

JOURNÉE
FRANÇAISE DE
L'INGÉNIERIE DES
EXIGENCES

5 | 6 | 7

NOVEMBRE 2024

11H30 - 13H30



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L'IA, nouvel assistant de l'ingénieur des exigences ?
Retours d'expérience au travers de cas d'usages

Introduction

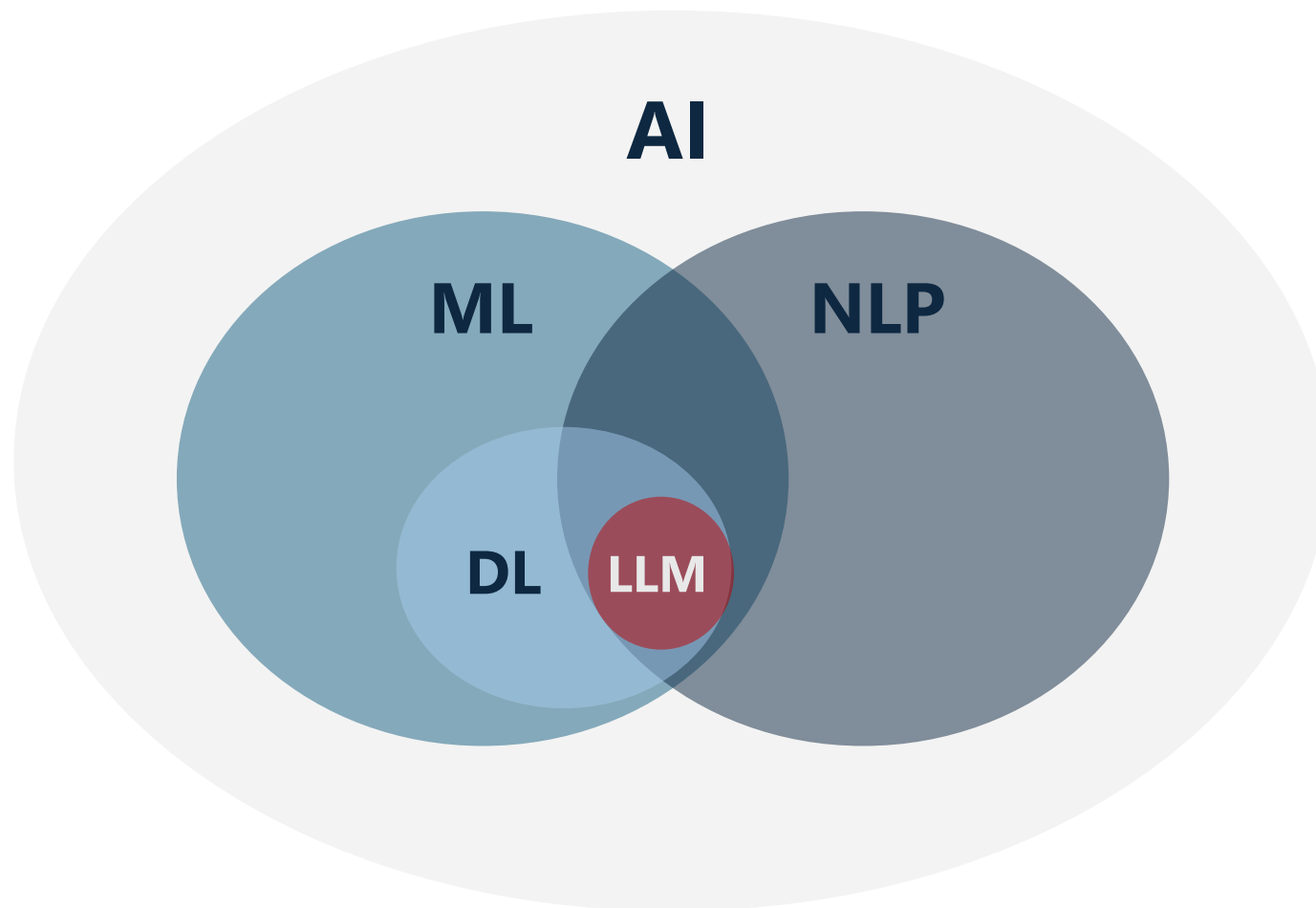
Comment l'IA peut aider l'ingénierie des exigences ?



L'intelligence artificielle (IA) peut jouer un rôle crucial dans l'ingénierie des exigences (ou **requirements engineering**) à travers plusieurs approches et outils. Voici comment l'IA peut être intégrée dans ce domaine :

1. Analyse et extraction automatique des exigences
2. Clarification et reformulation des exigences
3. Détection des incohérences et conflits
4. Validation et vérification automatique
5. **Prioritisation** des exigences
6. Gestion et traçabilité des exigences
7. Prédiction des risques et des impacts
8. Assistance à la collaboration
9. Utilisation de l'IA pour l'auto-apprentissage
10. Génération d'exigences à partir des spécifications fonctionnelles

En résumé, l'IA dans l'ingénierie des exigences aide à **automatiser**, **standardiser**, **prioriser**, et **valider** les exigences, tout en réduisant les erreurs humaines et en optimisant la collaboration entre les parties prenantes. Les systèmes d'IA peuvent transformer le processus en le rendant plus efficace, rapide et précis.



Objectif : Extraction d'exigences

Entrée : référentiel d'exigences

IHE Radiology Technical Framework Supplement – Web-based Image Access (WIA)

750 This example uses an Accept header to request the DICOM SOP Instance returned in the native DICOM PS3.10 file format.

4.107.4.1.3 Expected Actions

The Responder shall parse the request and return a response as described in Section 4.107.4.2.

4.107.4.1.3.1 XDS-I Backend Option

755 The Responder shall use the grouped XDS-I Imaging Document Consumer to retrieve the requested imaging objects.

4.107.4.2 Get Instances Response Message

The Responder reports the outcome of the Get Instances Request Message.

4.107.4.2.1 Trigger Events

The Responder completes processing of the Get Instances Request Message.

4.107.4.2.2 Message Semantics

760 The message shall be a DICOM WADO-RS response. The Requester is the User Agent, and the Responder is the Origin Server.

It is implemented as an HTTP response. It shall include a multipart/related media type with each part containing a DICOM instance, as requested.

765 The Responder shall provide a response as described in DICOM PS3.18 Sections 6.5.1.2, 6.5.2.2, 6.5.3.2, 6.5.4.2 including the appropriate status code indicating success, warning, or failure as described in DICOM PS3.18 Section 6.5.7.

4.107.4.2.3 Expected Actions

The Requester shall accept the response.

770 The Requester shall follow redirects (responses with values of 301, 302, 303 or 307. See <https://tools.ietf.org/html/rfc7231#section-6.4> for details) unless a loop or security policy violation is detected.

4.107.4.3 Get Metadata Request Message

The Requester retrieves metadata regarding one or more DICOM instances from the Responder.

775 The Requester shall support making requests to more than one Responder. The Responder shall support handling such messages from more than one Requester.

4.107.4.3.1 Trigger Events

The Requester wishes to retrieve metadata regarding DICOM instances.

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IHE

IHE Radiology

Technical Framework Supplement

Web-based Image Access
(WIA)

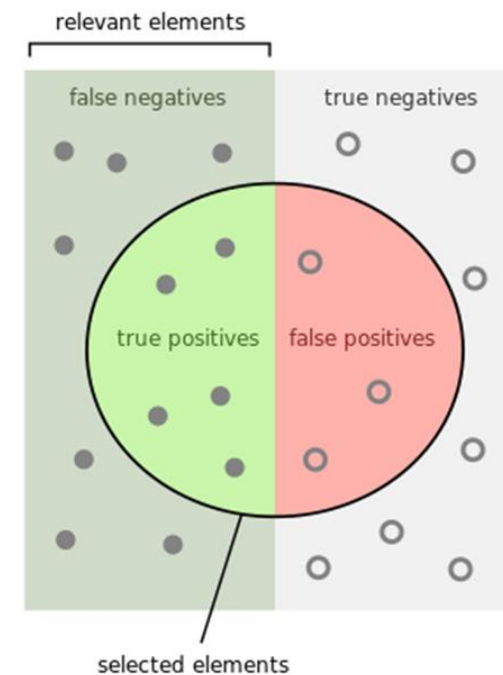
Sortie : liste d'exigences

Id scheme	Assertion id	Status	Testable?	#Coverage	#Applies to	Commentaire	Predicate	Page	Tags
RAD107	RAD107-001	to be reviewed	Testable	0	1	Simulator	Get Instances Request Message : The Requester shall support making requests to more than one Responder.	30	Section 4.107.4.1
RAD107	RAD107-002	to be reviewed	Testable	0	1	Simulator	Get Instances Request Message : The Responder shall support handling messages from more than one Requester.	30	Section 4.107.4.1
RAD107	RAD107-003	to be reviewed	Testable	0	1	Conformance checker	Get Instances Request Message : The message shall correspond to one of the Instance Resources in Table 4.107.4.1.2-1.	30	Section 4.107.4.1.2
RAD107	RAD107-004	to be reviewed	Testable	0	2	Conformance checker	Get Instances Request Message : The only binding required for both the Requester and Responder is HTTP-GET.	30	Section 4.107.4.1.2
RAD107	RAD107-005	to be reviewed	Testable	0	1	Conformance checker	Get Instances Request Message : The request shall include the header parameters defined in Table 4.107.4.1.2-3 to indicate the media type of the response. All header names and values are case-sensitive.	31	Section 4.107.4.1.2
RAD107	RAD107-006	to be reviewed	Testable	0	1	Simulator	Get Instances Request Message : The Responder shall parse the request, prepare representation(s) of the Instance Resource in the Selected Media Type (see DICOM PS3.18 Section 10.4.2), and return a response as described in Section 4.107.4.2.	32	Section 4.107.4.1.3

Classification binaire : évaluation

- Classe positive : exigence
- Classe négative : non exigence

		Ground truth		
		+	-	
Predicted	+	True positive (TP)	False positive (FP)	Precision = $TP / (TP + FP)$
	-	False negative (FN)	True negative (TN)	Recall = $TP / (TP + FN)$
				Accuracy = $(TP + TN) / (TP + FP + TN + FN)$



How many selected items are relevant?

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

How many relevant items are selected?

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

Méthode 1 : Extraction directe par LLM



Extraction du texte

- Extraction par page
- Utilisation d'un module Python (pymupdf)

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Extraction des exigences par LLM

Modèles et prompts

- Modèles utilisés (API)
 - gpt-4o et llama 3.1 8B
- Prompt: Instructions + texte d'une page
 - Format de sortie (à adapter au modèle)
 - Ajout d'un rôle possible

I will give you a text as input.

I want to extract the exact sentences from the text that are requirements.

A requirement must correspond to a single sentence and it is possible that you don't find any requirement.

Extract the requirement only if you are sure.

Extraction des exigences par LLM

Exemple

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Extraction des exigences par LLM

Résultats

		Ground truth			gpt-4o	llama 3.1 8B	Ground truth		
		+	-				+	-	
Predicted	+	44	23	Precision	0.65	0.54	+	40	34
	-	27	X	Recall	0.67	0.56	-	31	X
				f1 score	0.66	0.55			

2 sources d'erreurs possibles :

- Mauvais découpage
- Mauvaise classification

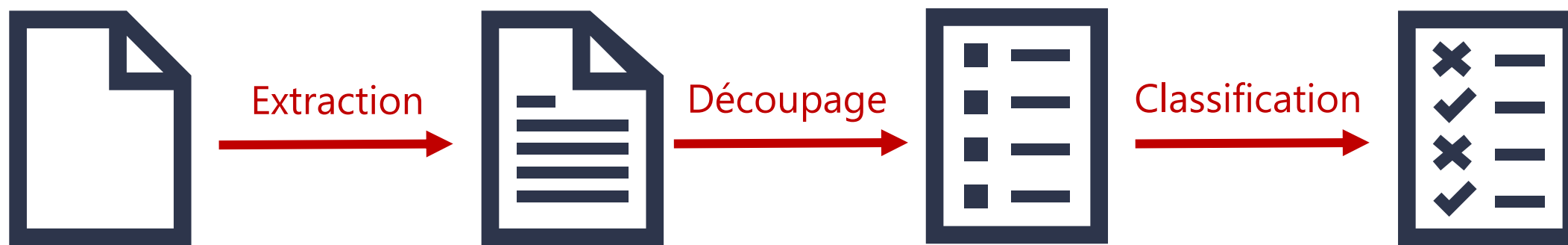
Extraction des exigences par LLM

Prompt engineering

- Prompt
 - Pas de rôle (NO)
 - « You are a professional software tester. » (ST)
 - « You are an expert in requirements engineering. » (RE)

	gpt-4o			llama 3.1 8B		
	NO	ST	RE	NO	ST	RE
Precision	0.65	0.64	0.66	0.54	0.58	0.63
Recall	0.67	0.64	0.62	0.56	0.66	0.62
f1 score	0.66	0.64	0.64	0.55	0.62	0.62

Méthode 2 : Extraction par étapes



Découpage en phrases

Méthodes

- Méthodes
 - NLP : Spacy (en_core_web_md) et NLTK
 - LLM : gpt-4o et llama 3.1 8B
 - API
 - Prompt : instructions + texte d'une page
 - Format de sortie (à adapter au modèle)

I will give you a text as input.
I want to split this text into sentences, considering titles as a sentence.

Découpage en phrases

Exemple

4.107.4.1.3 Expected Actions
The Responder shall parse the request and return a response as described in Section 4.107.4.2.

4.107.4.1.3.1 XDS-I Backend Option
The Responder shall use the grouped XDS-I Imaging Document Consumer to retrieve the requested imaging objects.

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The Responder completes processing of the Get Instances Request Message.



NLP : SpaCy	LLM : gpt-4o
750 4.107.4.1.3	4.107.4.1.3 Expected Actions
Expected Actions/ The Responder shall parse the request and return a response as described in Section 4.107.4.2./	The Responder shall parse the request and return a response as described in Section 4.107.4.2.
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4.107.4.2.1 Trigger Events/ The Responder completes processing of the Get Instances Request Message.	4.107.4.2.1 Trigger Events The Responder completes processing of the Get Instances Request Message.

Découpage en phrases

Résultats

	NLP : SpaCy	NLP : NLTK	LLM : gpt-4o	LLM : llama 3.1 8B
Nombre total de phrases extraites	313	240	541	708
Nombre d'exigences bien découpées (/71)	40	33	71	47



Découpage utilisé
dans la suite

Classification

Méthodes

- 4 méthodes
 - Naïve : règle (shall, may)
 - BERT : modèle de classification entraîné sur le jeu de données PURE (PUBlic REquirements dataset)
 - BERT "amélioré" : modèle de classification entraîné sur un jeu de données interne
 - LLM : gpt-4o et llama 8B 3,1
 - Prompt : instructions + phrase

I will give you a sentence as input.
I want to determine whether this sentence is a requirement.
If the sentence is a requirement, answer yes; if not, answer no.

Classification

Résultats

Méthode Métrique	Méthode 1 : gpt-4o	Naïve	BERT	BERT amélioré	LLM : gpt- 4o	LLM : llama 3.1 8B
Accuracy	X	0,88	0,88	0,92	0,91	0,50
Precision	0.65	0,61	0,58	0,75	0,71	0,19
Recall	0.67	0,73	0,79	0,73	0,75	0,90
F1-score	0.66	0,67	0,67	0,74	0,73	0,32

Faux négatifs : principalement phrases contenant le verbe « be »

Limites et pistes d'amélioration

- Sensibilité de l'utilisation des LLMs
 - Beaucoup de paramètres
 - Prompt engineering
 - Modèle open source vs closed source
 - Importance de l'évaluation
- Pistes d'amélioration
 - Récupération des sections
 - Traitement des images, tableaux, listes
 - Prise en compte d'autres format de documents
 - Amélioration de l'extraction du texte

Pour aller plus loin

Reformulation selon un pattern

I want to rephrase the following requirement in the following format

Format : "Condition", the "actor" shall "action" so that "objective"

where :

Condition: initial state / context

Actor: system / component

Action (condition / capability): intent of the actor

Objective (satisfy contract, standard, specification): new state / result of the action

Requirement : The Requester shall support making requests to more than one Responder.

→ gpt-40 : "When making a request, the Requester shall support making requests to more than one Responder so that multiple Responders can process the request concurrently."

Pour aller plus loin

Vérification du respect de critères

Does the following requirement meet the INVEST criteria?

Requirement : The Requester shall support making requests to more than one Responder.

→ gpt-4o :

Independent: The requirement seems broad and might depend on other functionalities, such as defining how the "Requester" interacts with multiple responders or other architectural factors. Therefore, it may not be fully independent without clarification.

Negotiable: The wording seems somewhat rigid ("shall support"), suggesting it may not be easily negotiable. More conversation with stakeholders might be needed to flesh out the details.

Valuable: Supporting requests to multiple responders can indeed provide value, likely improving scalability, flexibility, or fault tolerance. So it appears to deliver clear value.

Estimable: As written, it's vague, making it hard to estimate. More details would be required on how the system should function with multiple responders (e.g., parallel requests, load balancing, etc.).

Small: The requirement, as it stands, feels overly broad and may represent a larger, more complex piece of work. Breaking it down into smaller user stories or tasks would make it easier to plan and execute.

Testable: As written, it lacks enough detail to ascertain whether it's testable. What does "supporting" multiple responders mean in terms of interactions, error handling, and performance considerations? More specifics are needed to determine how the functionality would be tested.

Conclusion

- IA = assistant en fonction
 - Du cas d'usage
 - Des tâches
 - Du besoin
 - Des contraintes
 - ...
- Application de l'extraction d'exigences à d'autres cas d'usage
- Suite : génération de cas de tests à partir des exigences



Image générée par IA (DALL·E)