
expoQA®26
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expoqa.eu

Hello! 👋

I’m Jalpa Soni

Senior Data Scientist at Capitole

Welcome to our Talk:

The Rabbit Hole of Grammar: **LLMs on Trial with QA Adventures**

The Problem?

Traditional QA

- ✓ *Brittle scripts* break under dynamic UI changes
- ✓ *Hard-coded assertions* fail
- ✓ No reliable test oracles for *semantic correctness*
- ✓ *Multilingual testing multiplies complexity*

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# Pseudo-Selenium test

driver.find_element(By.ID, "submit-btn").click()

# Hard-coded assertion

message = driver.find_element(By.ID, "confirmation").text
assert message == "Your request has been submitted successfully."
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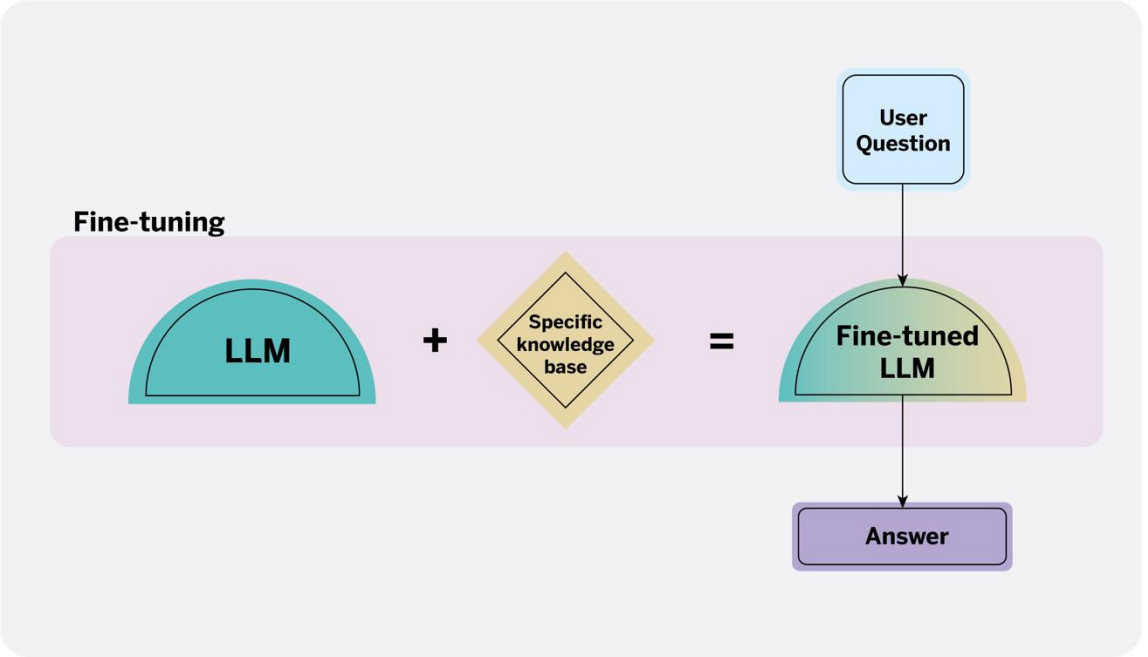
Enter LLMs,

- ✓ Outputs are probabilistic, not deterministic
- ✓ *Meaning matters more than exact string match*
- ✓ Need for semantic, not syntactic validation
- ✓ Opportunity: *LLMs can evaluate other LLMs*

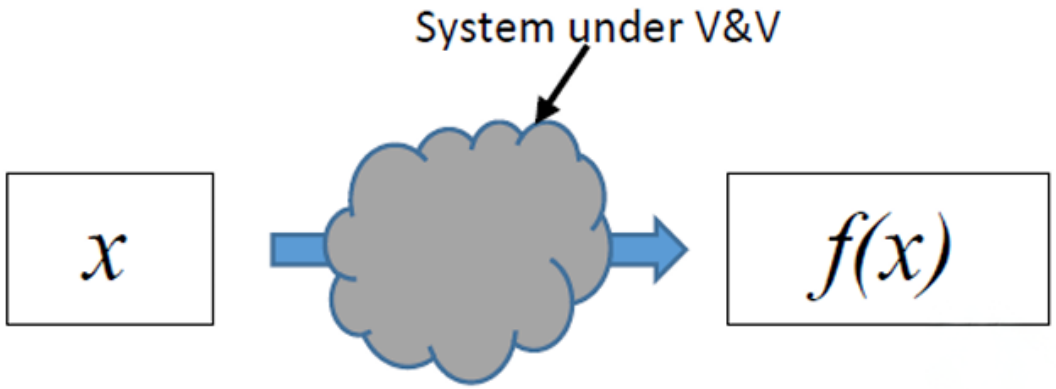
The Solution

Automated LLM Testing Pipeline

- ✓ End-to-end functional testing for web apps
- ✓ Generate, validate, and mutate test cases
- ✓ Metamorphic testing ensures consistency
  - If we **permute** the values in the text file, the results should stay the same
  - If we **multiply** each score by 10, the final results should all be multiplied by 10 as well
- ✓ Universal Grammar (UG) provides theoretical backbone



Metamorphic Testing



Raunak & Olsen (2015). Simulation Validation Using Metamorphic Testing

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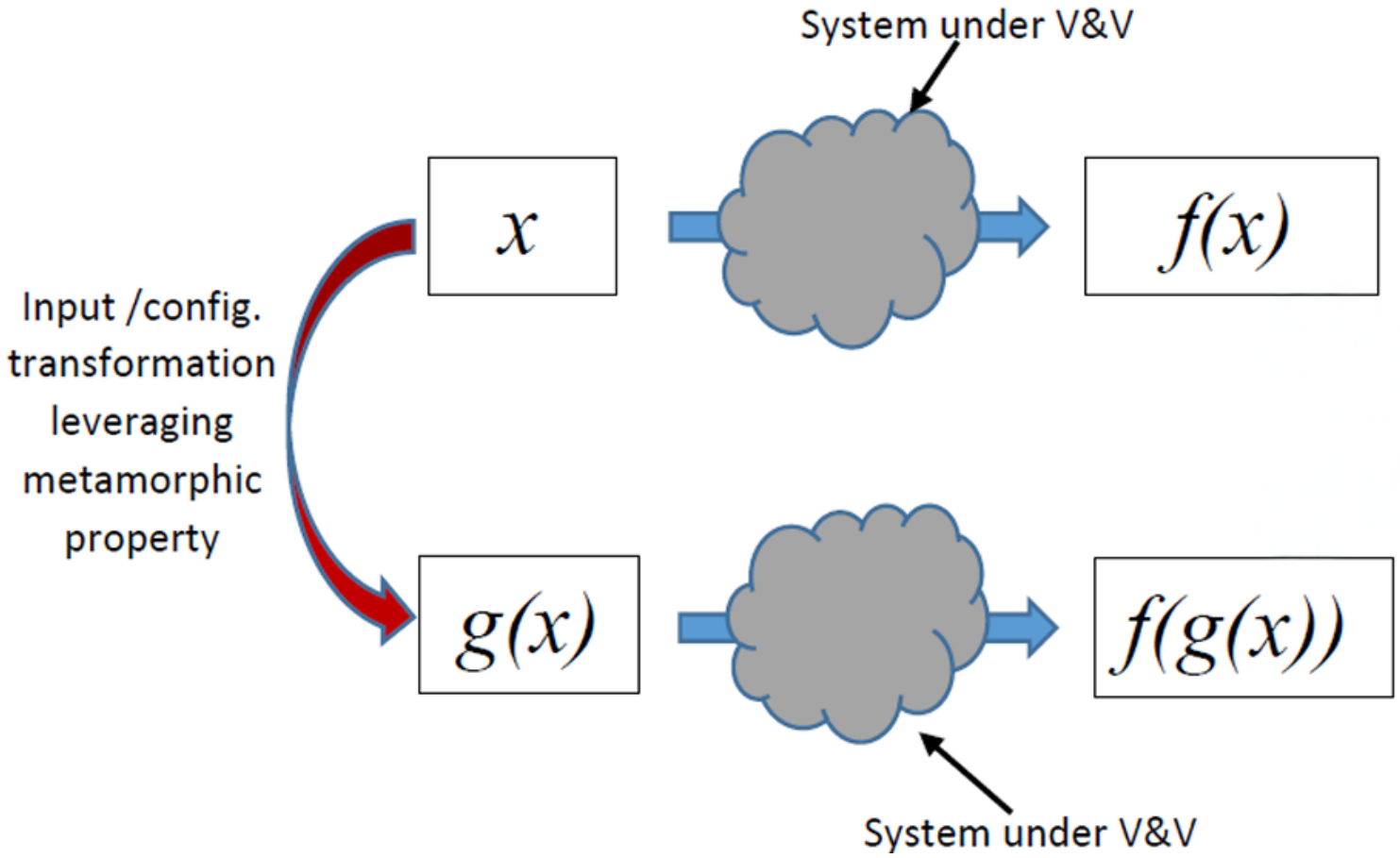

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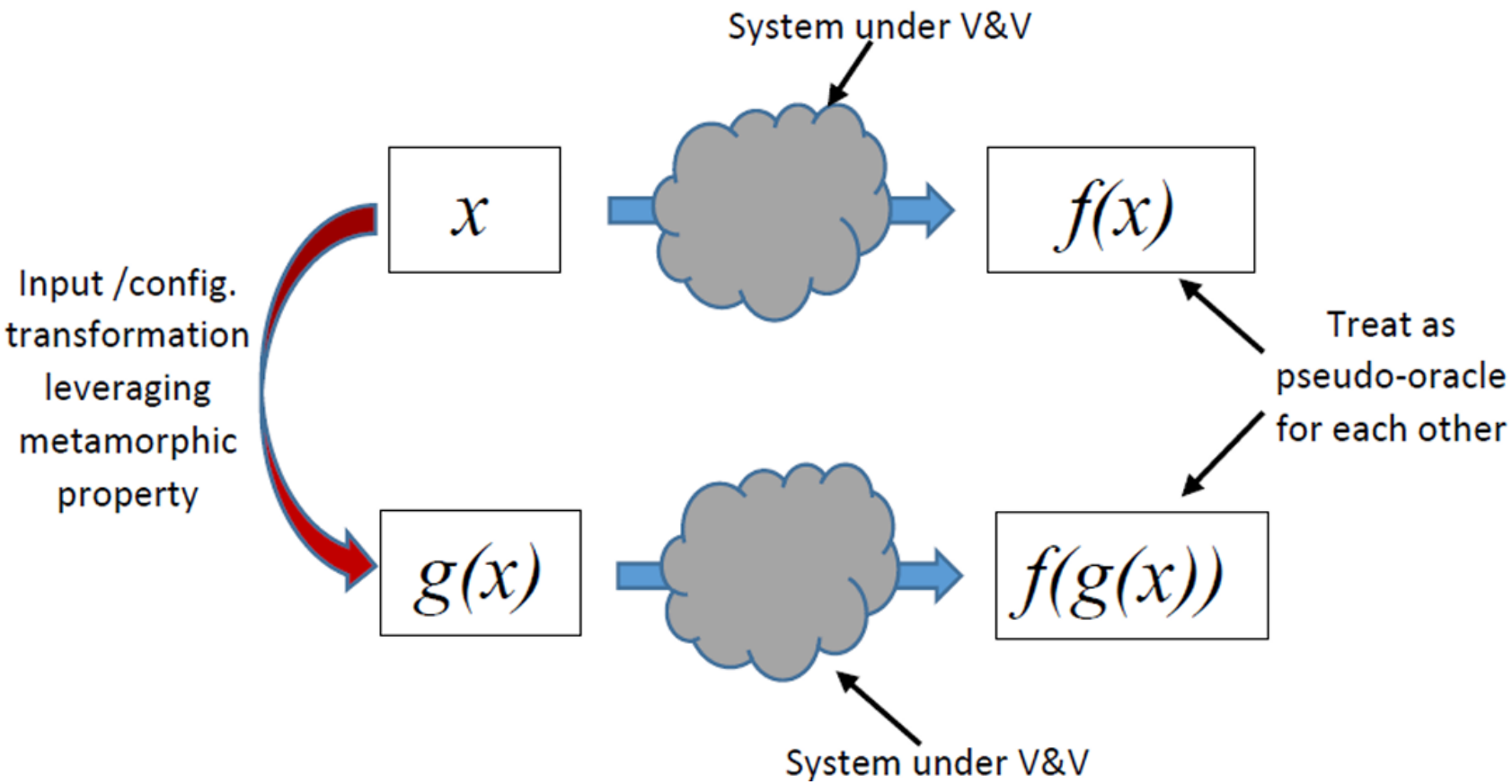

Theoretical Backbone

Connecting linguistic theory to software testing

Universal Grammar – In a Nutshell

Noam Chomsky:

- ✓ The human brain contains a limited ***set of rules*** for organizing language
- ✓ All languages have a ***common structural basis***
- ✓ This set of rules is known as ***Universal Grammar***

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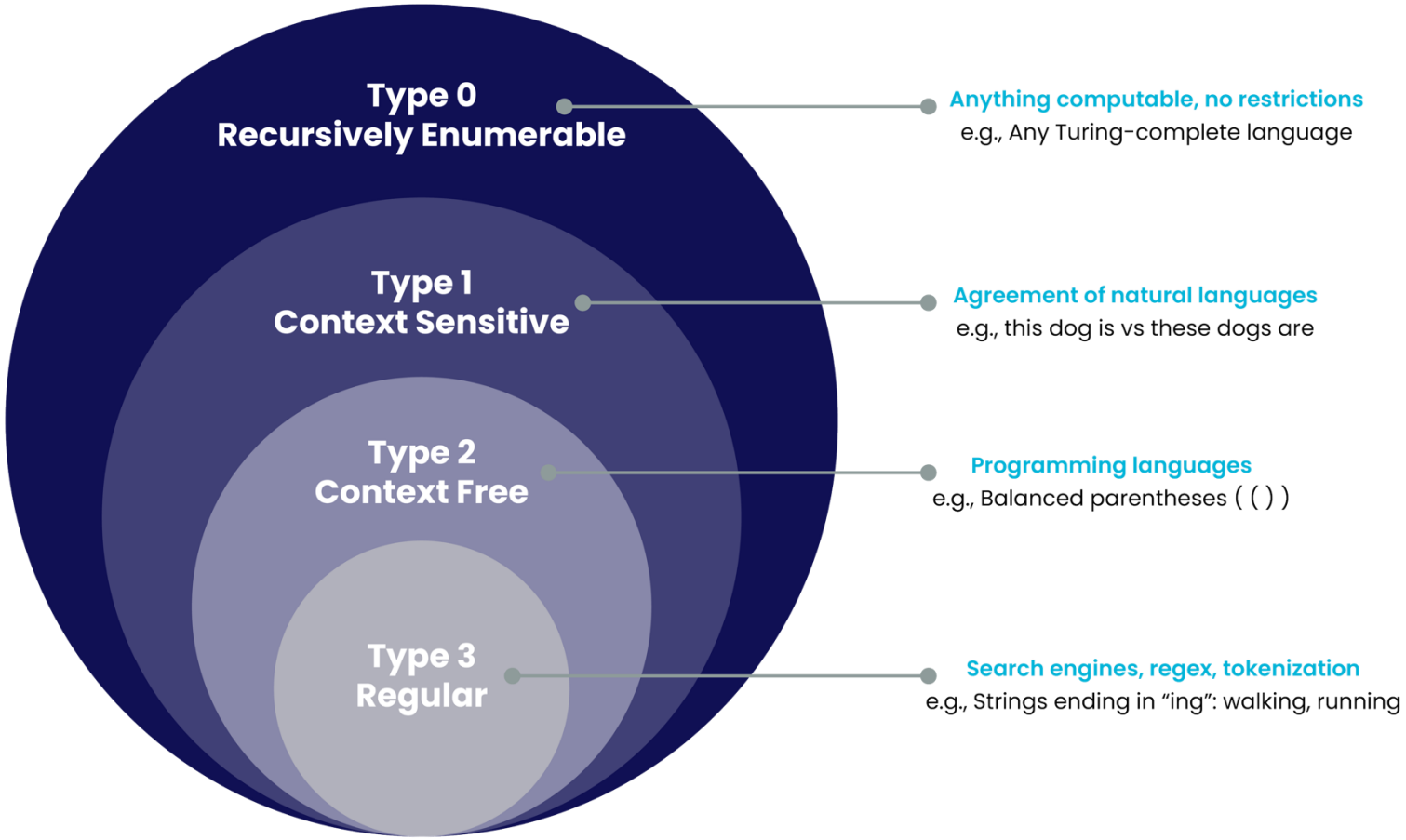

Universal Grammar – Why do we care?

LLMs don’t explicitly use grammars…

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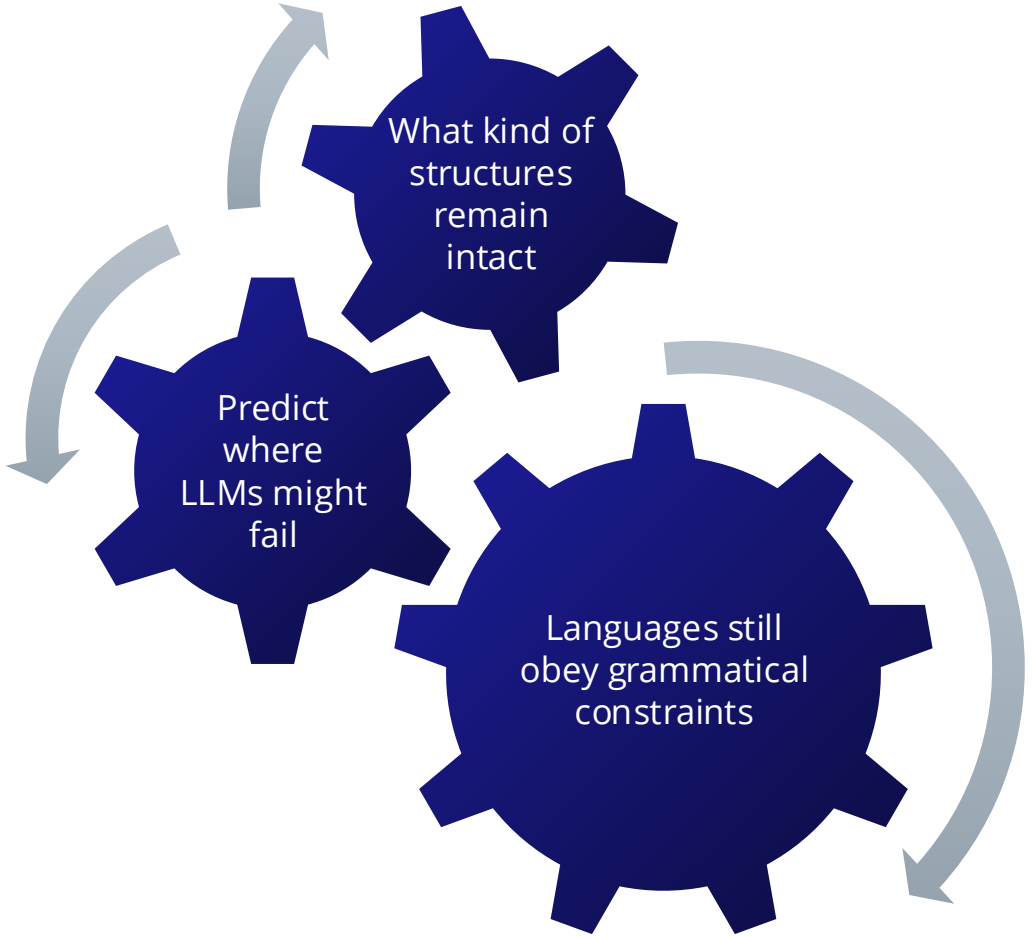

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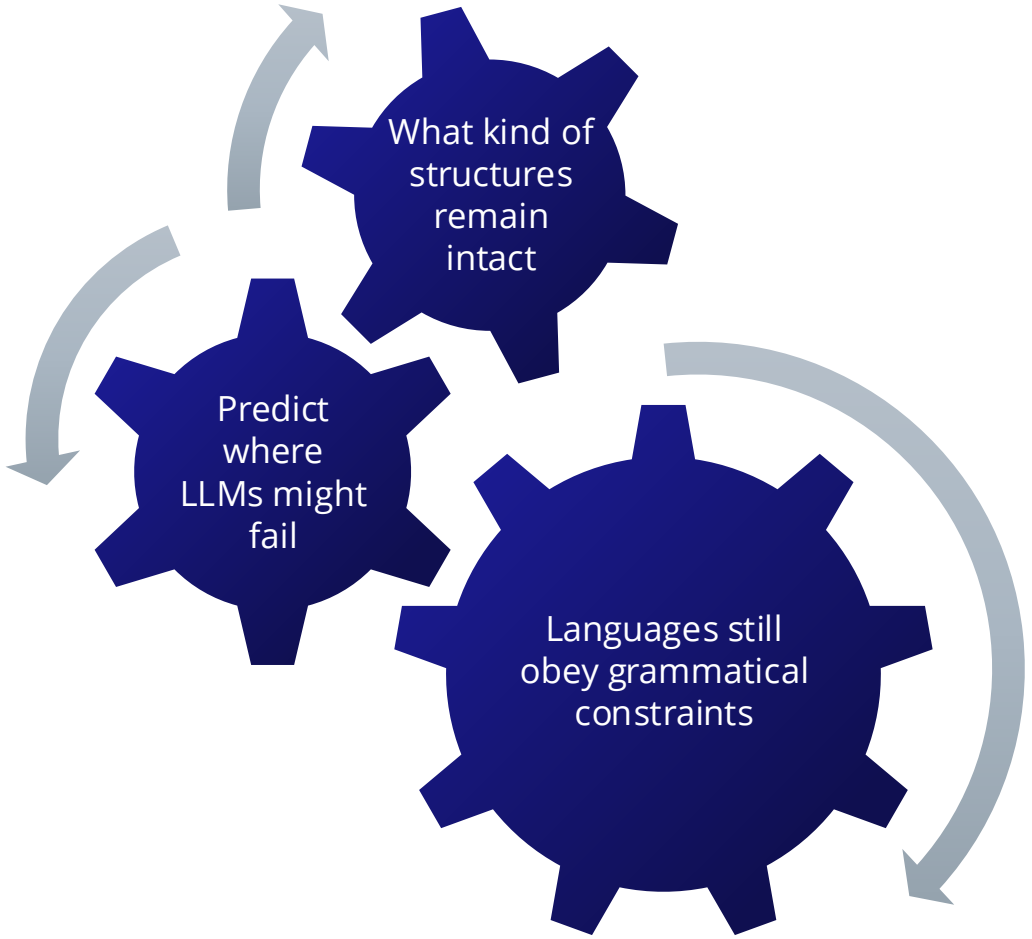

Using UG can help to highlight,

Language agnostic validation

semantic fidelity across translations.

Universal Grammar + Metamorphic Relations

MRs	Base	Transform	Expected	Check
1	She is happy	She is joyful	Ella está alegre → Ella está contenta	Reflect the synonym shift Not identical wording but equivalent meaning
2	He reads books	He reads books *in the evening*	Él lee libros por la tarde	Should include the temporal modifier
3	The tall man with a red hat walked slowly	The man ~~*with a red hat*~~ walked slowly	El hombre caminó despacio	Should reflect reduced structure without residual modifiers
4	Yesterday, she cooked dinner	She cooked dinner *yesterday*	Ayer, ella cocinó la cena	Should preserve meaning regardless of English word order
5	The boy runs	The boy*s* run~~*s*~~	El niño corre → Los niños corren	Should reflect correct gender and plural agreement

Universal Grammar + Mutations

Type	Mutation	Explanation
Lexical	Random Typos	Spelling errors at the word level
Lexical	Realistic Typos	Spelling errors mimicking human typing mistakes
Lexical	Shuffle Characters	Rearranging letters within a word
Lexical	Add Characters	Inserting extra letters into a word
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Semantic	Gender Swap	Alters meaning by changing gendered terms (e.g., “he” → “she”)
Semantic	Tense Shift	Changes temporal meaning (past *vs* present *vs* future)
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Syntactic	Word Shuffle	Rearranging word order affects sentence structure
Syntactic	Passive to Active	Voice transformation changes sentence structure
Syntactic	Cleft sentence	Restructuring into cleft form ("It is X that …")
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Surface form

Meaning change

Structure change

Results

Mutations Metrics

Metric	What it measures	In Chomskean mutation testing
Embedding Similarity $Sim_{cos}(x, y) = \frac{e_x \times e_y}{\|\|e_x\|\| \, \|\|e_y\|\|}$	Semantic closeness between original and mutated text	• Detects meaning drift when syntactic mutations are applied • Shows whether deep structure is preserved

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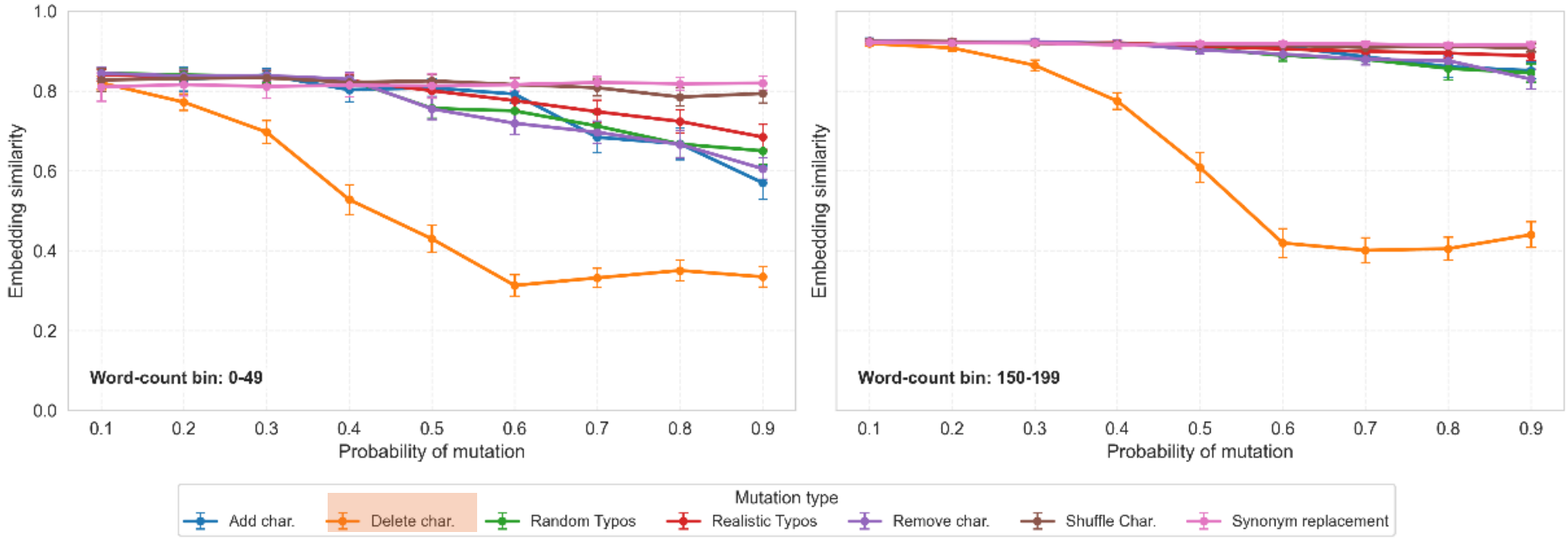
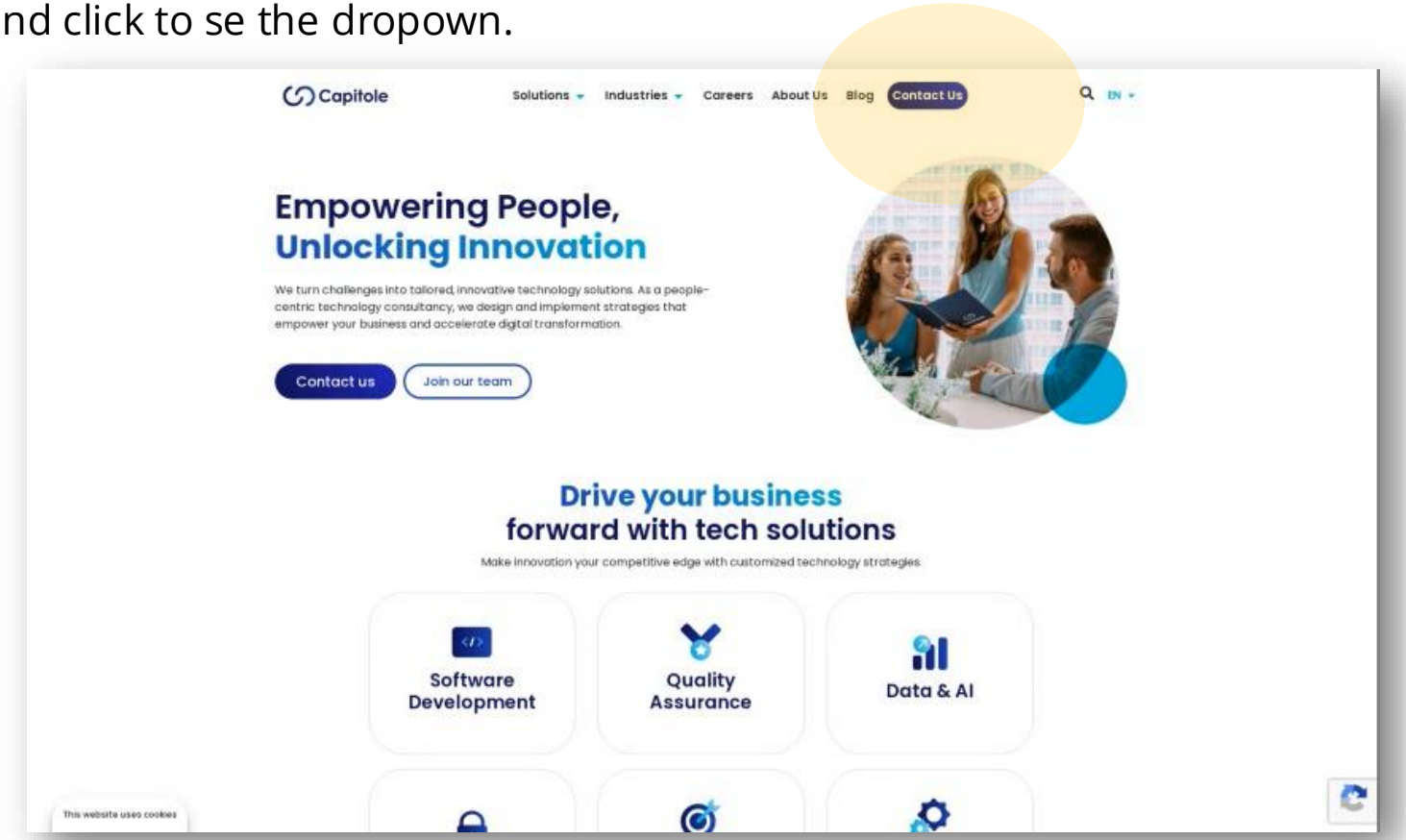


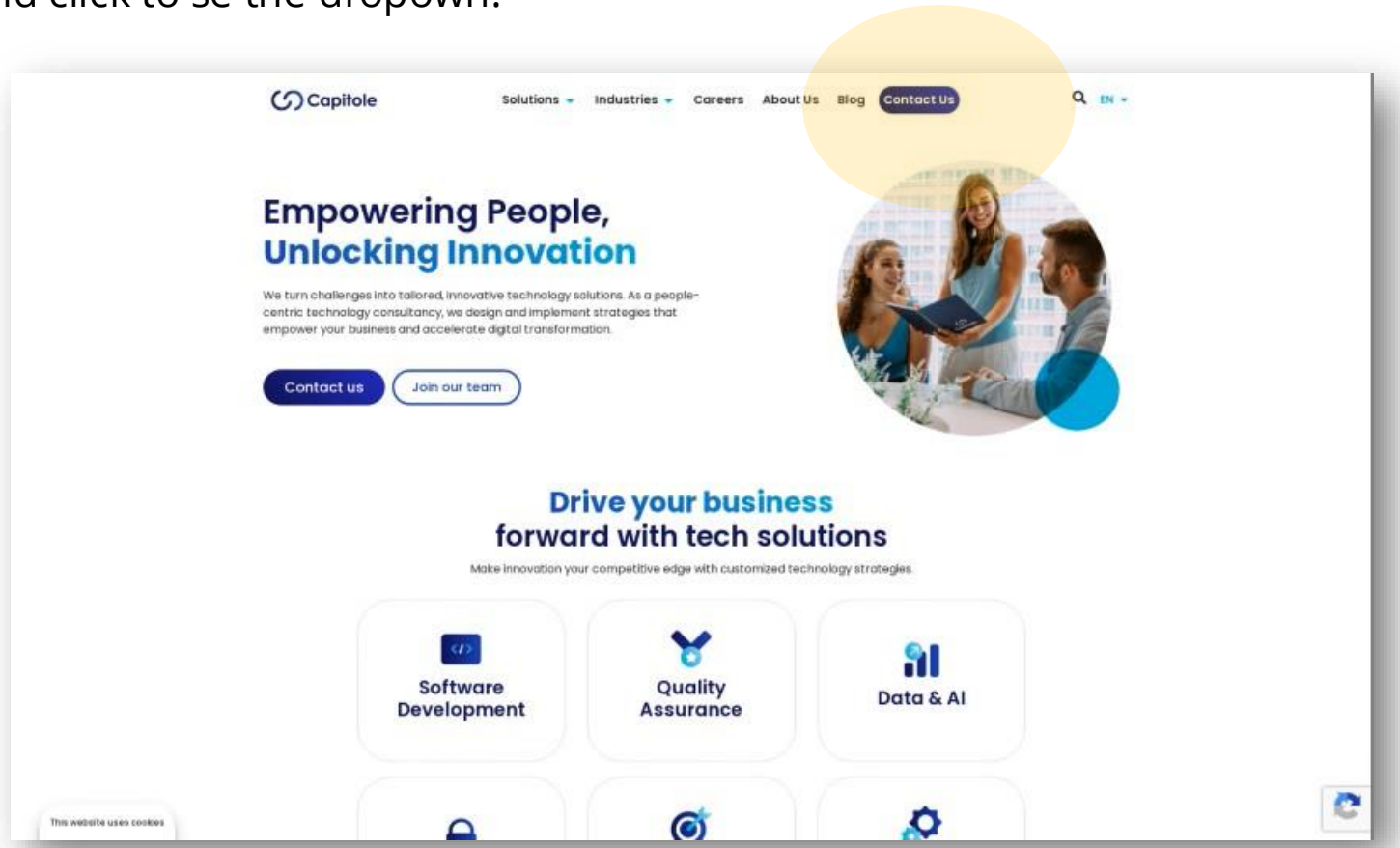
Example 1: No Mutation

Navigte to https://www.capitole-consulting.com/. Highlght the "Contct us" buton and click to se the dropown.



Example 2: 10% delete character

Navigte to https://www.capitole-consulting.com/. Highlght the "Contct us" buton and click to se the dropown.



Example 2: 70% delete character

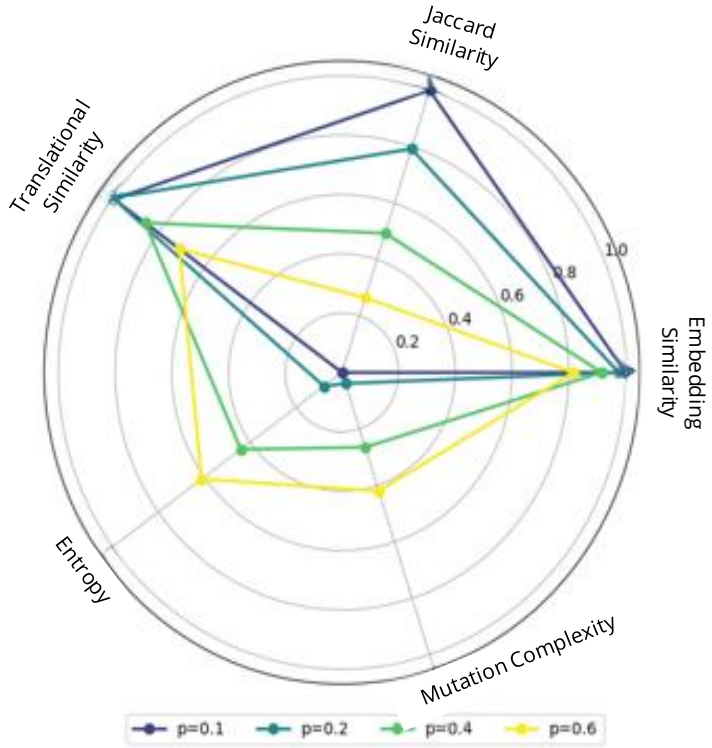
Go https://www.capitole-consulting.com/. hig t "cont us" bt cl t se drp.

Mutations Metrics

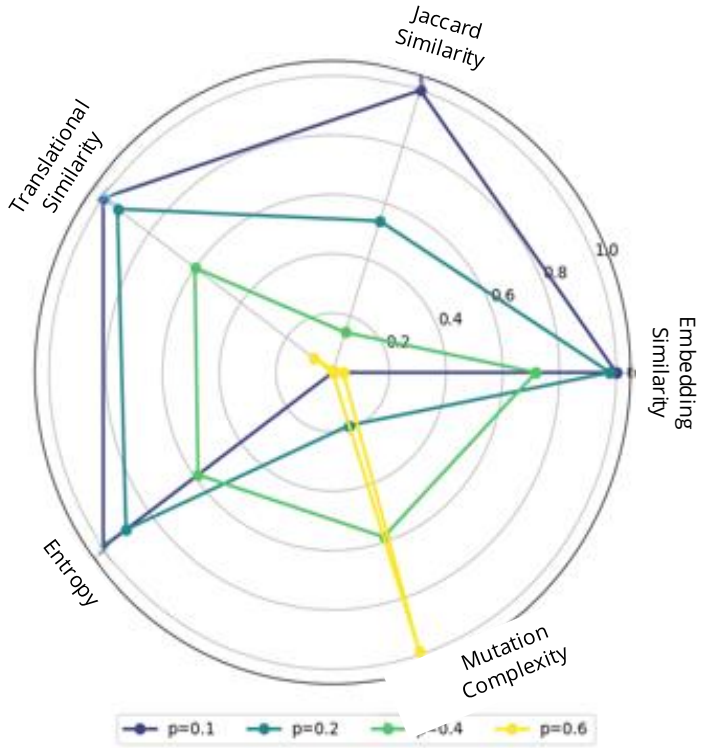
Metric	What it measures	In Chomskean mutation testing
Embedding Similarity $Sim_{cos}(x,y) = \frac{e_x \times e_y}{\|\|e_x\|\| \, \|\|e_y\|\|}$	Semantic closeness between original and mutated text	• Detects meaning drift when syntactic mutations are applied • Shows whether deep structure is preserved
Jaccard Similarity $J(A,B) = \frac{\|A \cap B\|}{\|A \cup B\|}$	Surface-level token overlap between two texts	• Distinguishes lexical vs. structural robustness • Shows whether the model paraphrases or copies
Translation Similarity	Semantic similarity between translations of original vs. mutated text	• Shows whether the model captures intended contrasts or ignores structural cues
Entropy $\mathrm{H} = -\sum_t p(t) \, log \, p(t)$	Unpredictability or dispersion of the model's output distribution	• Identifies mutation types that increase uncertainty or introduce ambiguity
Mutation complexity $C_{mut} = \frac{EditDistance(x,x')}{max(\|x\|, \|x'\|)}$	How disruptive a transformation is relative to the original input	• Enables correlation between linguistic complexity and translation degradation • Maps competence across syntactic phenomena

Add/Delete characters- comparison

Add Character



Delete Character



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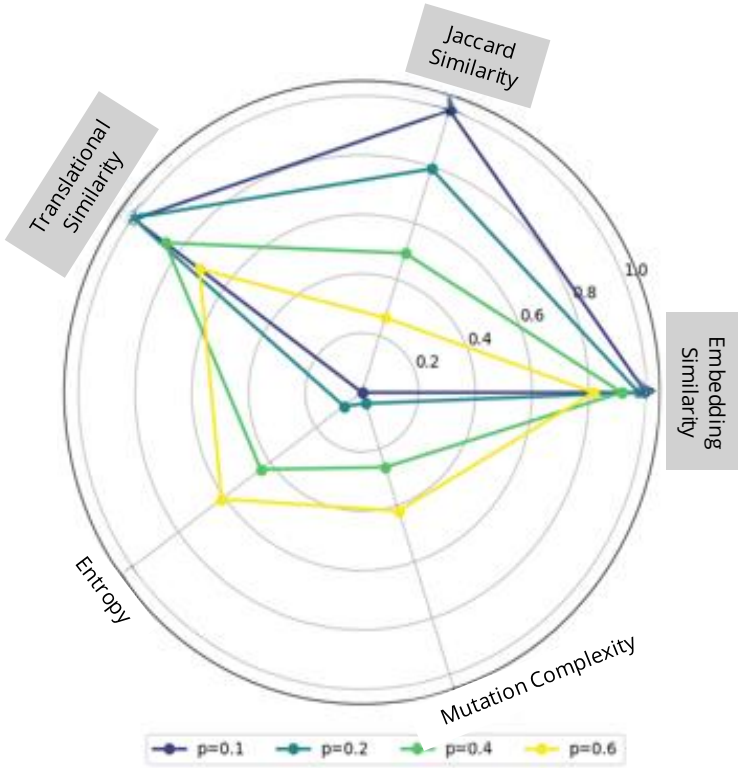
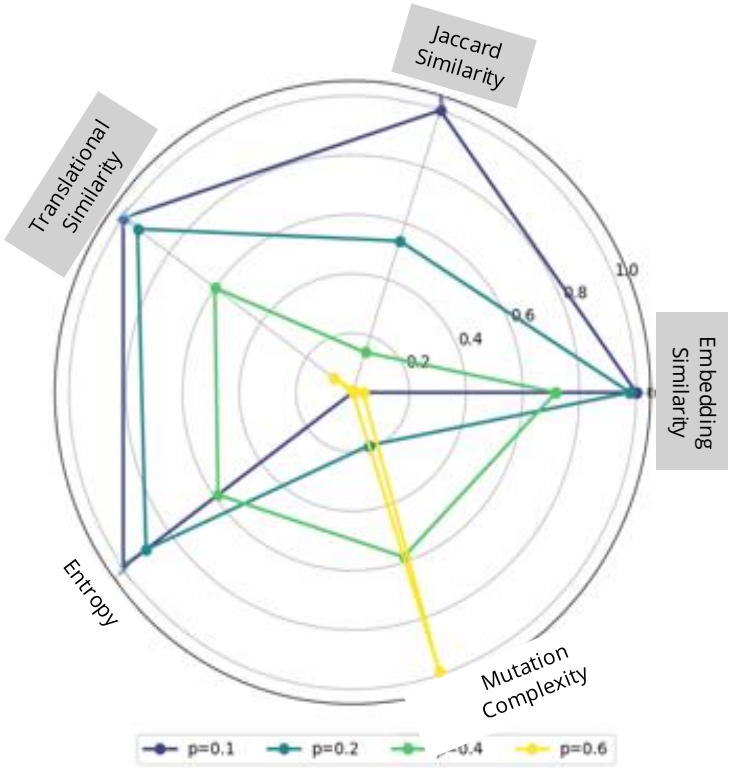


Delete Character



Mutation Probability

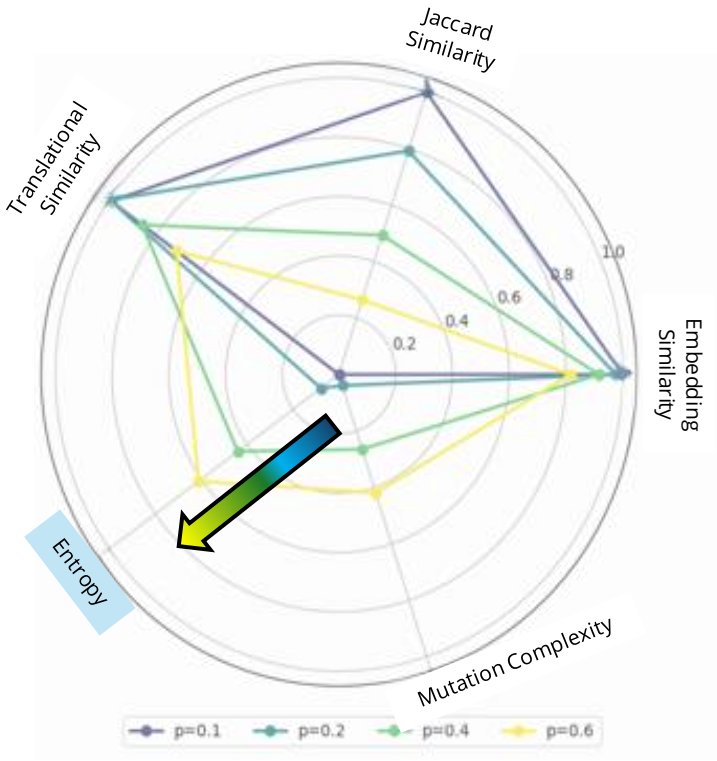
Similarity metrics

Higher Similarity metrics:

- Stronger semantic preservation
- More shared vocabulary
- Cross-lingual invariance

Add/Delete characters- comparison

Add Character



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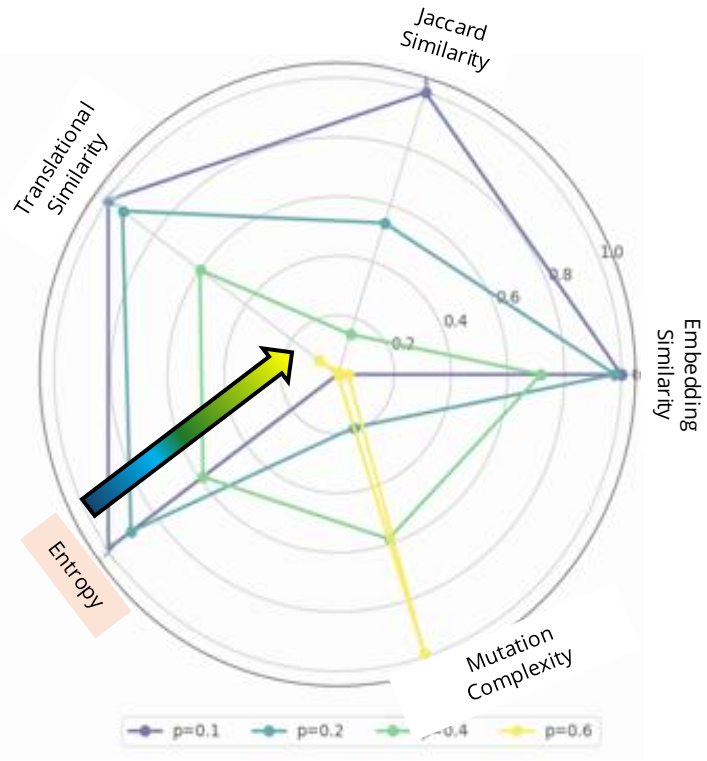

Entropy: *unpredictability of the output*

Higher value → more diverse responses

Lower value → deterministic behaviour

Increases for Add Char

Decreases for Delete Char

Add/Delete characters- comparison

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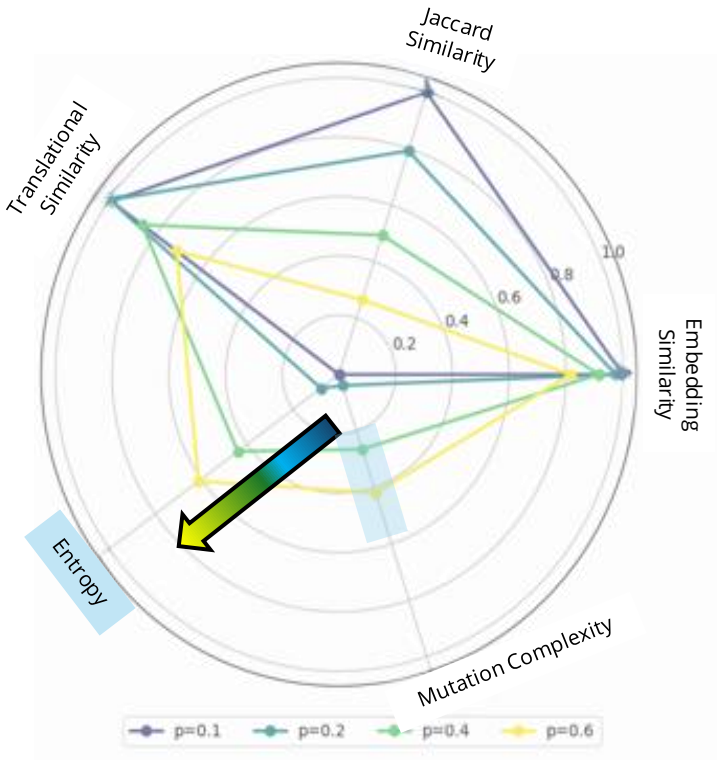
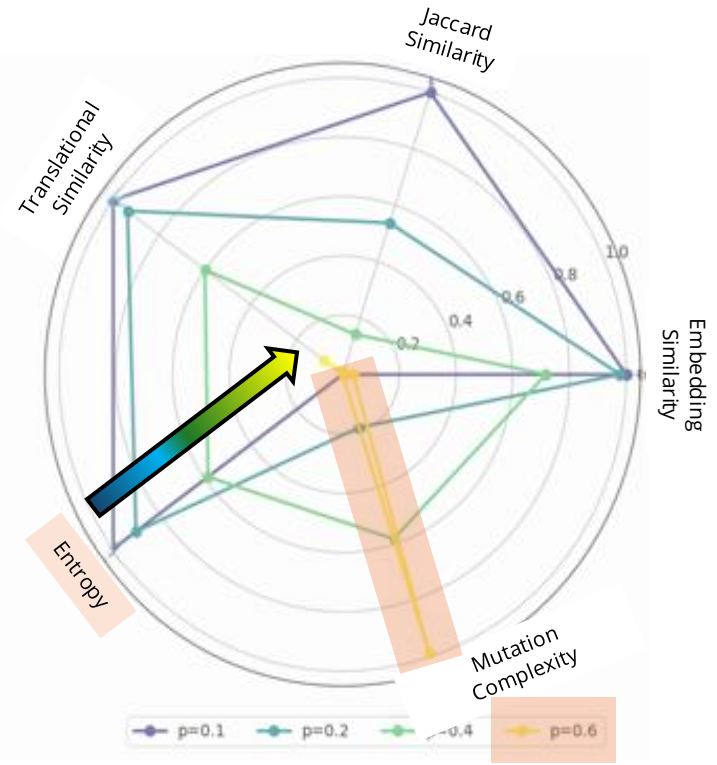


Delete Character



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Mutation Complexity:

Disruption relative to original

Higher values → more perturbations

Max for Delete Char at 60% mutation

Deterministic

Translation unreliable!

Conclusion

1. **Semantic stability of LLMs,**
   - ✓ Under wide range of perturbations
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3. **Assessing LLM resilience with,**
   - ✓ Chomsky's Universal Grammar → deep structural invariants for mutation sets
   - ✓ Metamorphic testing → systematic manipulation of input text to check consistency

Demo of **QALITY**

With this theoretical background,
now Victor will talk about our agent **QALITY**.

Why does this matter for QAs

1. **Understanding your LLM helps you improve your prompts**
   - *Example:* Biases affects LLM the same way the output like POs poor requirements can end up with a solution that it's not what he wanted.
   - When is it not reliable. Breaking point.
   - Understanding that automatic translations can result in different branches of the user journey

2. **There's a whole new range of parameters to take into consideration when Automatizing QA tasks with LLM**

Contact us for further questions

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