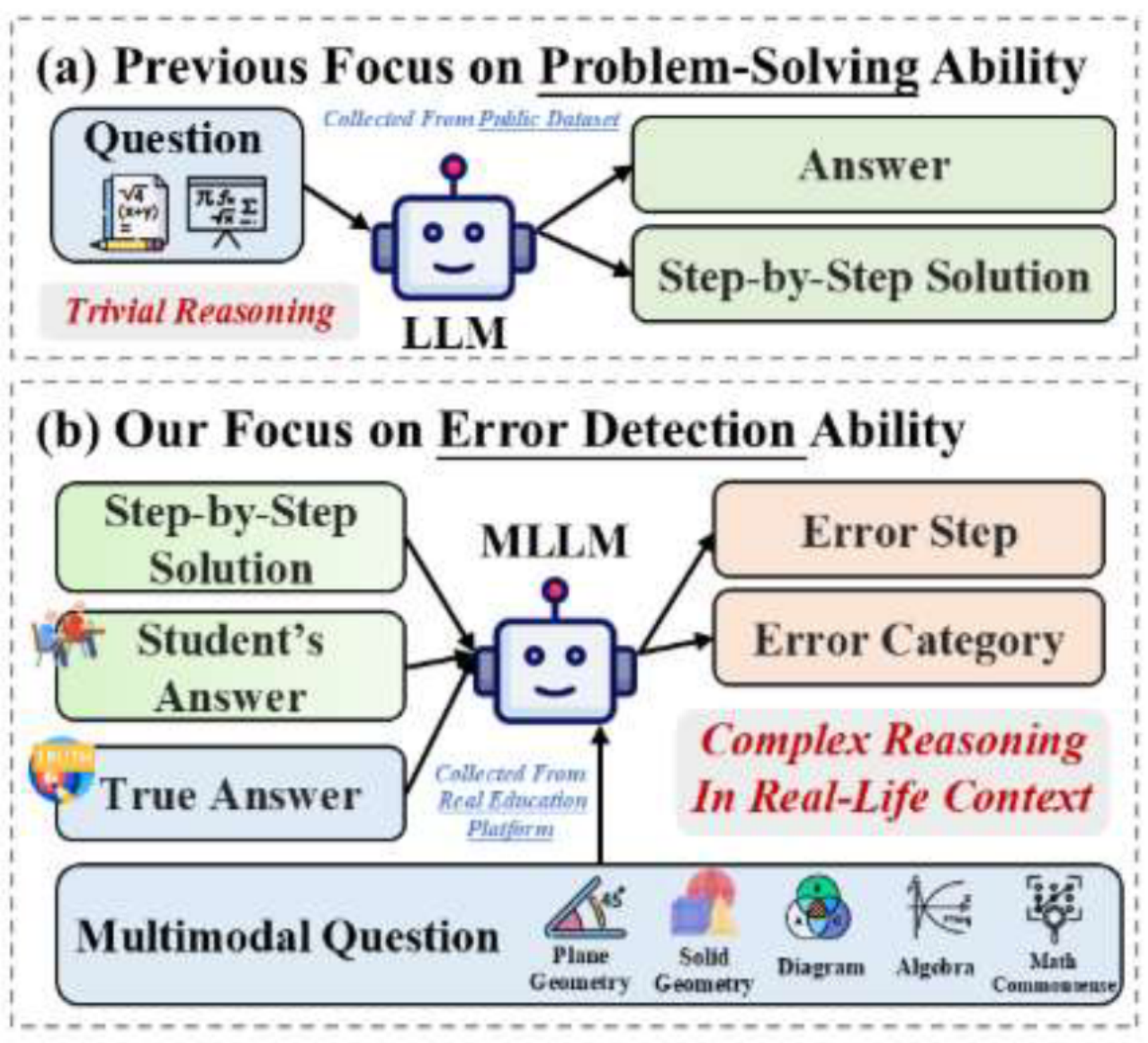
Introduction



We formulate the new task – **Multimodal Error Detection**, and introduce **ErrorRadar**, the **first benchmark** designed to assess MLLM's capabilities in such a task

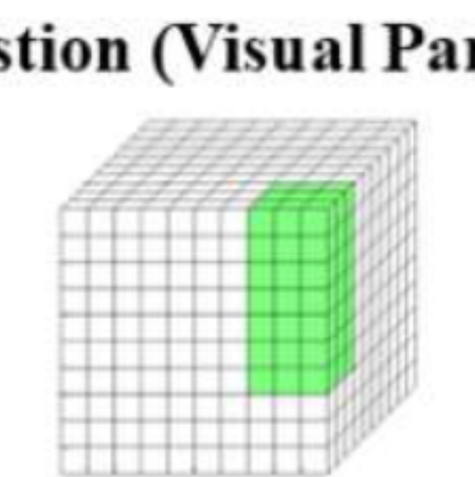
Benchmarks	Venue	Modality	Student Ans.	Error Det.
TheoremQA (Chen et al., 2023a)	EMNLP	T	-	-
MathBench (Liu et al., 2024b)	ACL	T	-	-
MR-GSM8K (Zeng et al., 2024)	arXiv	T	-	-
SciEval (Sun et al., 2024)	AAAI	T	-	-
EIC (Li et al., 2024b)	arXiv	T	-	✓
CMMaTH (Li et al., 2024c)	arXiv	T, I	-	-
MathScape (Zhou et al., 2024a)	arXiv	T, I	-	-
MATH-V (Wang et al., 2024a)	arXiv	T, I	-	-
QRData (Liu et al., 2024c)	ACL	T, I	-	-
IsoBench (Fu et al., 2024)	COLM	T, I	-	-
SciBench (Wang et al., 2024c)	ICML	T, I	-	-
MathVista (Lu et al., 2024b)	ICLR	T, I	-	-
MathVerse (Zhang et al., 2024)	ECCV	T, I	-	-
ErrorRadar (Ours)	-	T, I	✓	✓

Comparison w/ LLM-base math reasoning benchmarks

Dataset

Representative Case

Question (Visual Part):



Question (Textual Part):

What is the decimal representation of the shaded part in the figure below?

Student's Step-by-Step Solution (Reasoning Process):

- Step 1: Read the question and the accompanying image text "What is the decimal representation of the shaded area in the diagram below?"
- Step 2: Analyze the cube given in the diagram; it is a large cube representing "1."
- Step 3: Determine that the large cube is evenly divided into 1000 small cubes, with each small cube representing 1/1000.
- **Step 4: Count the total number of small cubes in the shaded area, which is 21.**
- Step 5: Calculate the proportion of the shaded area, which is 21 times 1/1000, totaling 21/1000.
- Step 6: Convert the fraction 21/1000 into a decimal, resulting in 0.021.
- Step 7: Output the result as 0.021.

True Answer: 0.063

Student's Answer: 0.021

Problem Type: Solid Geometry

Error Category: Visual Perception Error

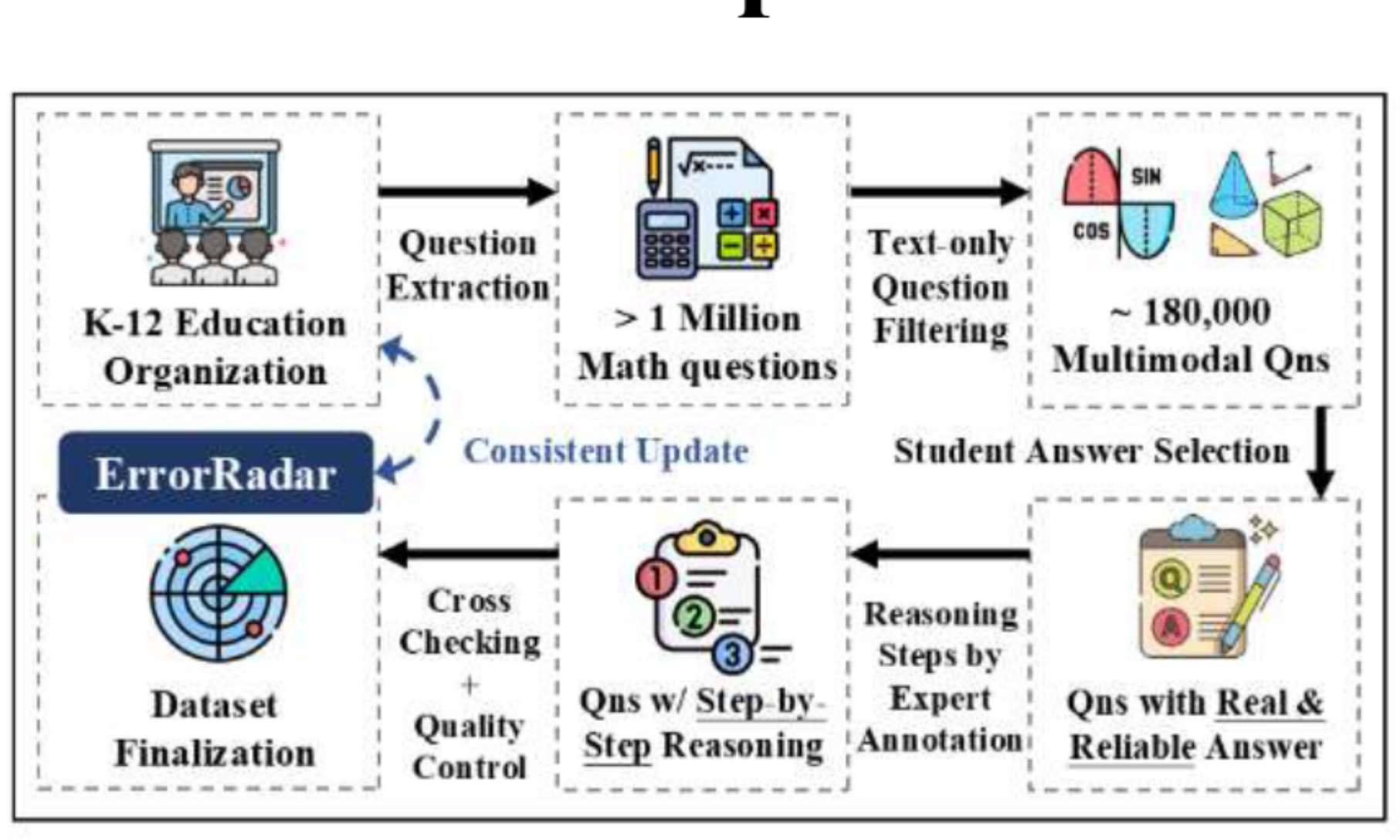
Error Step: Step 4

ErrorRadar	Error Category	Error Step
GPT-4o	Visual Perception Error	Step 4
GPT-4o-mini	Calculation Error ✗	Step 4
Gemini-Pro-1.5	Visual Perception Error	Step 3 ✗
LLaVA-v1.6	Calculation Error ✗	Step 5 ✗

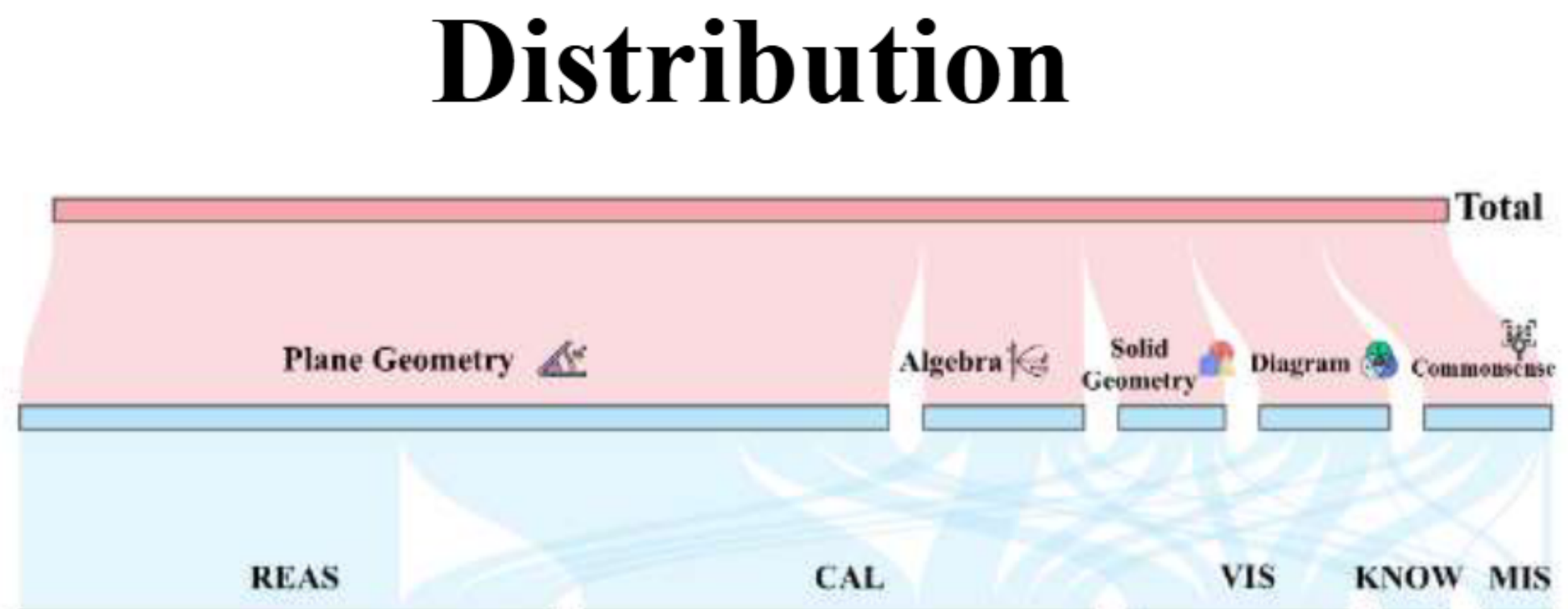
Key Statistics

Statistic	Number
Total multimodal questions	2,500
Problem Type	
- Plane Geometry	1559 (62.4%)
- Solid Geometry	191 (7.6%)
- Diagram	233 (9.3%)
- Algebra	288 (11.5%)
- Math Commonsense	229 (9.2%)
Error Category	
- Visual Perception Error	395 (15.8%)
- Calculation Error	912 (36.5%)
- Reasoning Error	951 (38.0%)
- Knowledge Error	119 (4.8%)
- Misinterpretation of the Qns	123 (4.9%)
Average Reasoning Step	7.6
Maximum Reasoning Step	20
Minimum Reasoning Step	3
Average Question Length	168
Maximum Question Length	719
Minimum Question Length	13

Data Pipeline



Distribution



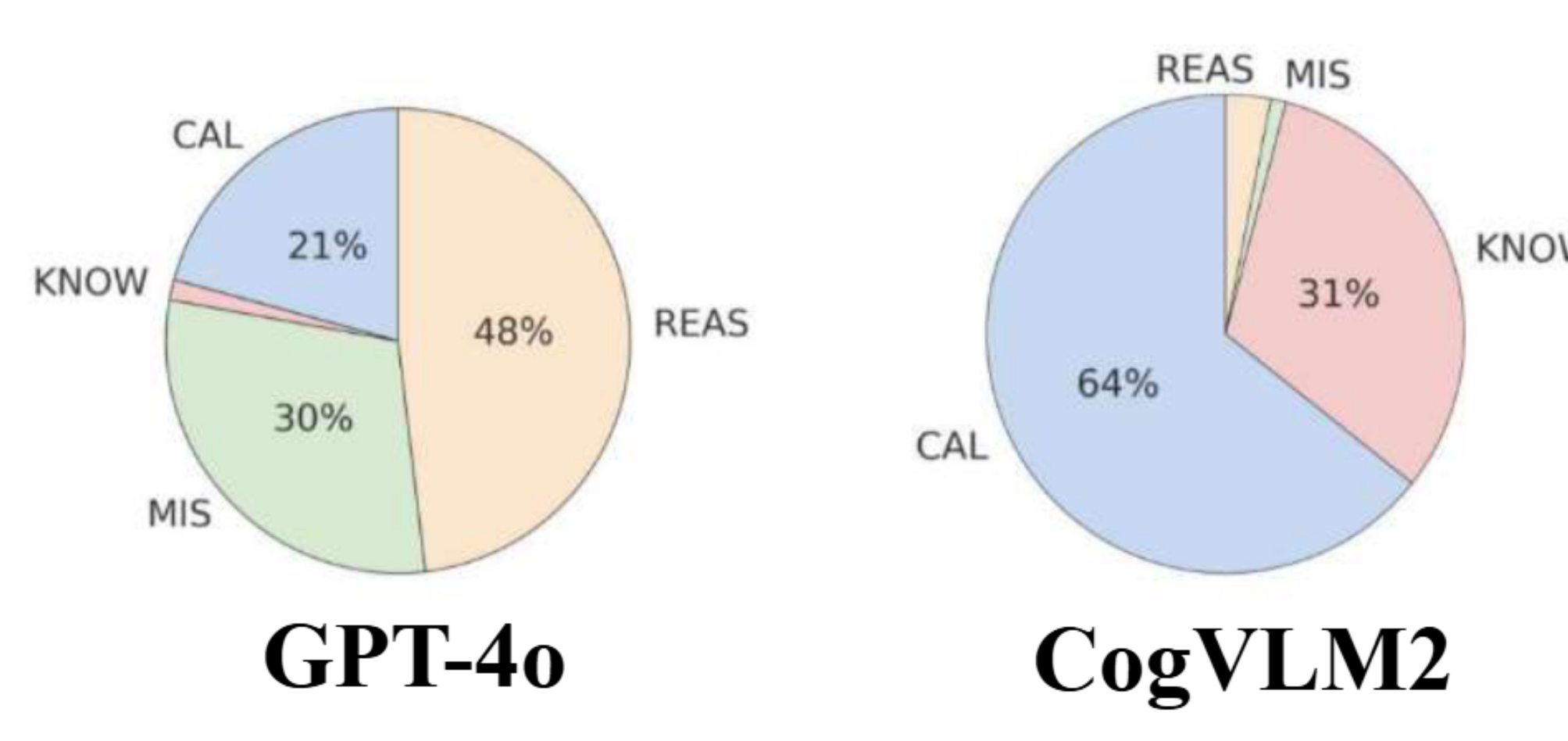
Experiment

➢ Main Result GPT-4o demonstrates the strongest performance

Multimodal Large Language Models	Parameters	LLM	STEP	CATE	VIS	CAL	REAS	KNOW	MIS
Open-Source MLLMs									
InternVL2 (Chen et al., 2023b)	2B	InternLM-2	9.8	25.1	32.2	38.8	12.2	0.0	24.4
Phi-3-vision (Abdin et al., 2024)	4B	Phi-3	37.5	40.7	9.6	99.6	6.6	3.4	4.1
Yi-VL (Young et al., 2024)	6B	Yi	15.7	32.1	9.1	77.1	4.9	14.3	0.0
DeepSeek-VL (Lu et al., 2024a)	7B	DeepSeek	16.2	35.7	4.6	90.9	0.4	28.6	6.5
LLaVA-v1.6-Vicuna (Liu et al., 2024a)	7B	Vicuna-v1.5	30.3	17.7	40.3	14.9	8.3	0.0	55.3
InternVL-2 (Chen et al., 2023b)	8B	InternLM-2.5	44.2	44.1	12.4	99.6	13.6	10.9	2.4
MiniCPM-LLaMA3-V2.5 (Yao et al., 2024)	8B	LLaMA3	37.4	38.0	4.1	100.0	2.1	2.5	0.0
MiniCPM-V2.6 (Yao et al., 2024)	8B	Qwen2	17.0	39.8	11.4	87.8	12.1	10.1	17.9
Qwen-VL (Bai et al., 2023)	9B	Qwen	23.8	38.9	8.6	99.1	3.5	0.0	0.8
GLM-4v (GLM et al., 2024)	13B	GLM-4	44.6	44.1	2.5	92.9	25.8	0.0	0.0
LLaVA-v1.6-Vicuna (Liu et al., 2024a)	13B	Vicuna-v1.5	36.9	47.8	0.0	74.5	53.7	0.8	2.4
CogVLM2-LLaMA3 (Wang et al., 2023a)	19B	LLaMA3	15.0	20.1	43.3	33.8	0.7	13.4	0.0
InternVL2 (Chen et al., 2023b)	26B	InternLM-2	50.4	51.2	39.2	84.6	35.6	0.8	10.6
LLaVA-NEXT (Liu et al., 2024a)	72B	Qwen1.5	51.8	45.0	7.1	86.0	32.0	7.6	0.8
InternVL2 (Chen et al., 2023b)	76B	Hermes-2 Theta	54.4	49.5	33.4	92.4	25.1	10.9	8.1
Closed-Source MLLMs									
Qwen-VL-Max (Bai et al., 2023)	-	-	48.7	52.9	15.2	78.9	50.5	14.3	36.6
Claude-3-Haiku (Anthropic, 2024a)	-	-	45.6	48.0	10.4	77.4	46.8	4.2	1.6
Claude-3.5-Sonnet (Anthropic, 2024b)	-	-	50.2	49.5	35.7	48.4	64.8	21.0	11.4
Gemini-Pro-1.5 (Reid et al., 2024)	-	-	55.0	52.7	43.5	55.7	63.1	18.5	13.0
GPT-4o-mini (OpenAI, 2024b)	-	-	52.0	44.5	9.1	46.8	62.7	31.9	13.0
GPT-4o (OpenAI, 2024a)	-	-	55.1	53.1	46.3	50.4	64.9	9.2	46.3
Human									
Human performance	-	-	69.8	60.7	66.8	75.9	47.6	35.3	53.7

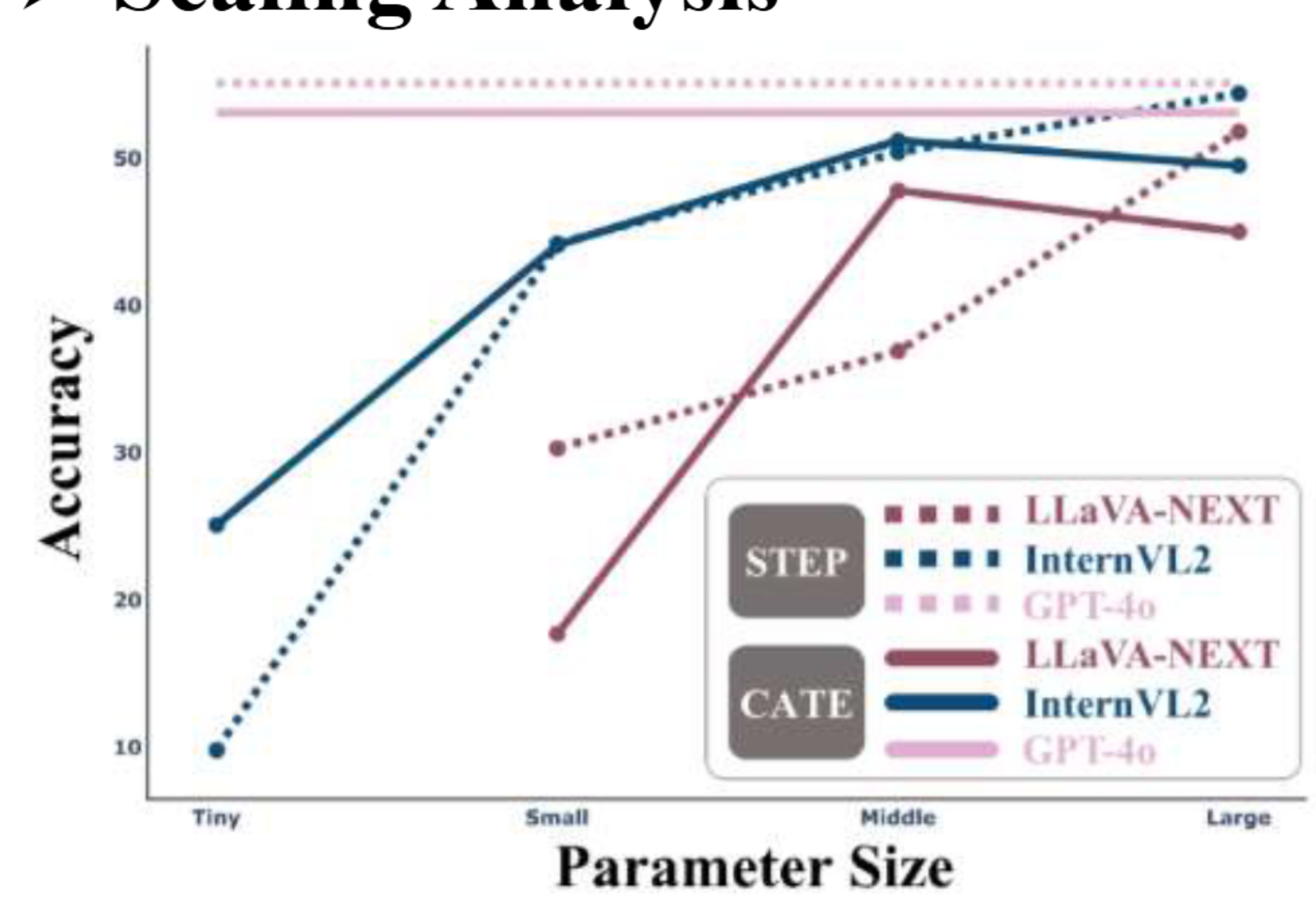
- **CAL is the easiest category, while KNOW is the most difficult**
- **MLLMs still have a gap to reach human-level error detection**

➢ Misjudged VIS Cases Distribution



- **Closed-source MLLMs tend to misjudge VIS as REAS**
- **Open-source MLLMs tend to misjudge VIS as CAL**

➢ Scaling Analysis

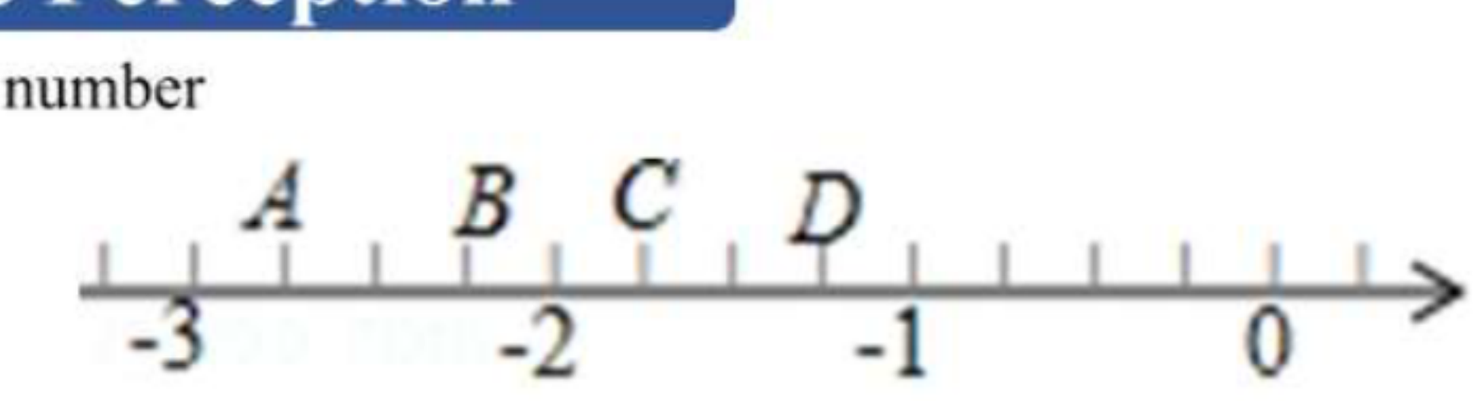


- **STEP performance increases via scaling**
- **CATE is relatively difficult to improve through scaling**

➢ Visual Bad Case Analysis

Distance Perception

Question: As shown in the figure, the point on the number line representing -2.75 is point ___.



True Answer: A

Student's Answer: B

Reasoning Steps:

- Step 1: Read the question and the text on the number line, which states "The point representing -2.75 on the number line is ______ point."
- Step 2: Determine the position of the point representing -2.75 on the number line.
- Step 3: Identify from the diagram the values represented by points A, B, C, and D.
- Step 4: Establish that point B is near the position representing -3, point A represents -2.25, point C represents -1.75, and point D represents -1.25.
- Step 5: Based on the number line position, conclude that the point representing -2.75 is point B.
- Step 6: Output the result as B.

Err. Cate. by GPT-4o: Reasoning Err.

Refer to *Diagram/Spatial/Flip&Fold/Shape Perception* in our paper

Conclusion

- By focusing on both ***error step identification*** and ***error categorization***, ErrorRadar bridges a critical research gap in assessing MLLMs' capabilities in **complex mathematical reasoning**.
- The dataset's construction, based on ***real-world student interactions***, ensures a robust evaluation framework that reflects **genuine user needs**.
- Our **extensive experimental analysis** reveals significant challenges in error detection, highlighting the need for continued advancements.