



Intelligence Artificielle et Formation en Santé

Pierre JANNIN
LTSI, INSERM, Université de Rennes
<http://medicis.univ-rennes1.fr>



1

Intelligence

La capacité d'une personne ou d'un être d'acquérir et
d'appliquer des **connaissances**

+

Intelligence **collective**
Intelligence **émotionnelle**

2

Intelligence Artificielle

La théorie et le développement de systèmes informatiques capables d'effectuer des tâches qui requièrent normalement l'intelligence humaine, telles que la **perception visuelle**, la **reconnaissance vocale**, la **prise de décision** et la **traduction entre les langues**.

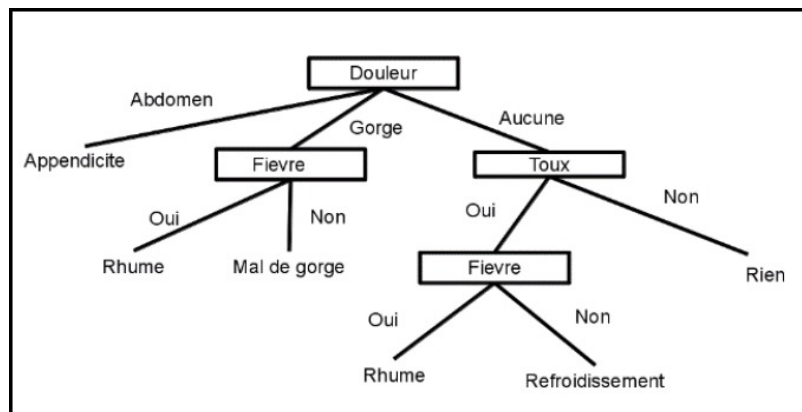
3

Intelligence Artificielle

Basée modèle
Basée données

4

Intelligence Artificielle basée modèle



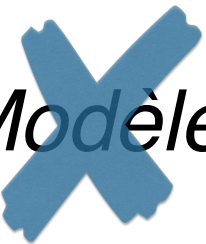
5

Intelligence Artificielle basée données

Apprentissage automatique
Apprentissage profond

6

Modèle



7

*Apprendre à
partir de
données*

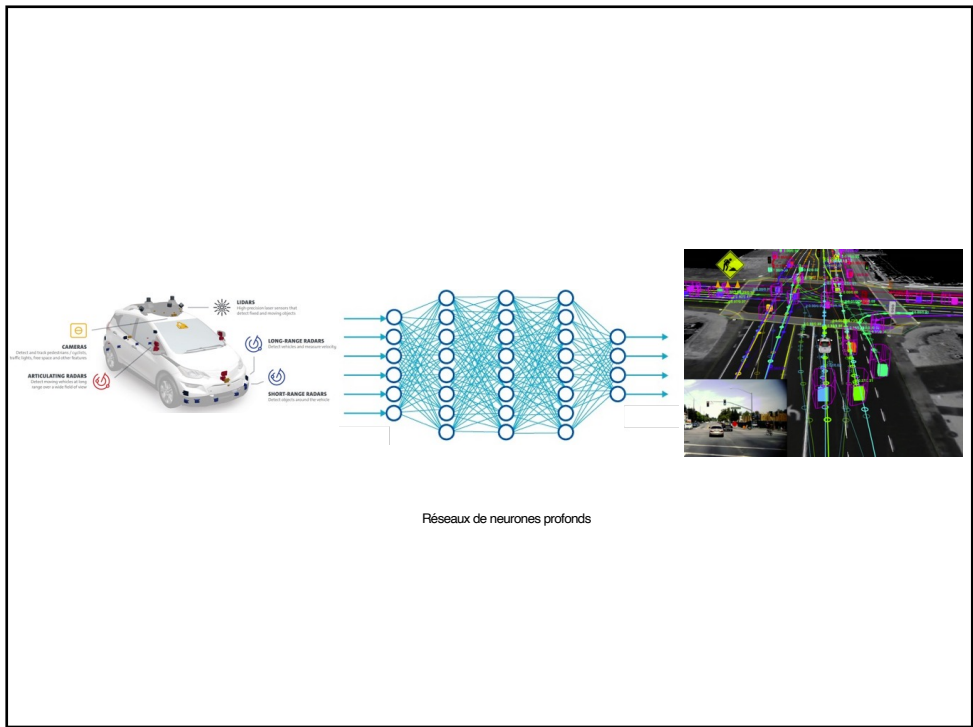
8

*Quand ça marche et
Quand ça ne marche pas*

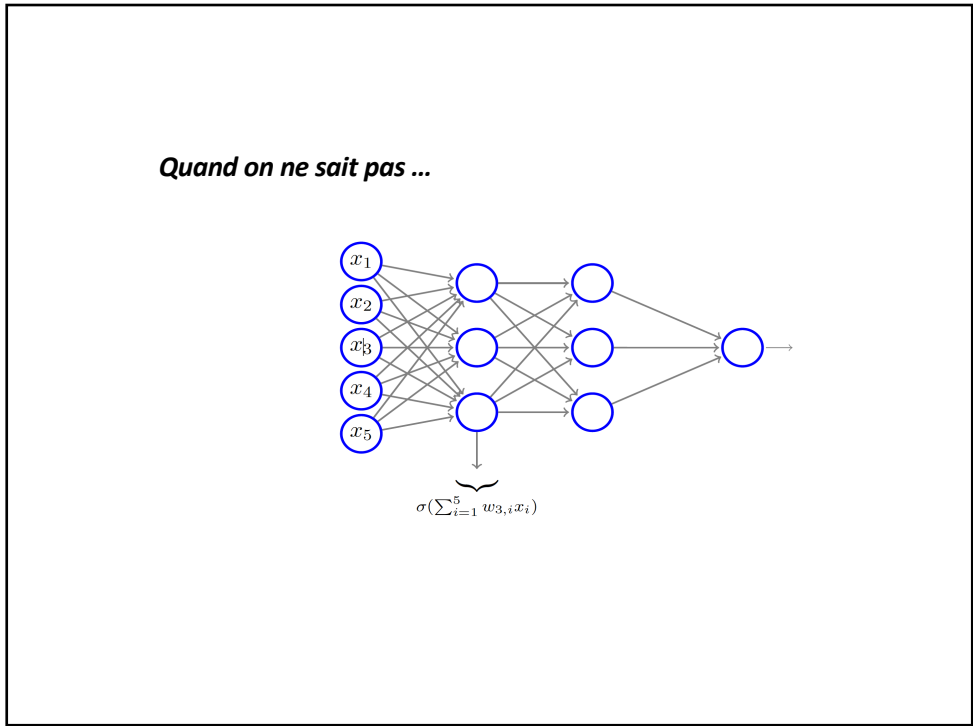
9



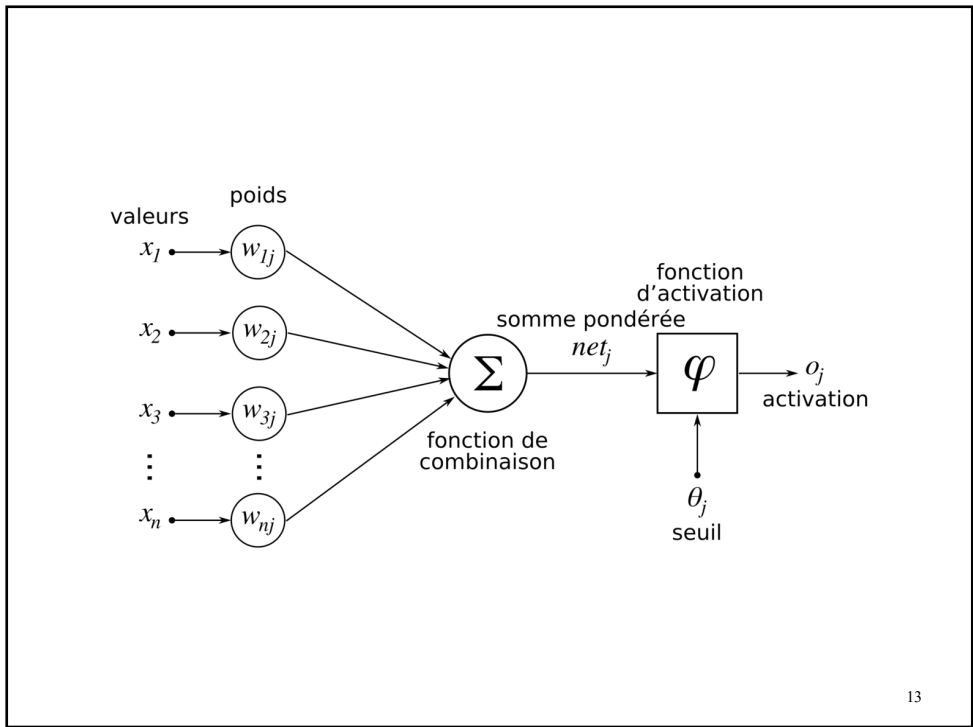
10



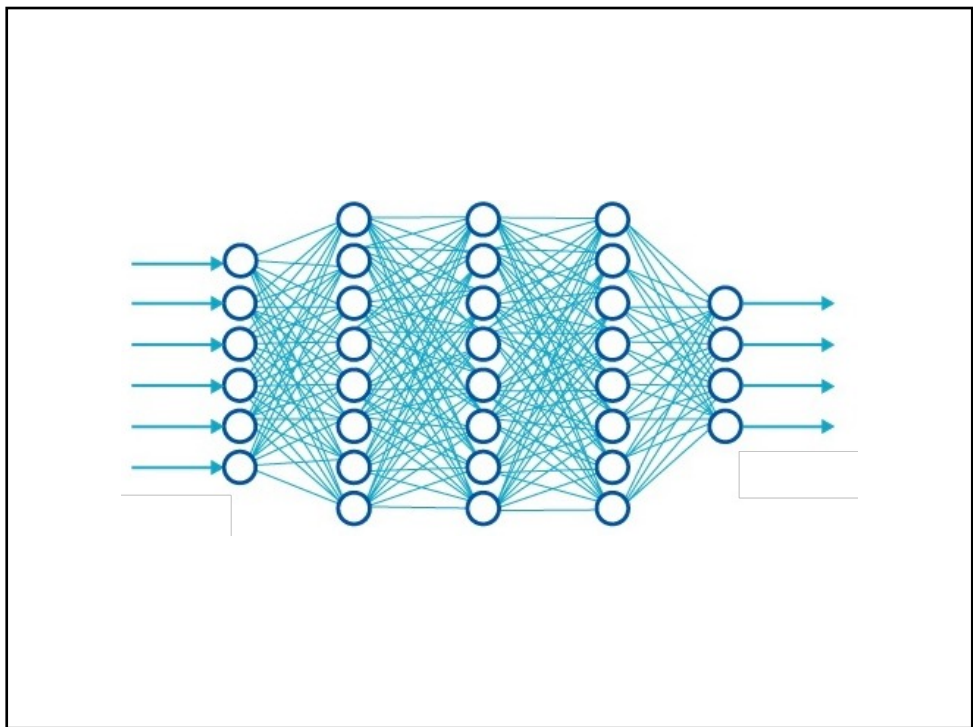
11



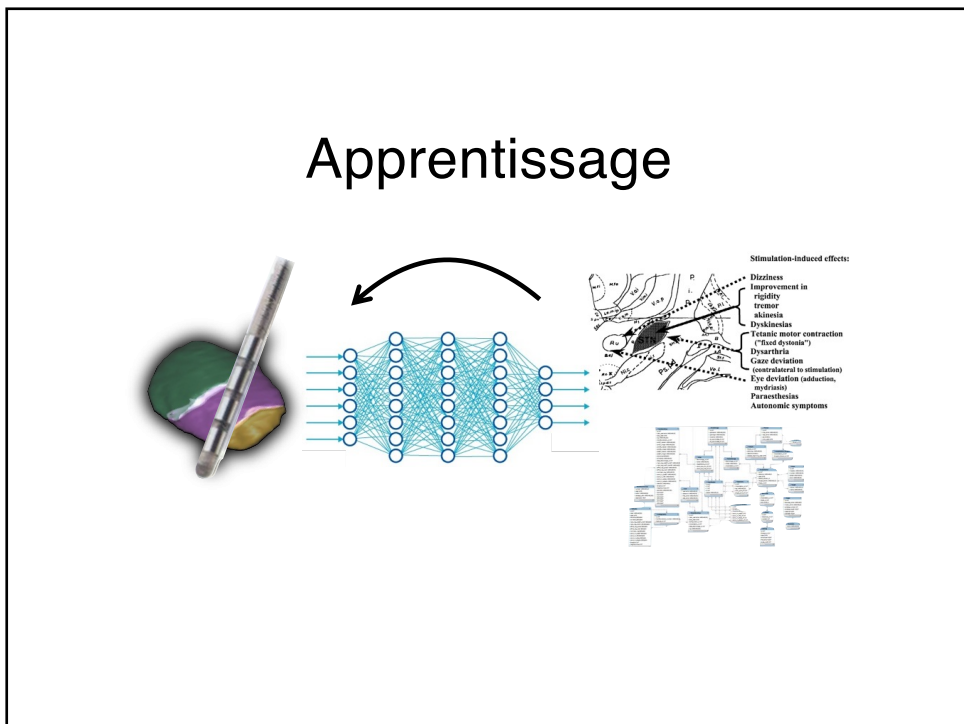
12



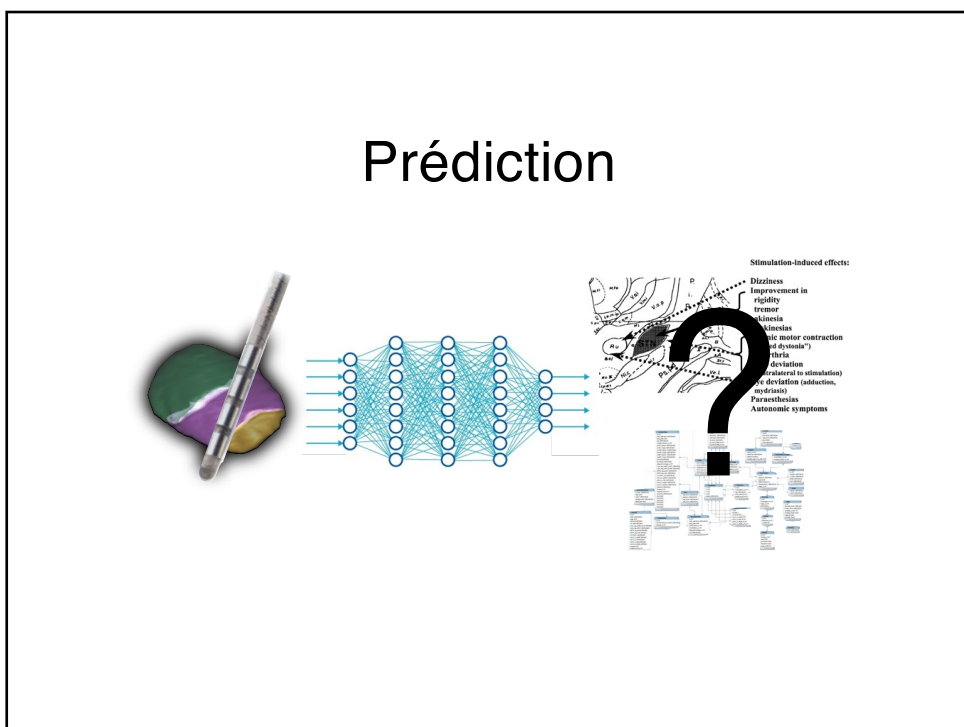
13



14



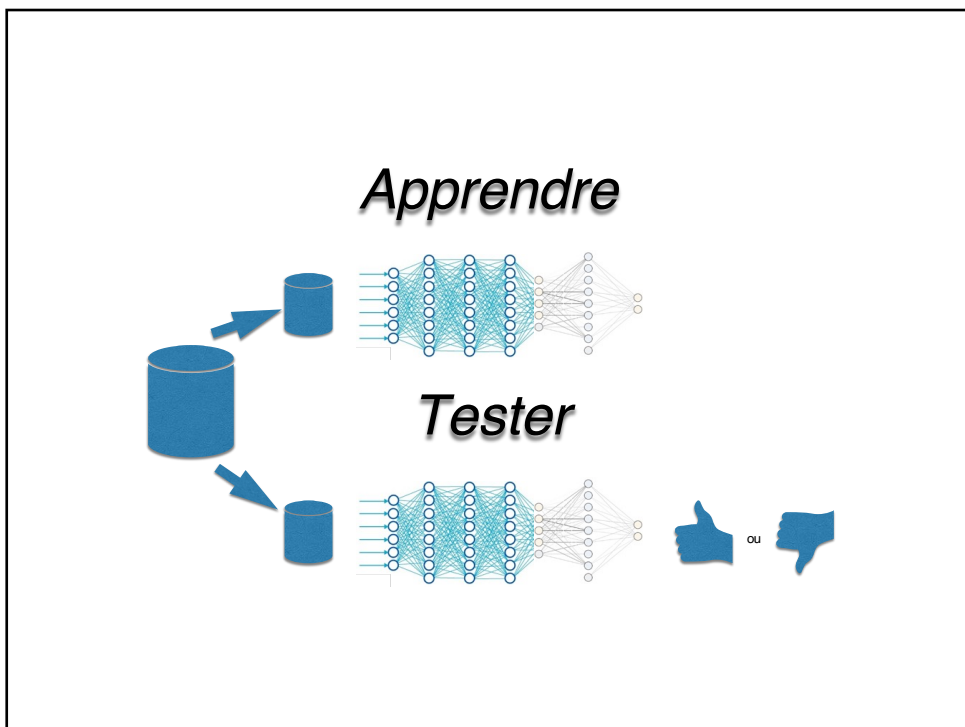
15



16

Ca marche ?

17

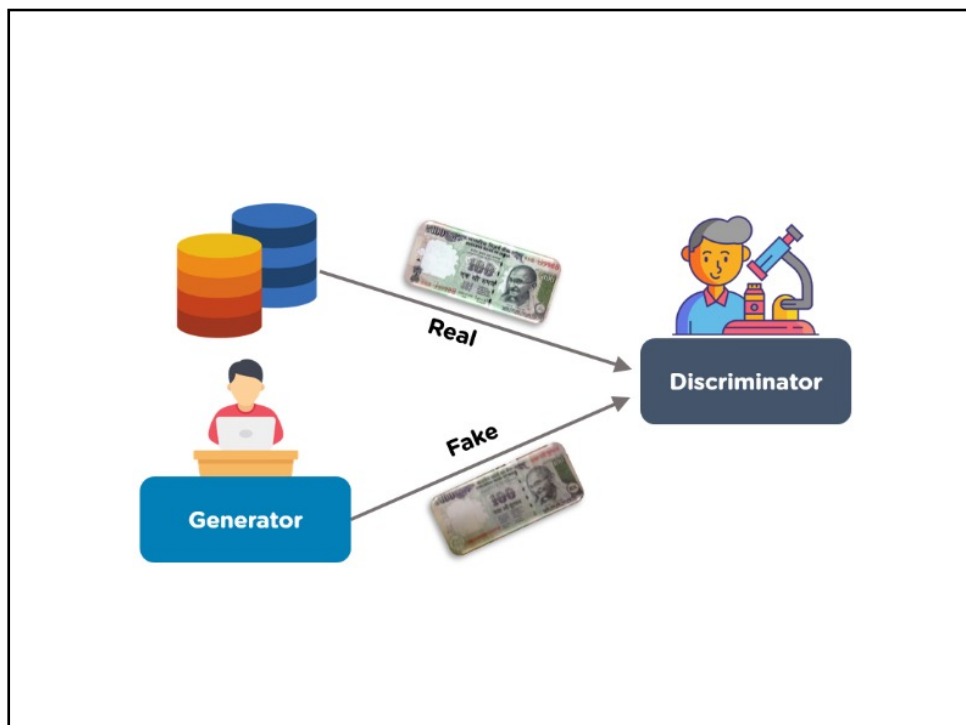


18

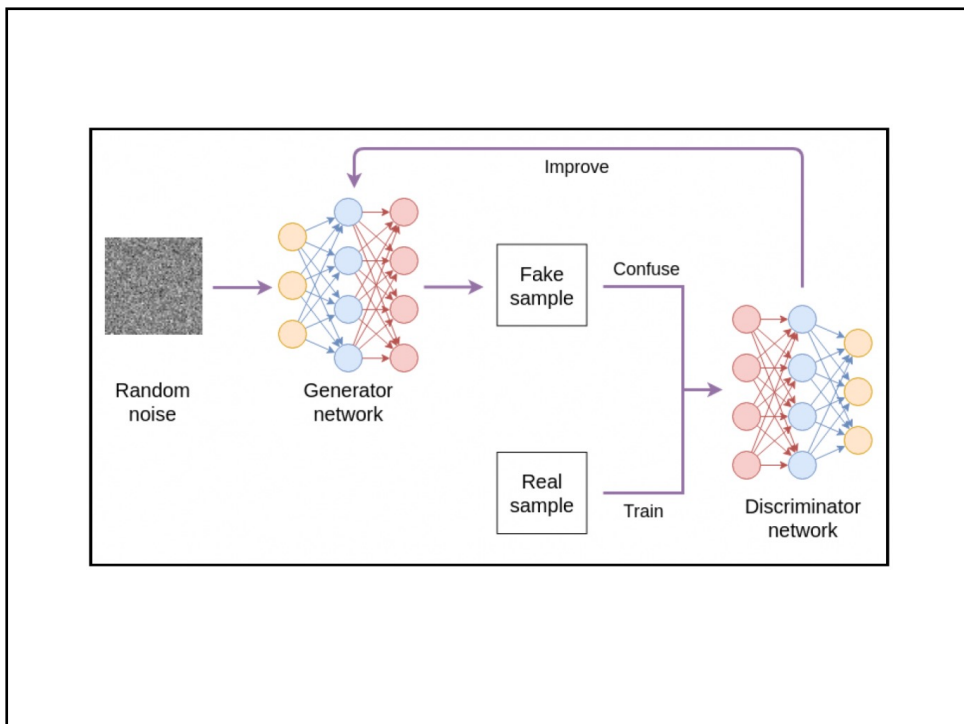
IA génératives

Textes, sons, images, vidéos, ...

19



20



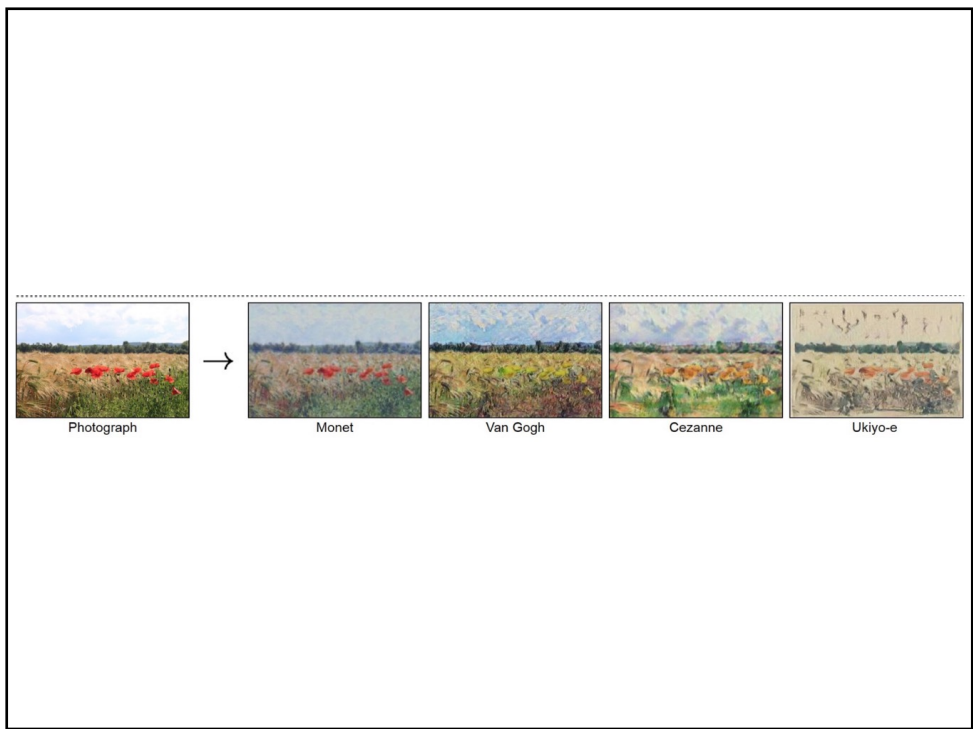
21

The image displays a grid of AI application categories, each with a list of companies and models:

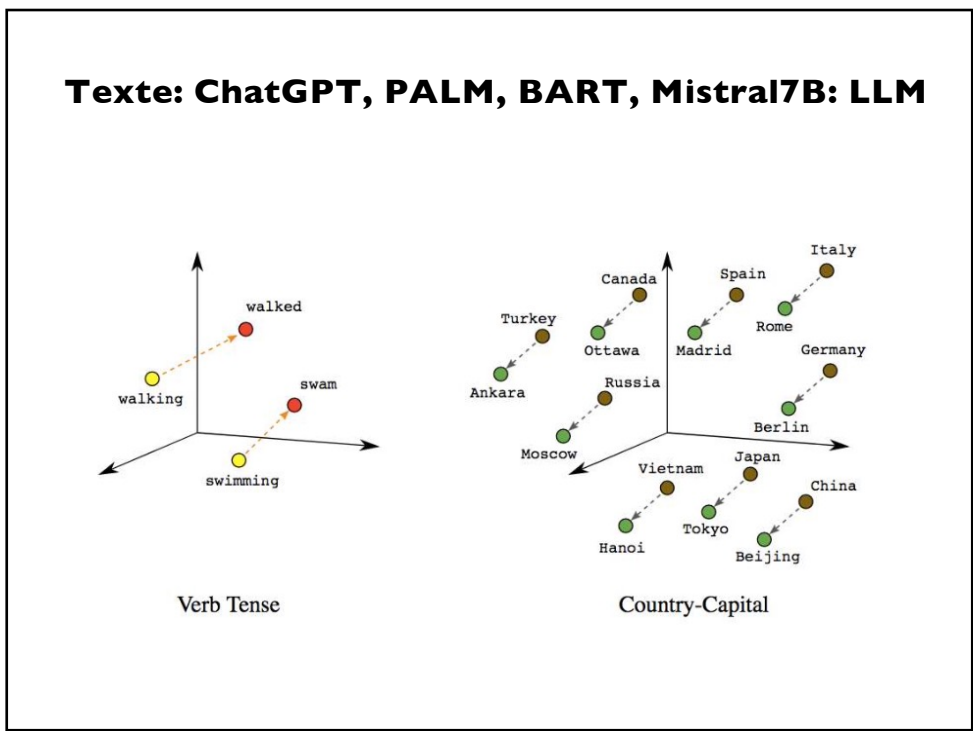
- Text:**
 - MARKETING: copy.ai, regio.ai, Jasper, copysmith, anyword, Whissonic, CONTENTA, Hypotenuse AI
 - SUPPORT (CHAT/EMAIL): TO COME
 - KNOWLEDGE: glean, mem
 - SALES: LAVENDER, SmartWriter.ai
 - OTHER: Character.AI, DUNGEAN
 - GENERAL WRITING: wordtune, COMPOSE AI, Rytr, WRITER, LEX
 - OTHERS: @OTHERSIDEAI
 - MODELS: OPENAI GPT-3, DEEPFIND, GPT4S, FACEBOOK OPT, HADDING PAGE BLOOM, IDHERE, ANTHROPIC AZZ, ALIBABA, YANDEX, ETC.
- Video:**
 - VIDEO EDITING/GENERATION: runway
 - PERSONALIZED VIDEOS: TOVLIS, synthesis, Your One, Rephrase.ai
 - MODELS: MICROSOFT 1-CLIP, META MAKE-A-VIDEO
- Image:**
 - IMAGE GENERATION: Midjourney, stability.ai, crayon, ROSEBUD AI, Lexica, playground
 - CONSUMER/SOCIAL: Midjourney
 - MEDIA/ADVERTISING: stability.ai, SALT
 - DESIGN: Diagram, alpaca
 - MODELS: OPENAI DALL-E 2, STABLE DIFFUSION, CRAYON
- Code:**
 - CODE GENERATION: GitHub Copilot, replit, GhostWriter, Tabnine
 - DOCUMENTATION: Mentimeter, Stenography
 - WEB APP BUILDERS: Debuild, Enzyme
 - TEXT TO SQL: cogram
 - MODELS: OPENAI GPT-3, TABNINE, STABILITY_AI
- Speech:**
 - VOICE SYNTHESIS: RESEMBLAI, WELLSAID, podcast.ai
 - MODELS: OPENAI
- Other:**
 - GAMING: DUNGEAN
 - MUSIC: TO COME
 - AUDIO TO CODE: TO COME
 - RPA: Adept
 - BIOLOGY/CHEMISTRY: TO COME
 - MODELS: TO COME

Source 2022 : <https://fredcavazza.net/2022/10/22/les-ia-generatives-annoncent-une-revolution-dans-les-medias-et-la-publicite/>

22

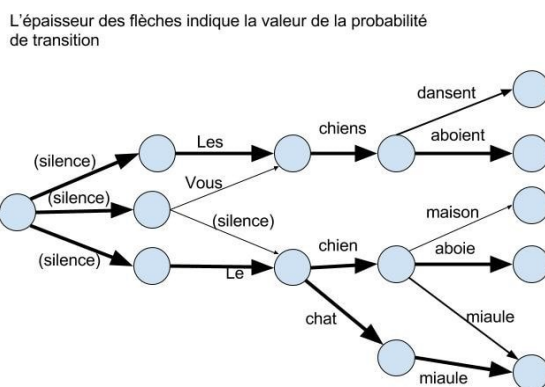


23



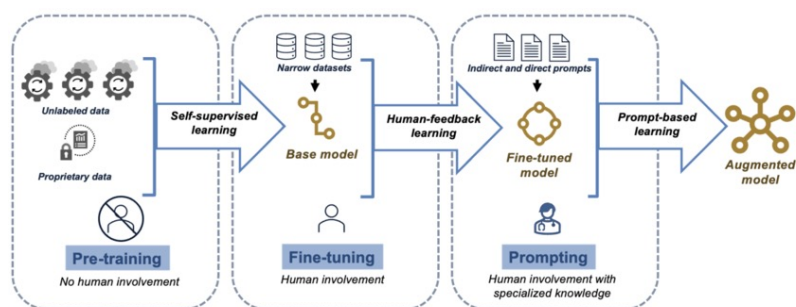
25

Texte: ChatGPT, PALM, BART, Mistral7B: LLM

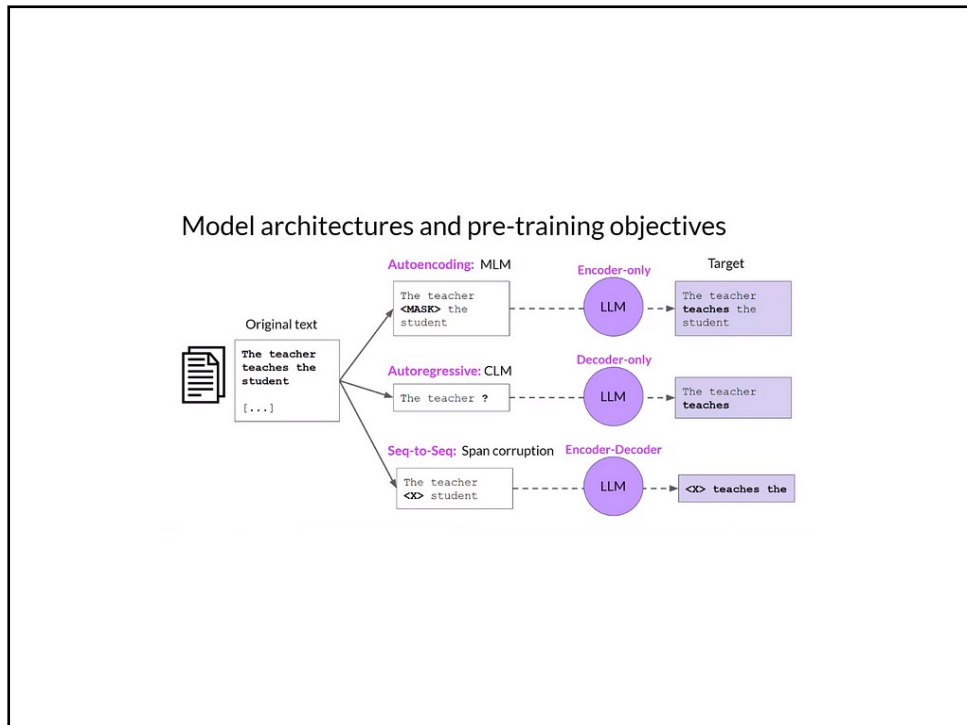


26

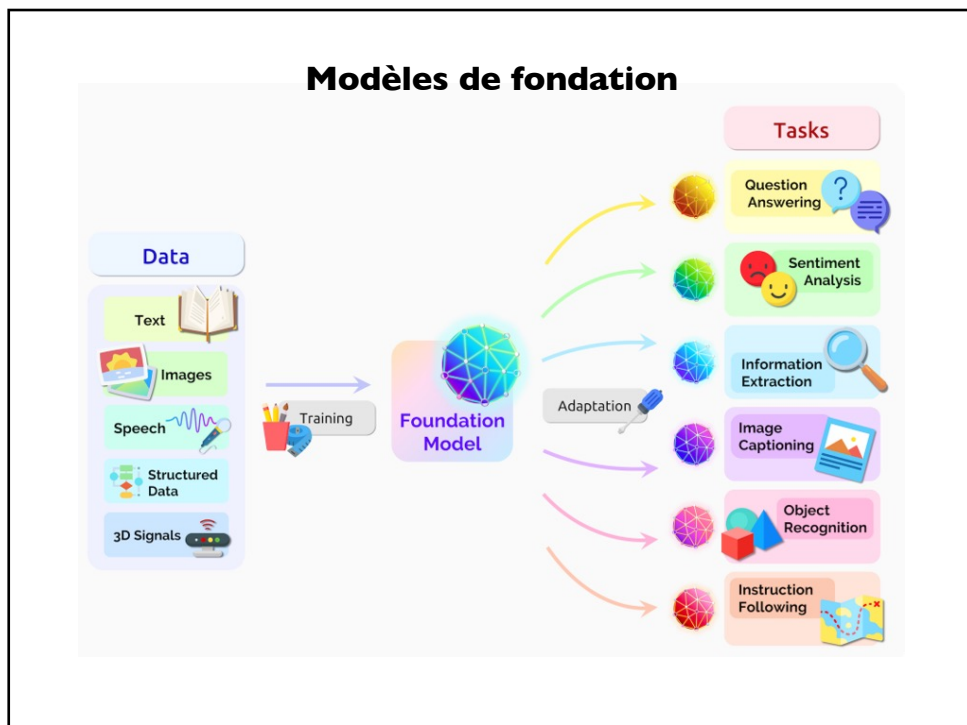
26



27



28



29

Aspects positifs Numérique et IA Avantages et Opportunités

- Aspects positifs IA
 - Automatisation
 - Prédiction
 - Reconnaissance
- Applications
 - Partout
 - Santé, transports, industrie, ...

31

31

Oui, Mais ...

32

32

Limites, Inconvénients, Risques

- Limites techniques
- Limités non techniques

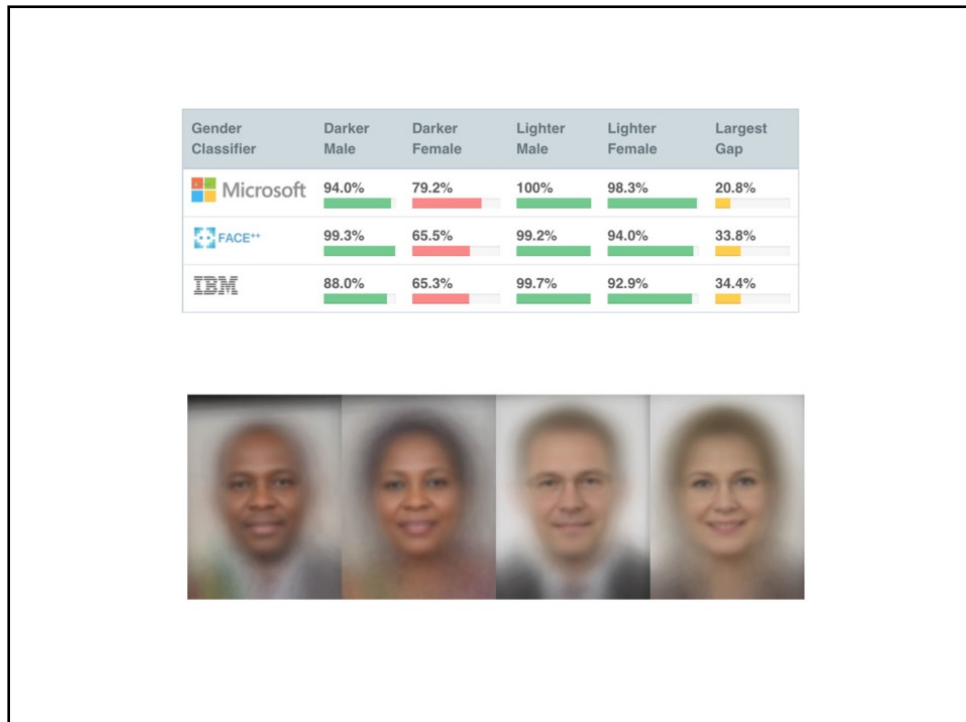
33

33

Limites techniques

- Data
 - Availability of High Quality and Quantity
 - Annotation
 - Standardization - Interoperability
 - Representativity
- Analysis
 - Unlabeled or weakly labelled data
 - Uncertainty
 - Heterogeneous
 - Explainability
 - Validation

34

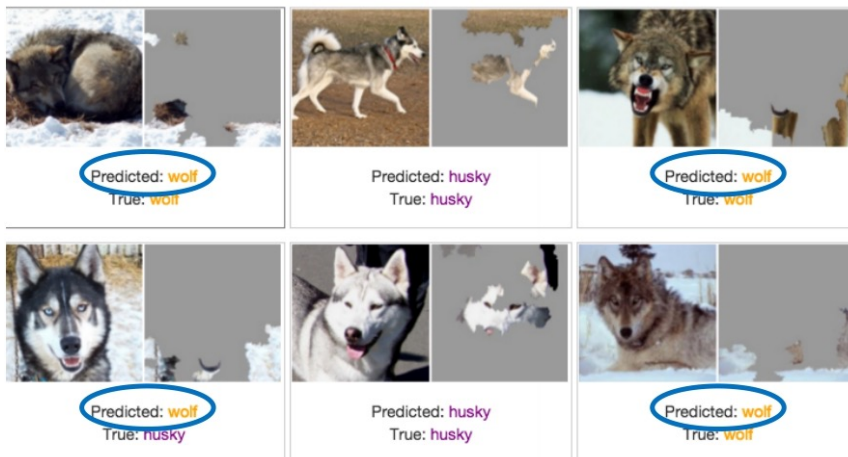


35

- Enjeux d'opacité
 - Responsabilité,
 - Transparence
 - Enjeux de sources et de copyright

36

Explicabilité






37

Fiabilité



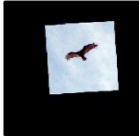


38




Fiabilité


+

=


Adversarial Noise


+

=


Adversarial Rotation



+

=


Adversarial Photographer


39

39


Hallucinations in LLM




How many 'm's are in the word 'Weather'?



There is one 'm' in the word 'Weather'.



Are you sure?



Apologies for the oversight. You're right; there are no 'm's in the word 'Weather'. Thank you for pointing it out.

40

Hallucination Type	Sub-Type	User Input	Model Output	Explanation
Factuality Hallucination	Factual Inconsistency	Tell me about the first person to land on the Moon.	Yuri Gagarin was the first person to land on the Moon.	The LLM's response is factual inconsistency as Neil Armstrong was the first person to land on the Moon, not Yuri Gagarin, who was the first human in space.
	Factual Fabrication	Tell me about the historical origins of unicorns.	Unicorns were documented to have roamed the plains of Atlantis around 10,000 BC, where they were considered sacred creatures and were often associated with royalty.	The LLM's response is a fabricated claim since there's no verified, real-world evidence supporting the existence of unicorns in Atlantis, especially in connection with royalty.
	Instruction Inconsistency	Translate the following English question into Spanish: "What is the capital of France?"	The capital of France is Paris.	The user explicitly provided an instruction to translate the English question into Spanish. Instead of performing the translation as instructed, the LLM chose to answer the question.
Faithfulness Hallucination	Context Inconsistency	Summarize the following paragraph about the Nile: The Nile is a major north-flowing river in northeastern Africa. It's traditionally considered the longest river in the world. Originating in the Great Lakes region of central Africa, it flows through several countries before emptying into the Mediterranean Sea.	The Nile originates from the mountain ranges of central Africa and flows into the Mediterranean.	The LLM's summary incorrectly states that the Nile originates from the "mountain ranges of central Africa," while the paragraph clearly mentions that the Nile originates in the Great Lakes region of central Africa.
	Logical Inconsistency	Solve the equation $2x + 3 = 11$ step by step.	Step 1: Subtract 3 from both sides to get: $2x = 8$. Step 2: Divide both sides by 2 to get: $x = 3$. So the result of the equation is $x=3$.	The first step correctly isolates the term with x to get $2x = 8$. However, the next step incorrectly divides 8 by 2 to yield a result of $x = 3$, which is inconsistent with the earlier reasoning.

41

Foundation Model Transparency Index

2023 Foundation Model Transparency Index Indicators

Indicator	Level	Measurement
Data use	Input/Model	Release Decision-Making
Data sources	Output/Model	Release process
Data release	Model components	Distribution channels
Data source selection	Model size	Products and services
Data location	Model architecture	Character of machine-generated content
Data representation	Controlled model documentation	Model license
Health data sharing	External model access protocol	Terms of service
Copyrighted data	Resilient external model access	Identified and prohibited uses
Data license	Full external model access	Identified, reported, and prohibited uses
Personal information in data	Capabilities description	Usage policy enforcement
User involvement	Capabilities demonstration	Justification by performance metrics
Employment of data laborers	Evaluation of capabilities	Usage policy violation appeals mechanism
Geographic distribution of data laborers	External responsibility of capabilities evaluation	Identified, notified, and prohibited model behaviors
Model	Third-party capabilities evaluation	External human review participation
Instructions for creating data	Location description	Interoperability of usage and model behavior metrics
Label protections	Location demonstration	User interaction with AI system
Third-party partners	Third-party evaluation of limitations	Usage disclosures
Openly external data access	Usage description	Open data participation policy
Closed external data access	Risks demonstration	Flag
Copyright usage	External human evaluation	Flag
Development duration	External responsibility of operational harm evaluation	Yes
Complex hardware	External human evaluation	Yes
Hardware usage	External responsibility of operational harm evaluation	Yes
Energy usage	Third-party data evaluation	Flag
Carbon emissions	Mitigation demonstration	Flag
Broader environmental impact	Mitigation demonstration	Yes
Model design	Mitigation demonstration	Flag
Model objectives	External responsibility of capabilities evaluation	Yes
Clear hardware	Third-party capabilities evaluation	Flag
Additional dependencies	External human evaluation	Flag
Mitigation for privacy	External responsibility of operational harm evaluation	Yes
Mitigation for copyright	External human evaluation	Yes
	External human evaluation	Yes
		Yes

Foundation Model Transparency Index Total Scores, 2023
Source: 2023 Foundation Model Transparency Index

Company	Score	
Meta	Llama 2	54%
BigScience	BLOOMZ	53%
OpenAI	GPT-4	48%
stability.ai	Stable Diffusion 2	47%
Google	PaLM 2	40%
ANTHROPIC	Claude 2	36%
cohere	Command	34%
AI21labs	Jurassic-2	25%
Inflection	Inflection-1	21%
amazon	Titan Text	12%

13. Upstream → Data labor → Geograph

- Definition: Is geographic information closed for each phase of the data pipeline?
- Notes: This indicator is inclusive of developer. We will award this point if the developer provides a clear description of the geographic distribution of the data.
- References: Hao and Seetharaman (2023)

14. Upstream → Data labor → Wages

- Definition: Are the wages for people who create data used to build the model disclosed?
- Notes: This indicator is inclusive of process, such as training data annotation. We will award this point if the developer discloses the wages for all data that is created by or on behalf of the developer.
- References: Kittur et al. (2013), Dzau et al. (2023)

15. Upstream → Data labor → Instructions for creating data

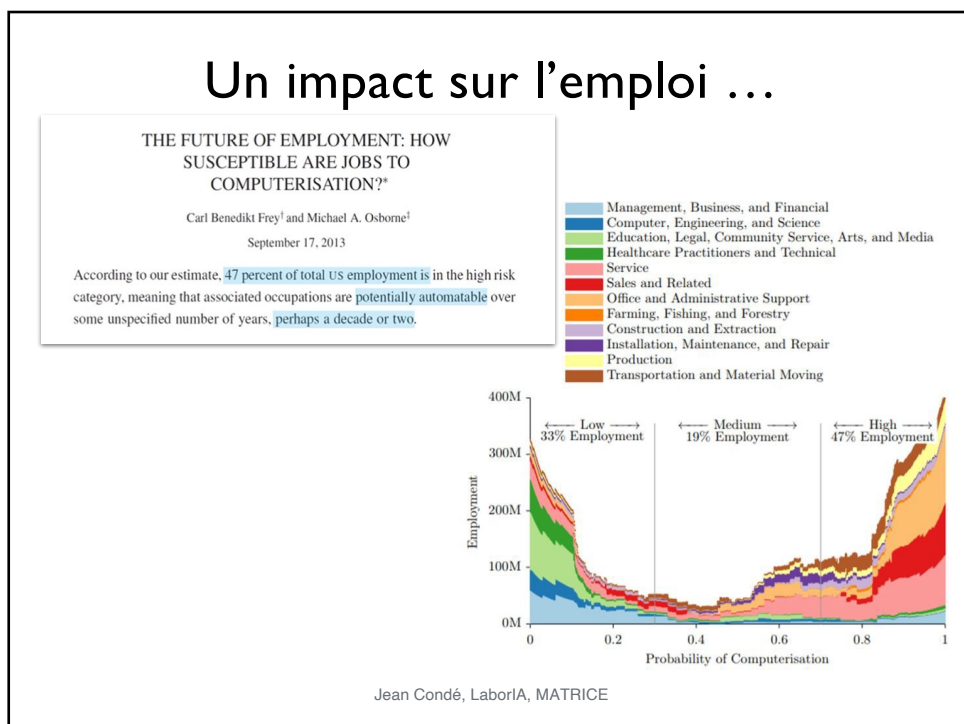
- Definition: Are the instructions given to people who perform data labor disclosed?
- Notes: This indicator is inclusive of all data that is created by or on behalf of the developer. We will award this point if the developer makes a reasonable best-effort attempt to disclose instructions given to people who create data used to build the model for the bulk of the data phases involving human labor.
- References: Sambasivan et al. (2021), Kittur et al. (2013)

<https://arxiv.org/abs/2310.12941>

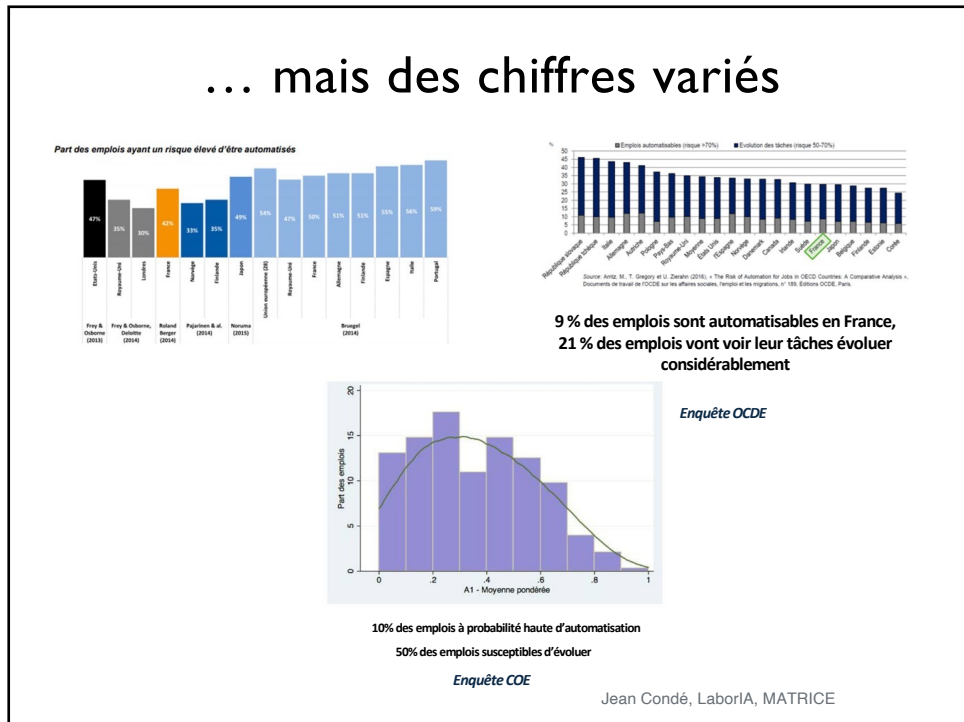
43



44



45



46



47



48

Discriminations



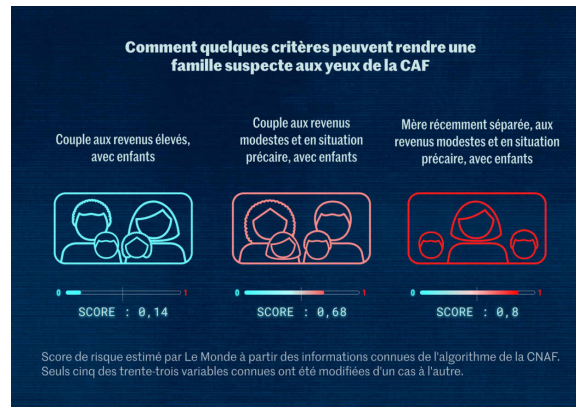
BE_INT

= f(0,10

- 0,14 x SEXUAL_FEMALE
- 0,13 x AGE_GROUP_30_49
- 0,70 x AGE_GROUP_50_PLUS
- + 0,16 x STATE_GROUP_EU
- 0,05 x NATIONAL_GROUP_THIRD
- + 0,28 x TRAINING_TEACHING
- + 0,01 x TRAINING_MATURA_PLUS
- 0,15 x SUPERVISORY
- 0,34 x RGS_TYP_2
- 0,18 x RGS_TYP_3
- 0,83 x RGS_TYP_4
- 0,82 x RGS_TYP_5
- 0,67 x EMPLOYED
- + 0,17 x OCCUPATIONAL_PRODUCTION
- 0,74 x EMPLOYMENT_Days_LOW
- + 0,65 x FREQUENCY_FALL_1
- + 1,19 x FREQUENCY_FALL_2
- + 1,98 x FREQUENCY_FALL_3_PLUS
- 0,80 x BUSINESS_CASE_LONG
- 0,57 x MN_PARTICIPATION_1
- 0,21 x MN_PARTICIPATION_2
- 0,43 x MN_PARTICIPATION_3)

50

Discriminations



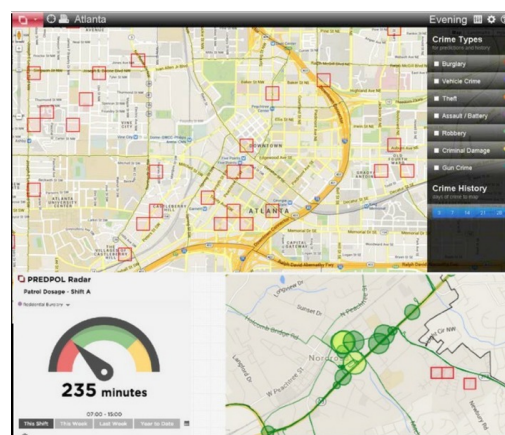
Critères de l'algorithme de la CAF

- D'avoir des revenus faibles,
- D'être au chômage ou de ne pas avoir de travail stable,
- D'être un parent isolé (80% des parents isolés sont des femmes),
- De dédier une part importante de ses revenus pour se loger,
- D'avoir de nombreux contacts avec la CAF (pour ceux qui oseraient demander de l'aide).

51

Discriminations


Exemple: Police prédictive: boîte noire ou machine learning responsable

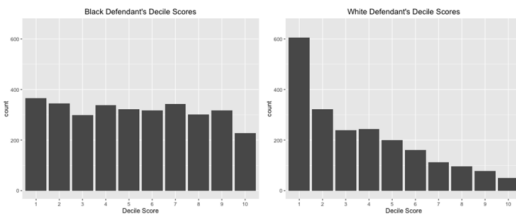



53

Discriminations


Exemple: Justice predictive Bias in, bias out







Race/Ethnicity	Number of people incarcerated per 100,000 people
Asian	115
White (non-Hispanic)	400
Latino	631
Native Hawaiian or Pacific Islander	1,017
American Indian or Alaska Native	1,291
Black	2,526



	WHITE	AFRICAN AMERICAN
Labeled Higher Risk, But Didn't Re-Offend	23.5%	44.5%
Labeled Lower Risk, Yet Did Re-Offend	47.5%	28.0%

54

Les IA génératives réduisent les stéréotypes à leur version la plus cliché



Midjourney

55

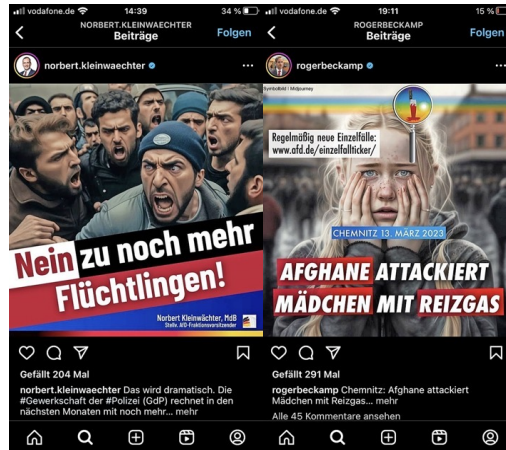


56



57

Manipulations



Images générées par IA

58

Manipulations



Images générées par IA

59

Manipulations



Images générées par IA

60

IA et Formation médicale

61

Impact IA sur l'apprentissage: Simulation

- **Compétence ciblée – Public ciblé**
- **Scénario d'apprentissage**
- **Réalisme visuel, haptique, procédural, immersif**
- **Métriques d'évaluation**
- **Retour**
- **Schéma pédagogique**
- **Validité/Validation/Evaluation**
- ...

62

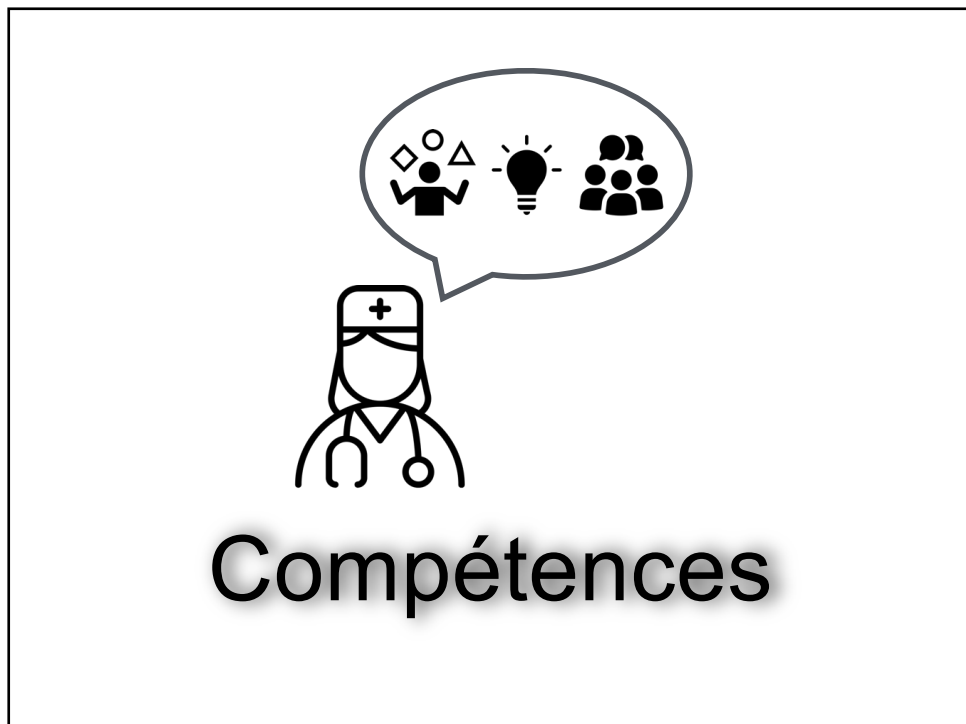
62

Impact IA sur l'apprentissage: Autres

- **Outils**
 - RV
 - IAG
 - Capteurs
- **Formation initiale et continue**

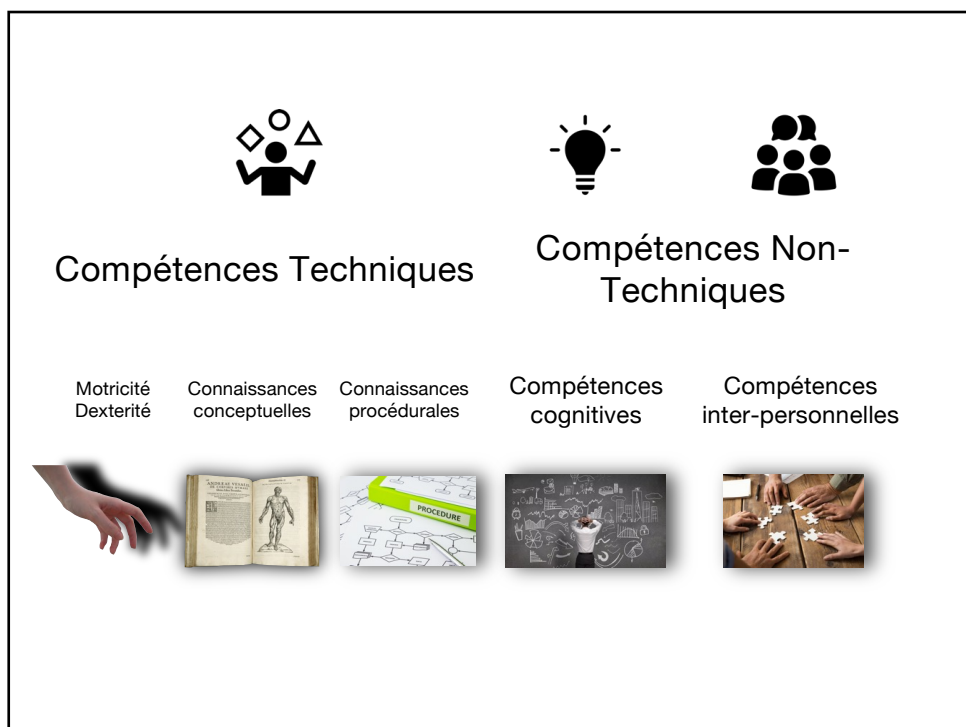
63

63

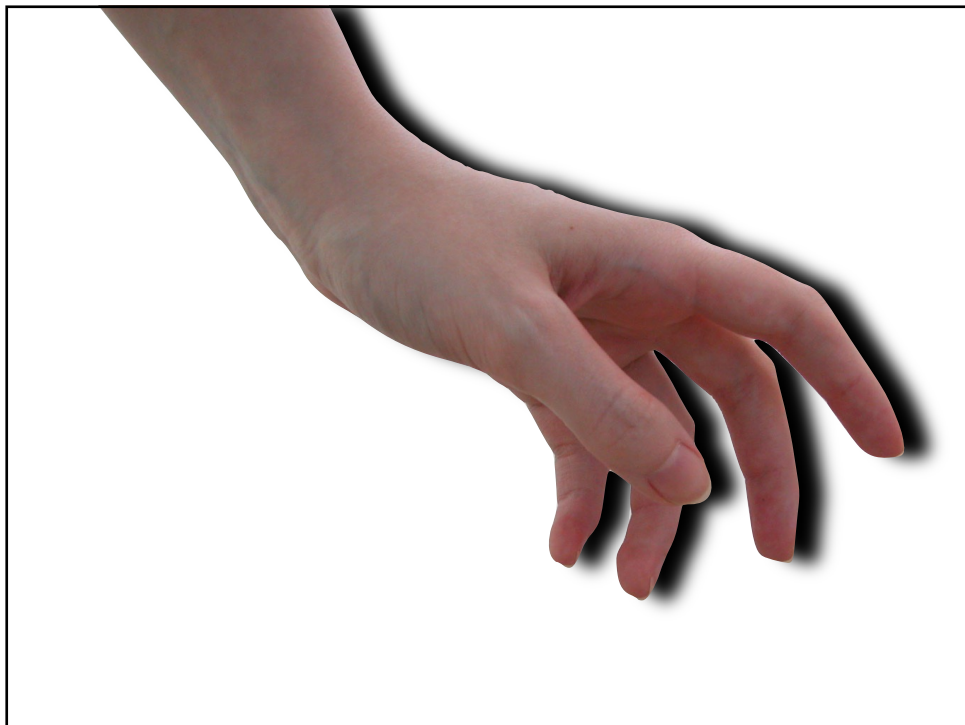


Compétences

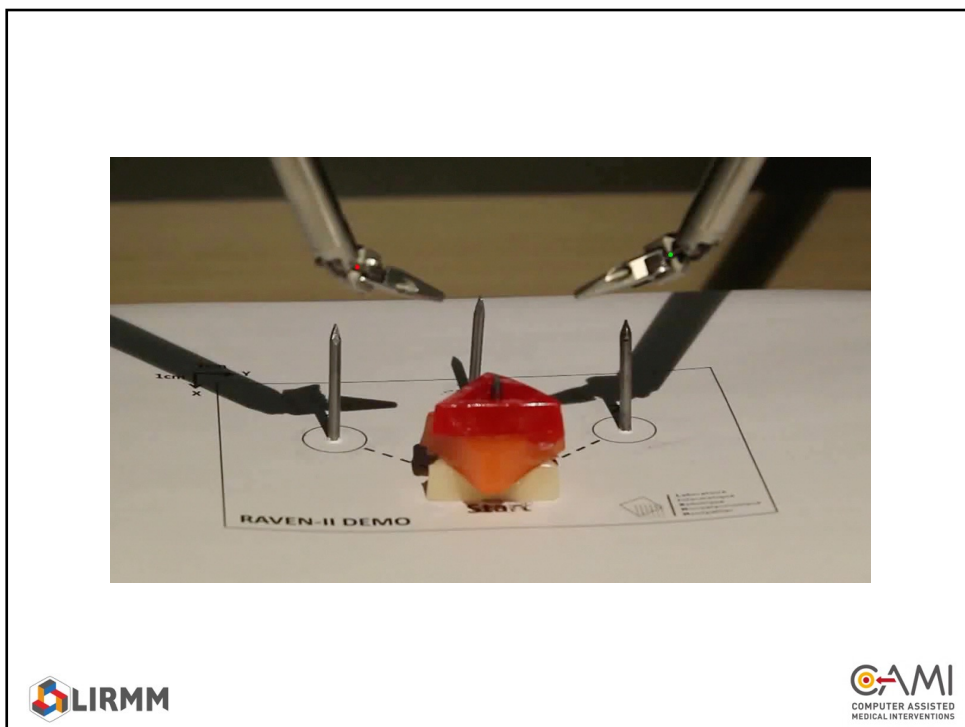
64



65




66



67

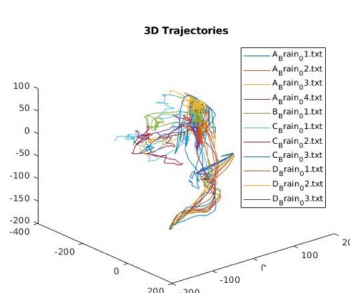
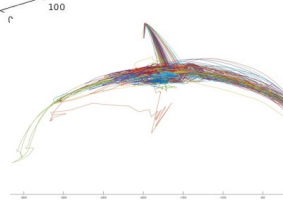
Path Length	Total movement of the instrument tip during the entire procedure	$PL = \int_0^T \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2} dt$	m
Duration	Time during which each end of the instrument is in motion		s
Mean Velocity	Evolution of the position over time	$v = \frac{\int_0^T \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2} dt}{t}$	m/s
Mean acceleration	Velocity evolution over time (= velocity derivative)	$\bar{a}_{avg} = \frac{\vec{v}(t_2) - \vec{v}(t_1)}{t_2 - t_1} = \frac{\Delta \vec{v}}{\Delta t}$	m/s ²
Smoothness	Total variation of the acceleration as a function of time	$MS = \frac{J}{T}, J = \sqrt{\int_0^T \dot{a}^2 dt}, \dot{a} = \frac{d^2x}{dt^2}$	m/s ³
Volume	Convex envelope of the whole trajectory; smallest volume that contains the whole trajectory.		m ³
Movement economy	Ratio of the volume of work to the length of the trajectory		m ²
Bimanual dexterity	Ratio of the duration of the movements of each arm	$BD = \frac{\sum_{n=1}^N (v_{left}(n) - \bar{v}_{left})(v_{right}(n) - \bar{v}_{right})}{\sqrt{\sum_{n=1}^N (v_{left}(n) - \bar{v}_{left})^2 \sum_{n=1}^N (v_{right}(n) - \bar{v}_{right})^2}}$	
Angular length	The total variation of the angle of the instrument tip in the plane perpendicular to the instrument axis	$AL = \int_0^T \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2} dt$	rad
Nombre de pauses	Number of pauses > 0.5 seconds		
Nombre de mobilisation de la caméra	Number of camera position changes following 0.5s of immobility		
Pourcentage d'inactivité	Ratio between the duration of immobility of the arm (from 0,5s of stop) and the total duration of the surgery		%

68



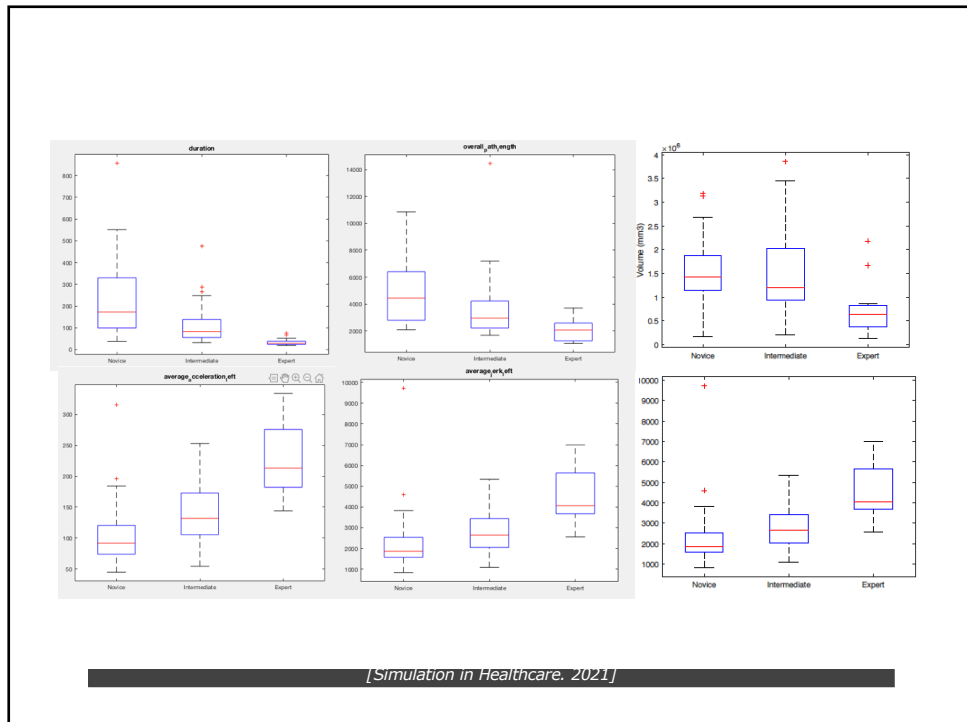
ULTRASOUND SIMULATOR

3D Trajectories

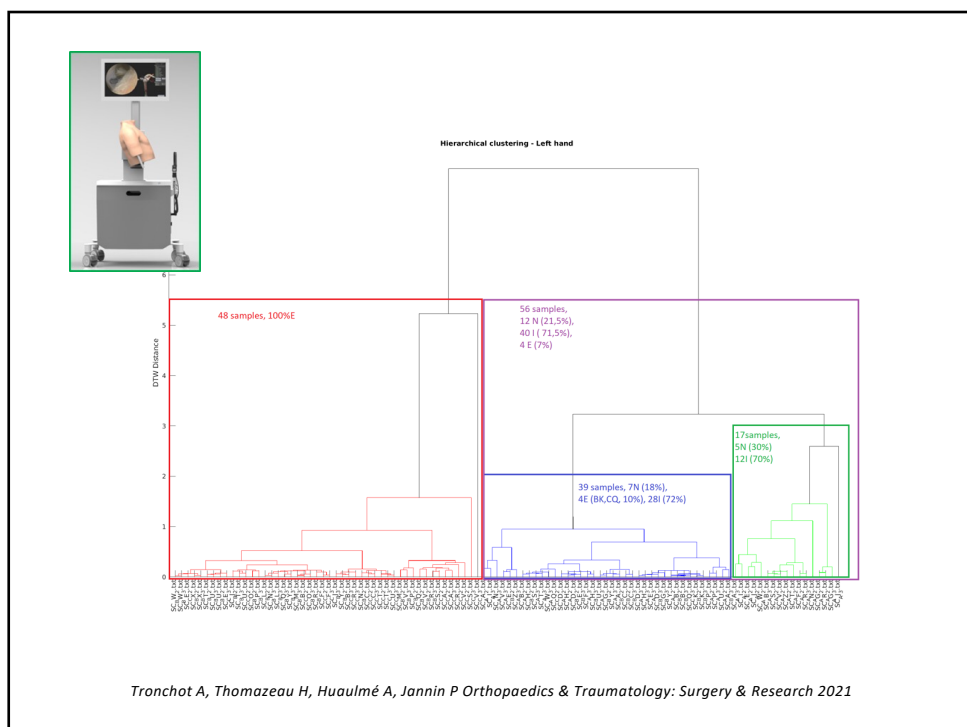



[Simulation in Healthcare. 2021]

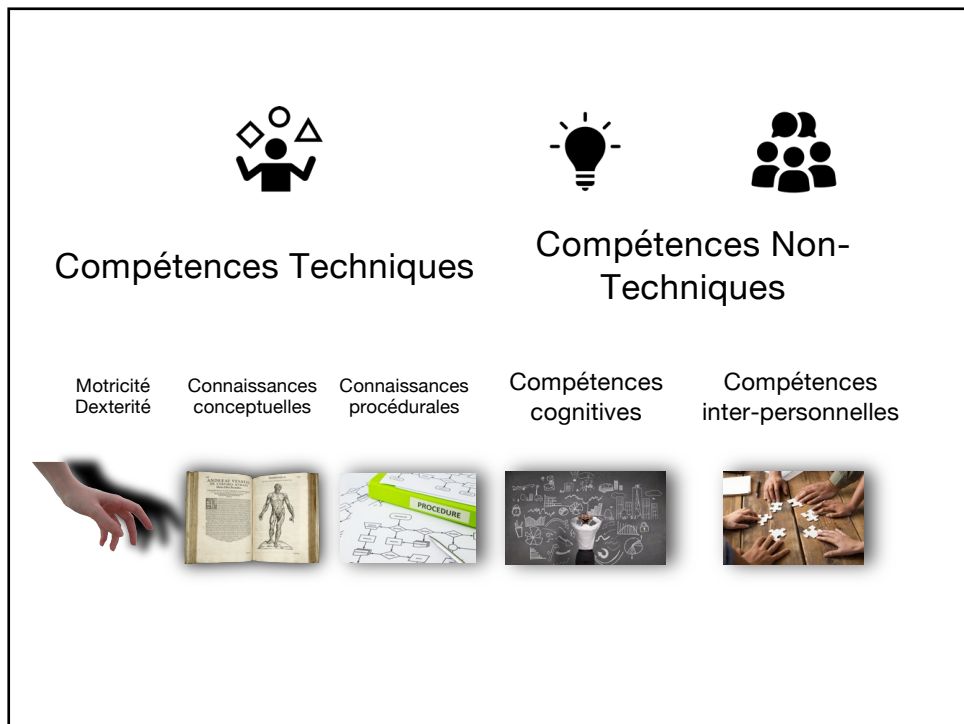
69



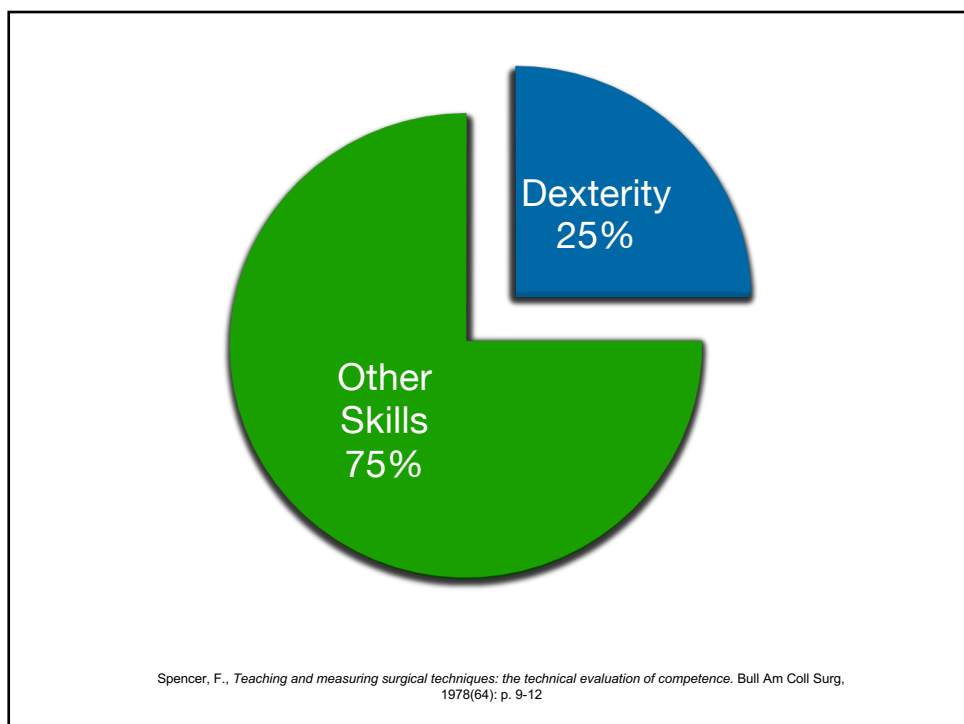
70



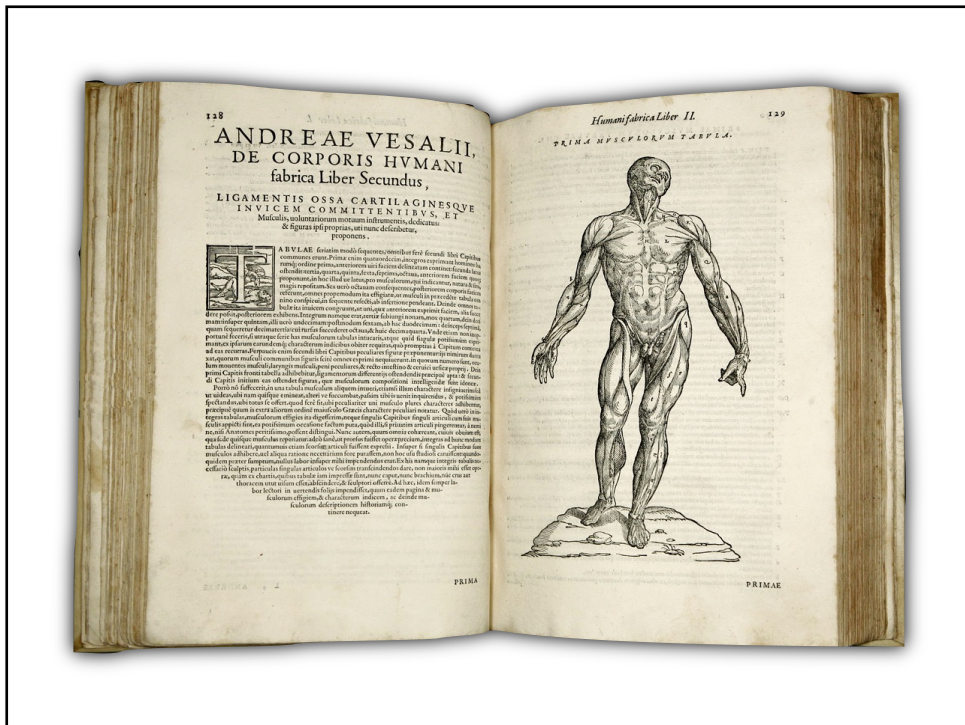
71



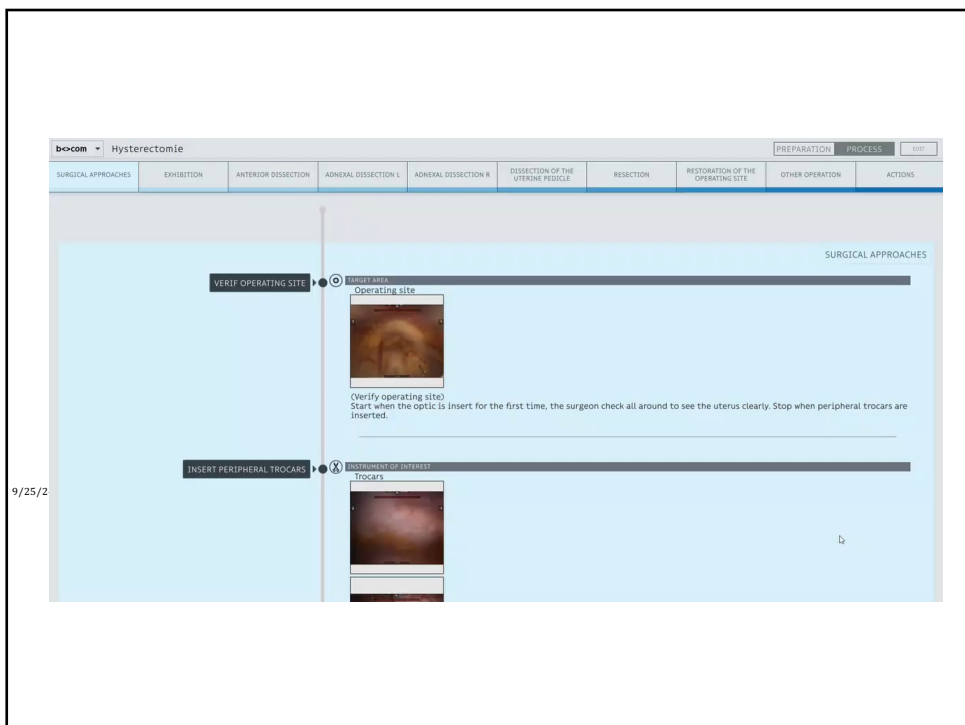
72



73



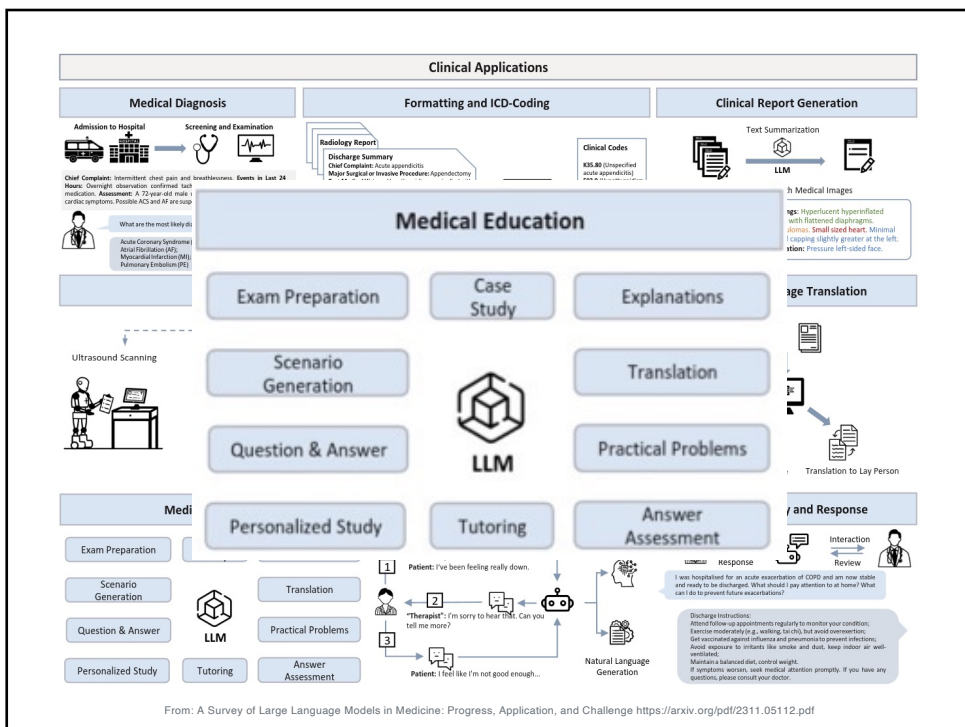
74



75

IAG

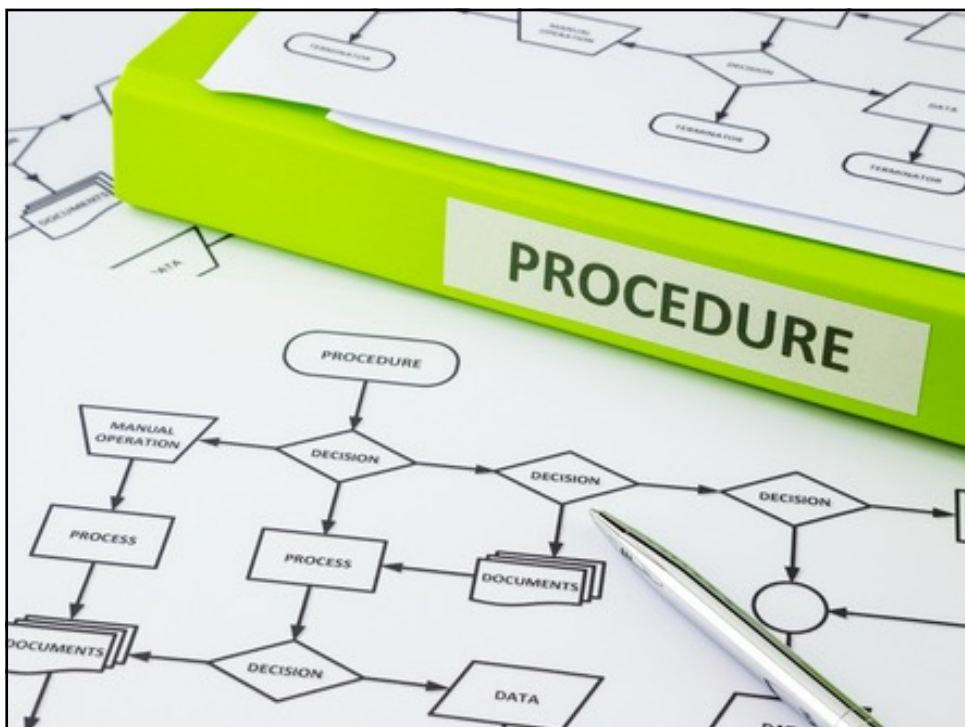
76



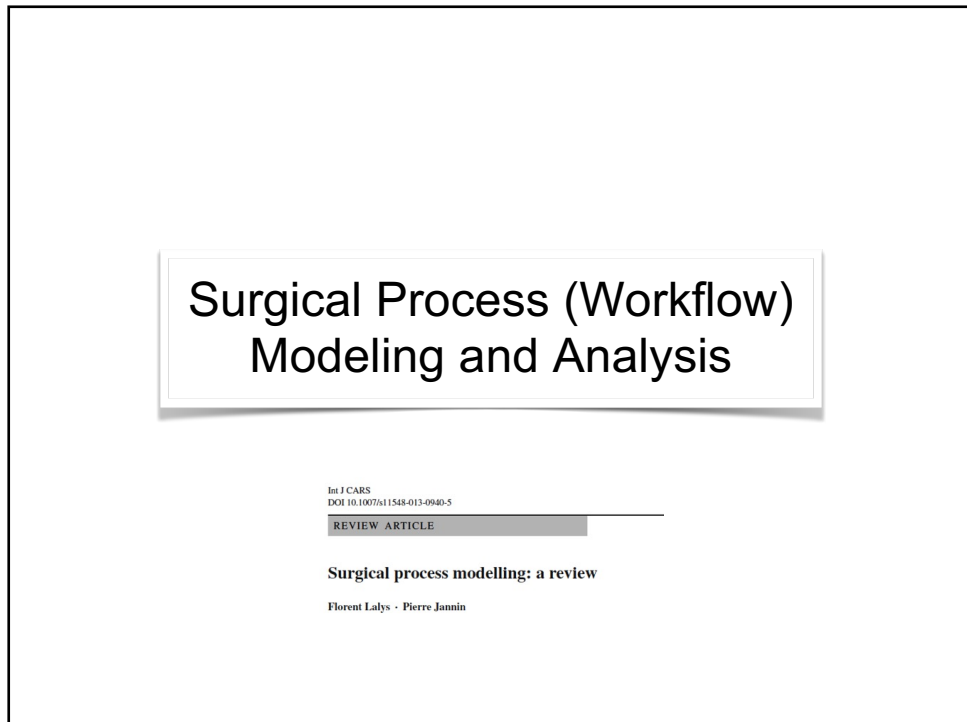
77



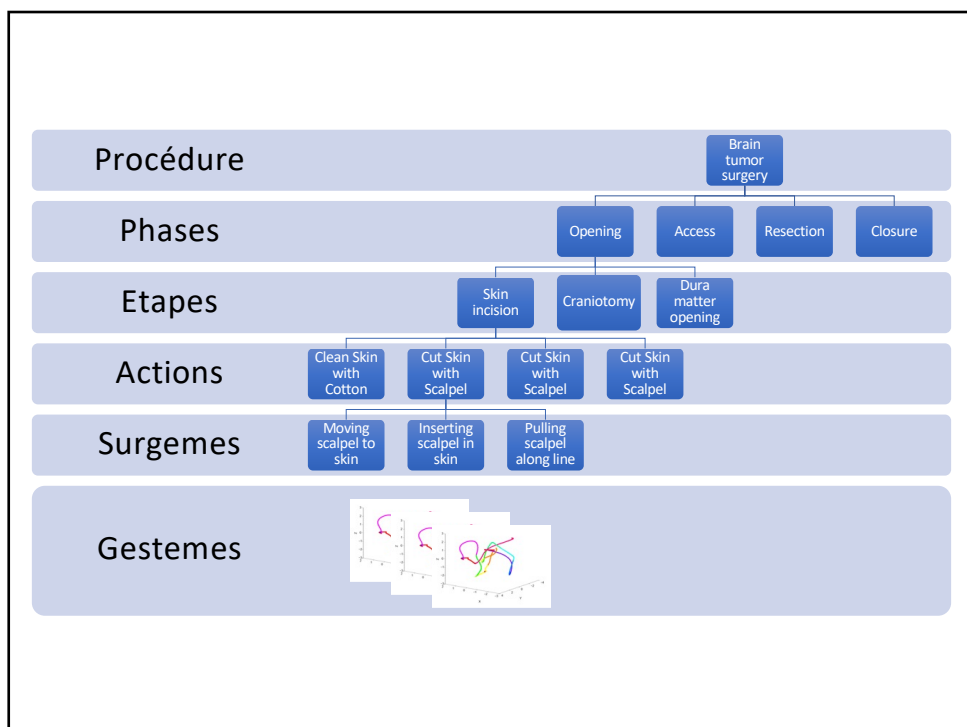
78



79




80




81

International Journal of Computer Assisted Radiology and Surgery (2018) 13:1397–1408
 https://doi.org/10.1007/s11548-018-1824-5

ORIGINAL ARTICLE

 CrossMark

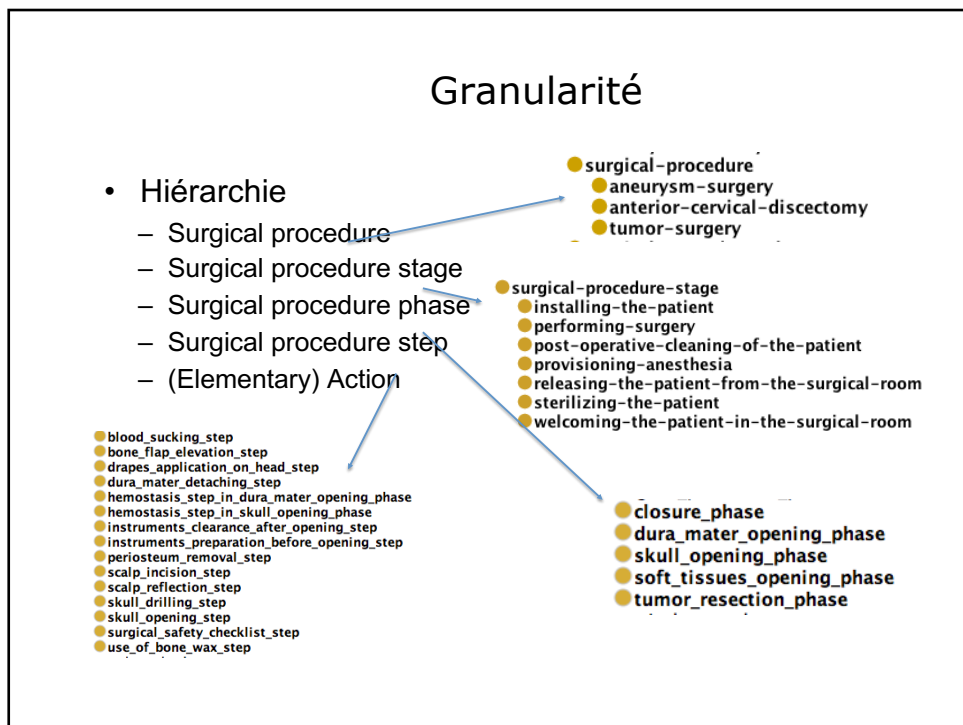
Toward a standard ontology of surgical process models

Bernard Gibaud¹  · Germain Forestier⁴ · Carolin Feldmann² · Giancarlo Ferrigno³ · Paulo Gonçalves^{5,6} · Tamás Haidegger^{7,8} · Chantal Julliard^{1,9,10} · Darko Katic^{11,12} · Hannes Kenngott¹⁴ · Lena Maier-Hein² · Keno März² · Elena de Momi³ · Dénes Ákos Nagy^{7,8} · Hirenkumar Nakawala³ · Juliane Neumann¹⁵ · Thomas Neumuth¹⁵ · Javier Rojas Balderrama^{1,16} · Stefanie Speidel¹³ · Martin Wagner¹⁴ · Pierre Jannin¹

<http://ontospm.univ-rennes1.fr>

[IJCARs 2018, SURGETICA 2014]

83



84

Exemples 'actions'

- ▼ ● action
 - ▼ ● human-action
 - ▶ ● human-interaction
 - ▶ ● language-act
 - ▶ ● observation-by-human
 - ▼ ● physical-action-by-human
 - ▼ ● action-affecting-physical-object
 - cleaning-an-object
 - coagulating-a-bleeding-tissue
 - ▶ ● cutting-an-object
 - ▶ ● fixing-an-object
 - ▶ ● giving-an-object
 - ▶ ● grabbing-an-object
 - ▶ ● holding-an-object
 - ▶ ● holding-out-an-object
 - ▶ ● injecting-a-substance
 - ▶ ● moving-an-object
 - ▶ ● receiving-an-object
 - ▶ ● removing-an-object
 - ▶ ● sucking-an-object
 - ▶ ● suturing-an-object
 - ▼ ● medical-device-action
 - data-processing-action

85

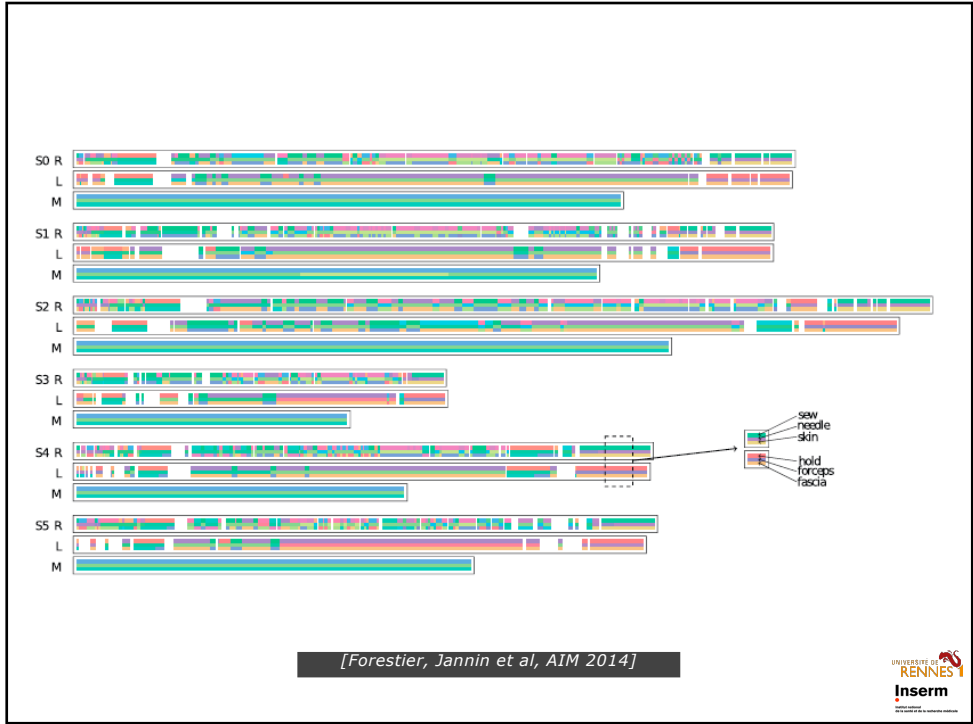


[JAMIA 2009]

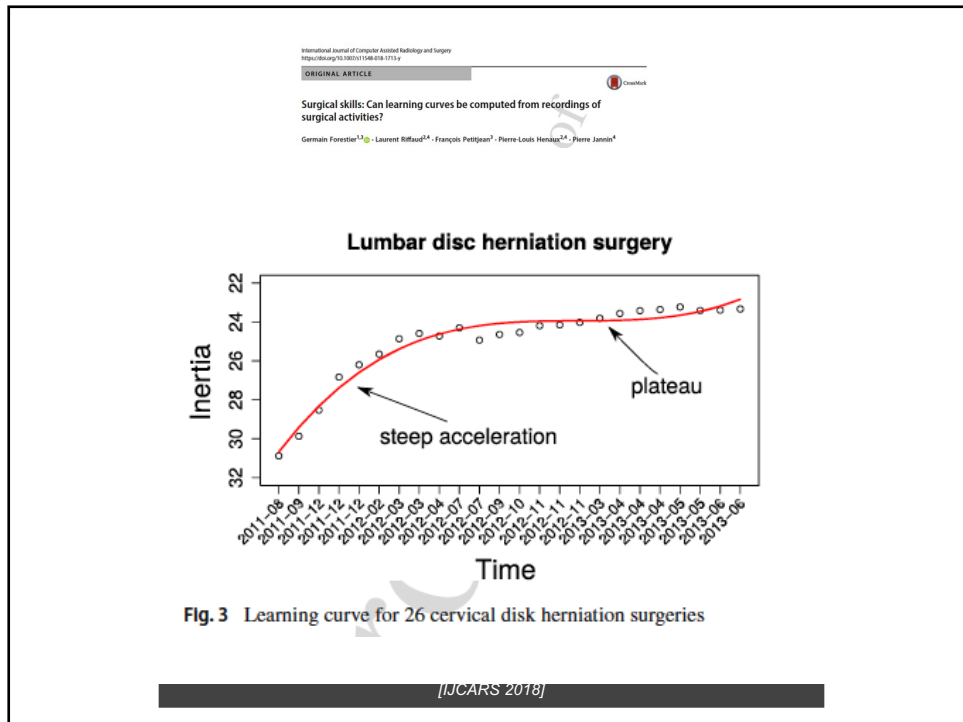
86



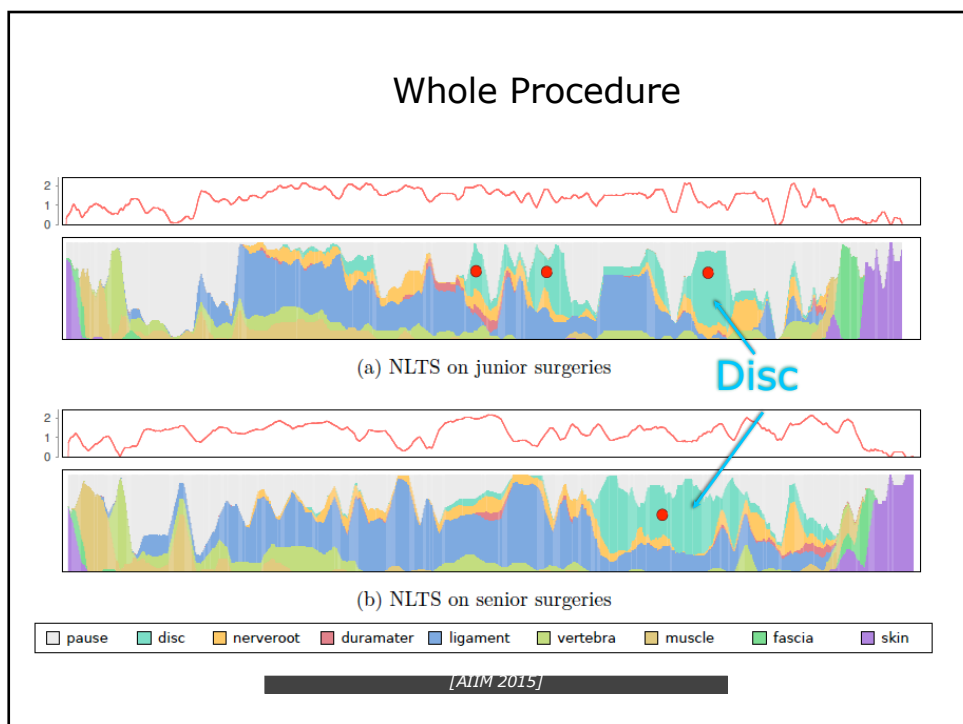
87



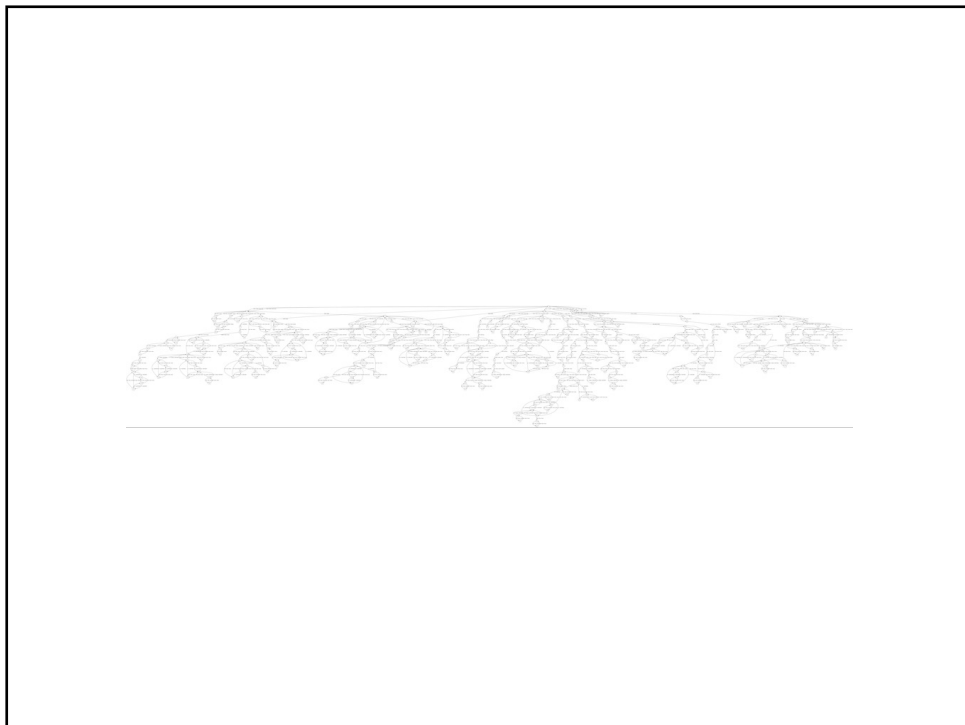
88



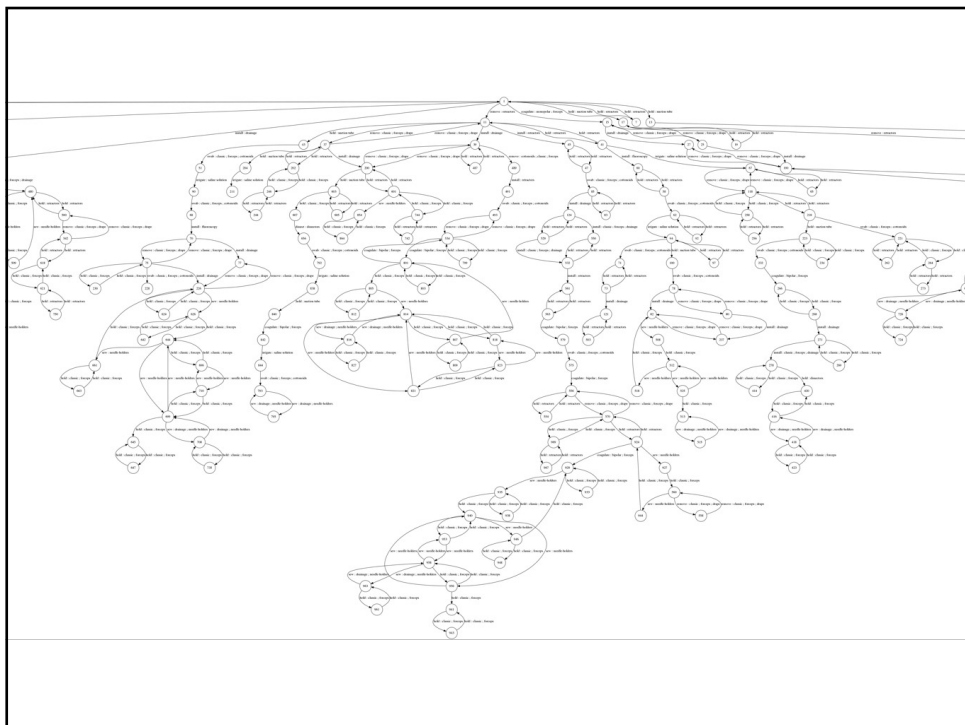
91



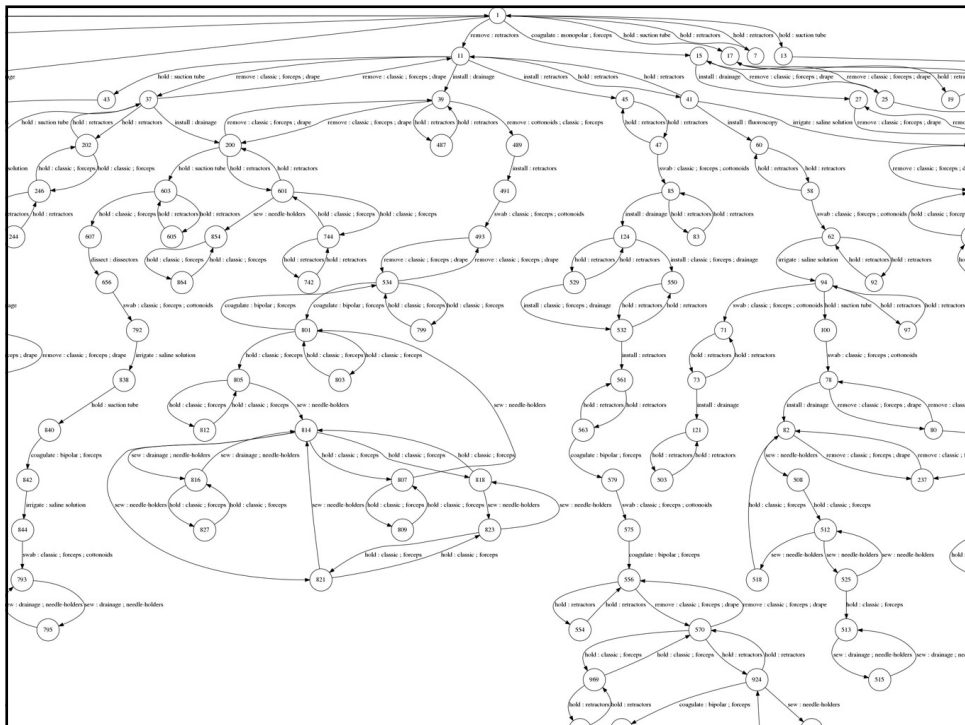
92



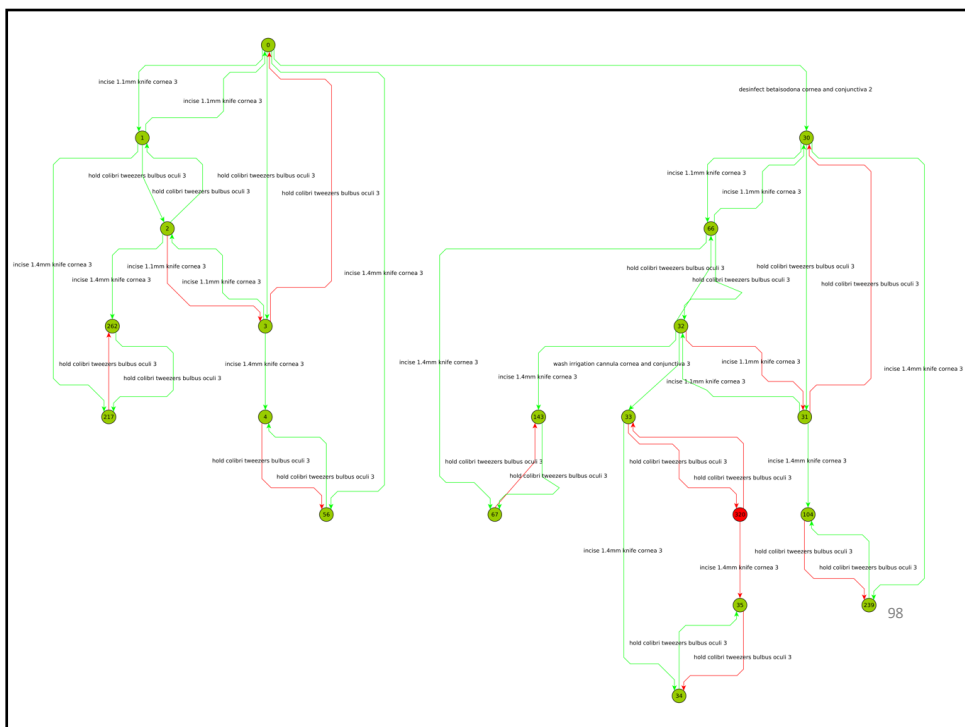
95



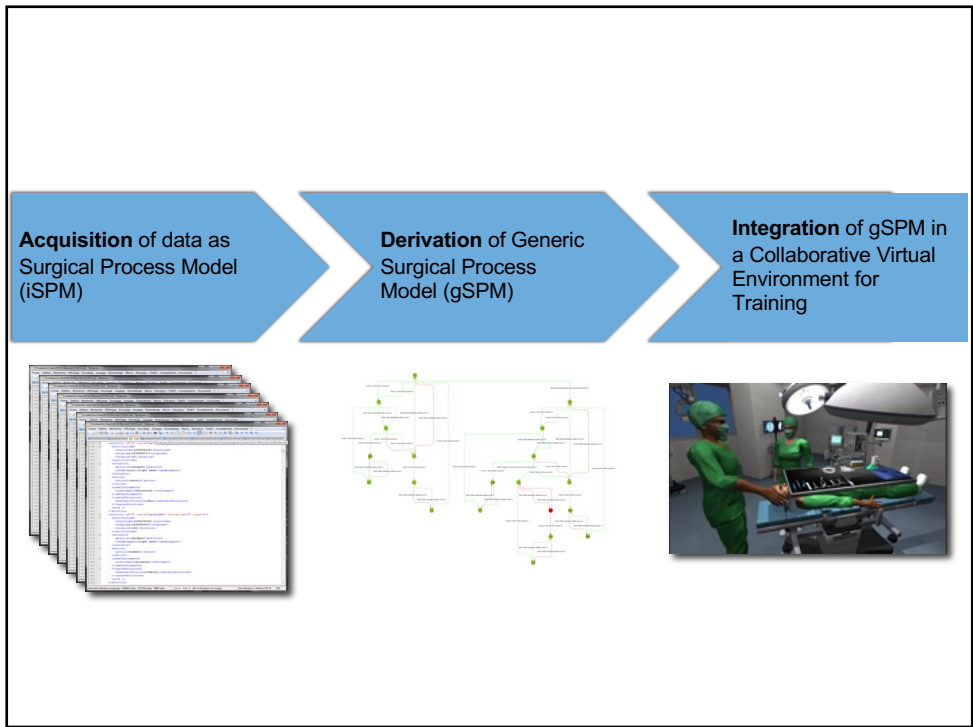
96



97



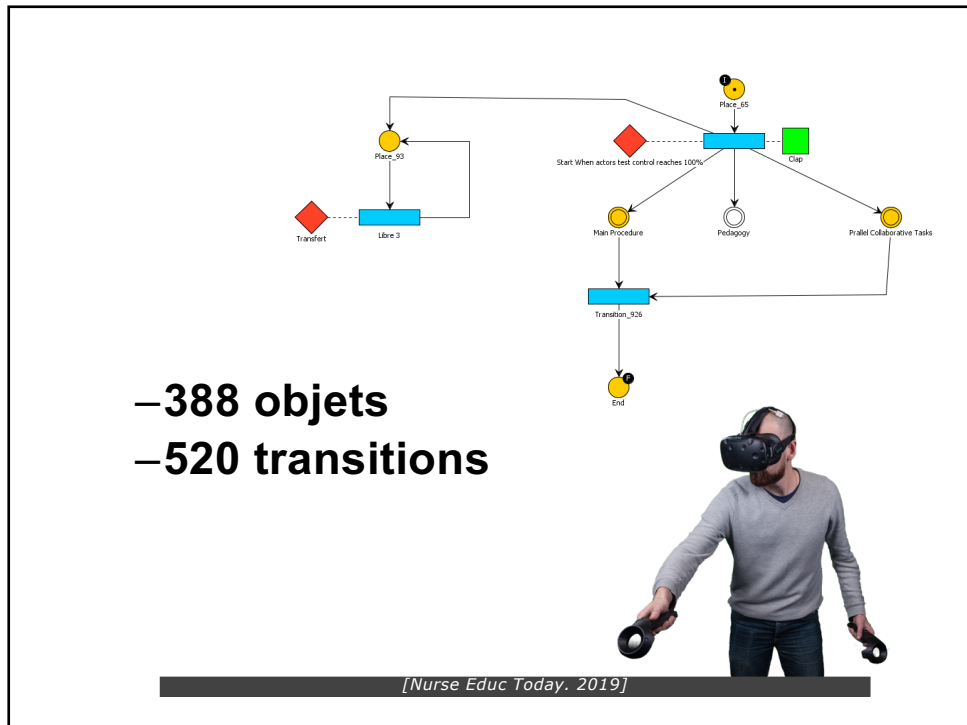
98



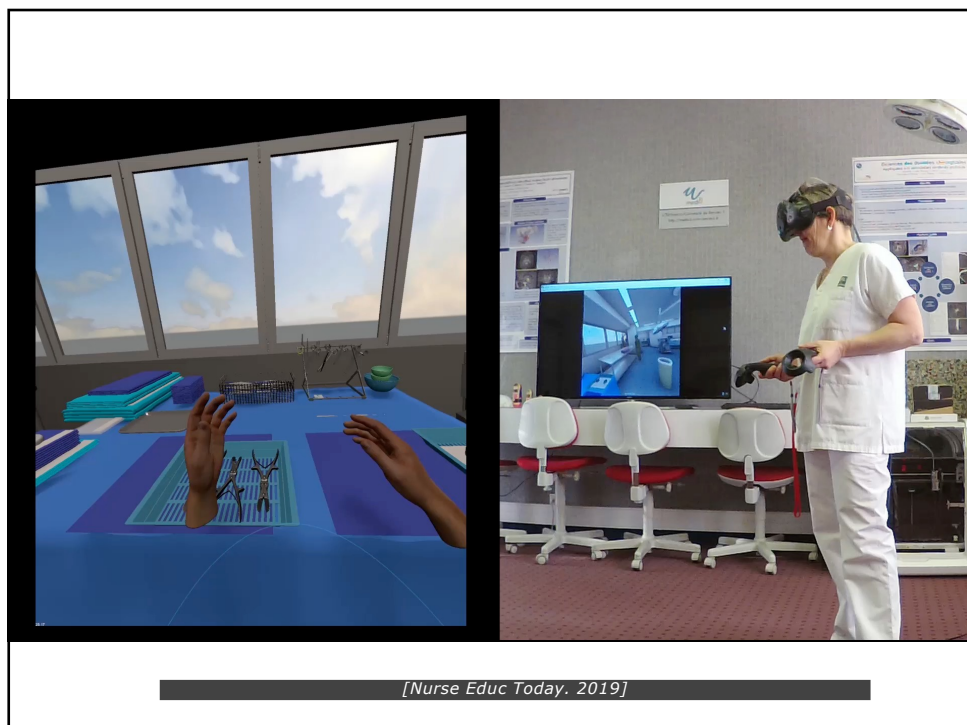
100



101



102



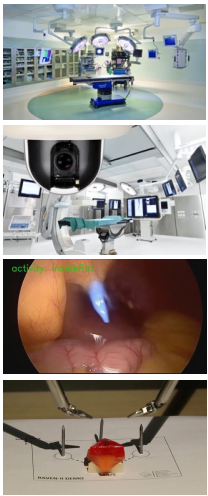
103



105

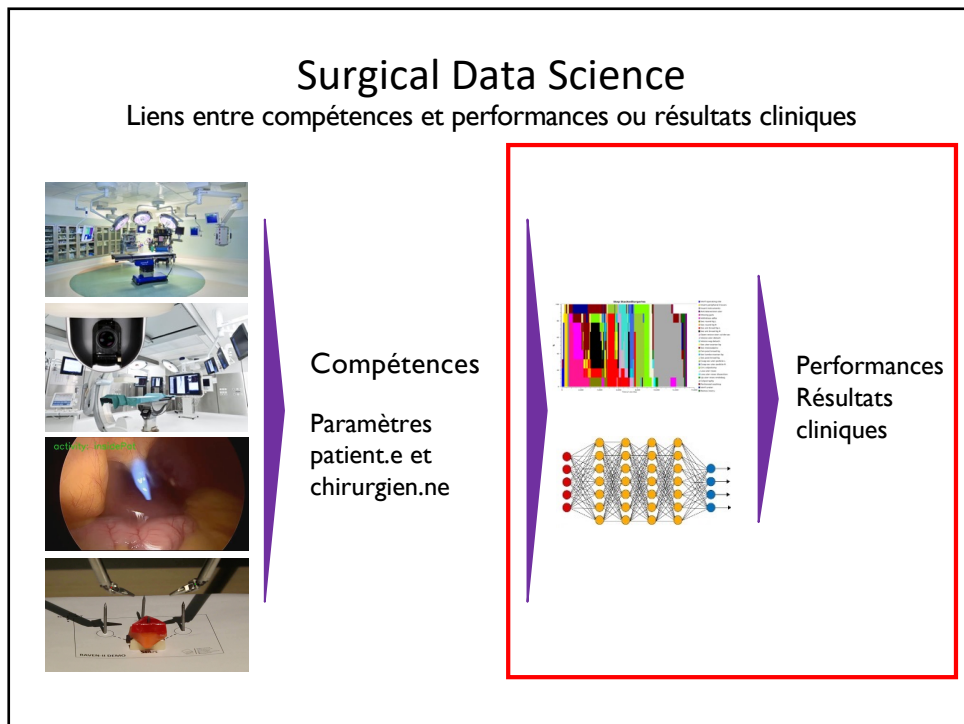
Surgical Data Science

Liens entre compétences et performances ou résultats cliniques



Compétences
Paramètres
patient.e et
chirurgien.ne

106



107

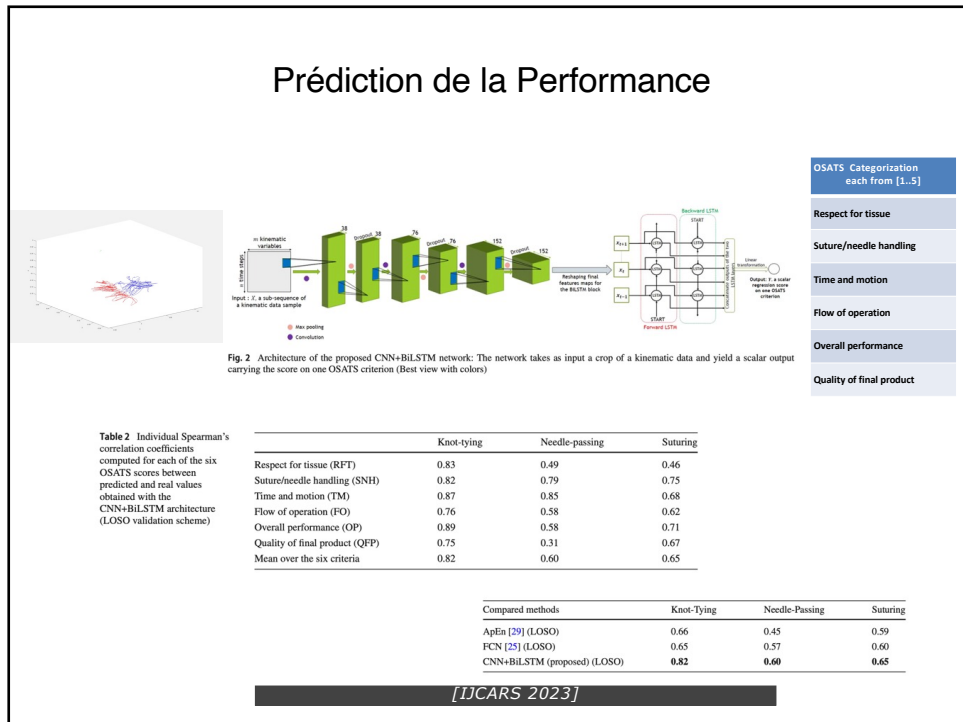
Prédiction de l'Expertise

Trajectory of the right tool tip

Submission to AIME 2017 - for review purposes - video from JIGSAWS/JHU

[AIME 2018]

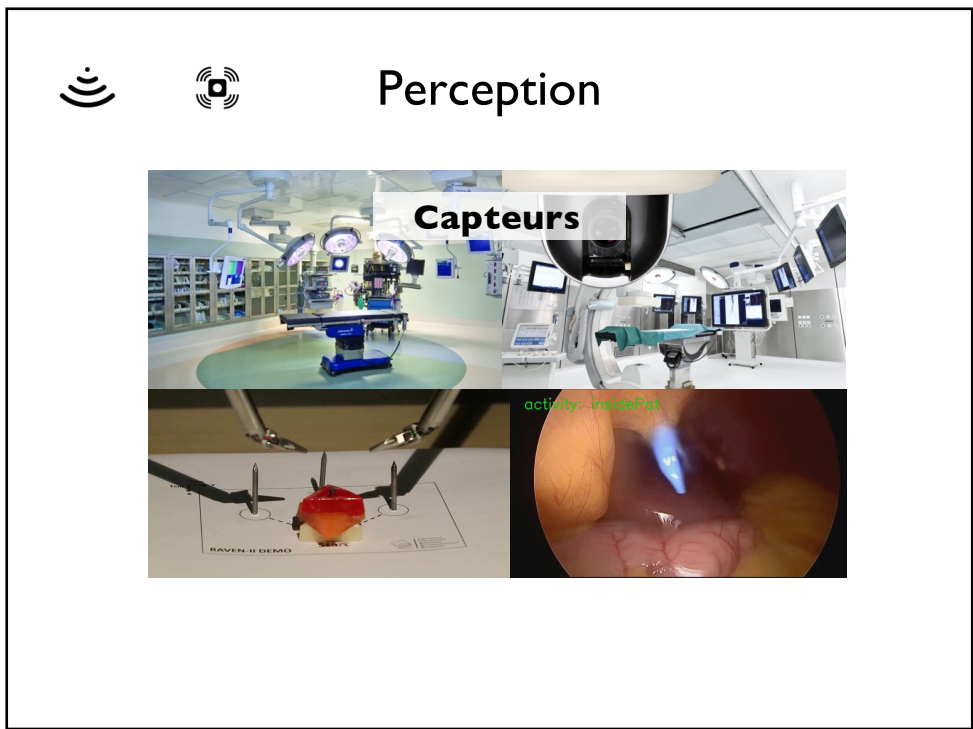
108



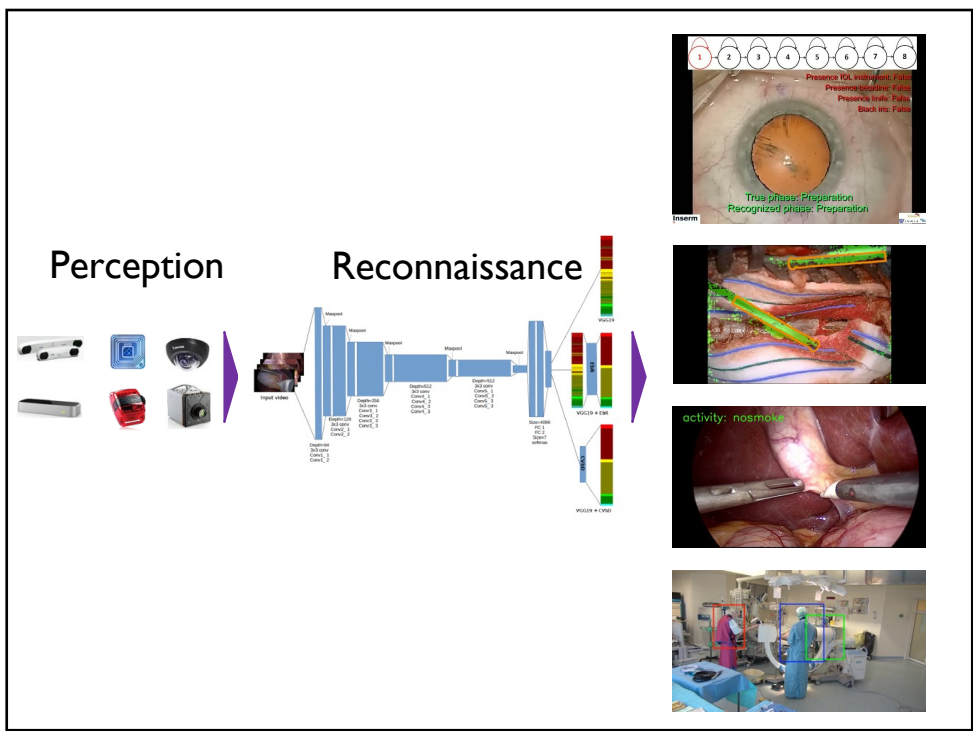
109

Evaluation et formation continues

110



111



112

Prédiction de la Qualité Chirurgicale

International Journal of Computer Assisted Radiology and Surgery (2020) 15:39–47
<https://doi.org/10.1007/s11548-019-02072-3>

ORIGINAL ARTICLE

Predicting the quality of surgical exposure using spatial and procedural features from laparoscopic videos

Feature name	Feature type	Feature count	Segment	Feature name	Feature type	Feature count	Effector count
Perimeter	Int	1	10	Mean/std activities duration	Float	2	4
Surface	Int	1	10	Activity zero-order entropy	Float	1	
Barycenter	Int	2	10	Activity first-order entropy	Float	1	
Main directions	Float	5	10	Triplet of longest/shortest activity	String	6	
Texture	Int	1	10	Exposure duration	Int	1	1
Color	Int	3	10	Count of activity pattern	Int	11	
				Count of verb pattern	Int	10	
				Count of target pattern	Int	16	

[A. Derathe et al., IJCARS 2020, IJCARS 2021]

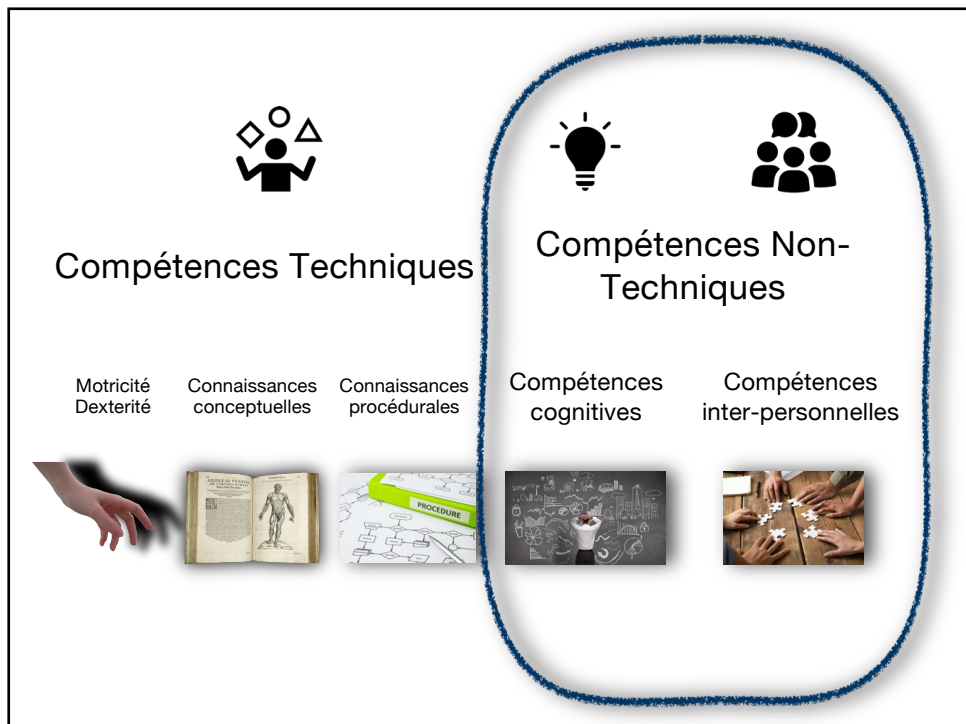
113

Prédiction de Déviations

Artificial Intelligence in Medicine (AI) (2020) 10:887
 Contents lists available at ScienceDirect
 Artificial Intelligence in Medicine
 journal homepage: www.elsevier.com/locate/artmed

Offline identification of surgical deviations in laparoscopic rectopexy
 Arnaud Huard^{a,*}, Pierre Jansin^{b,c}, Fabian Becker^a, Jean-Luc Faucher^a,
 Alexandre Moreau Gaudry^{a,d}, Sandrine Voron^a

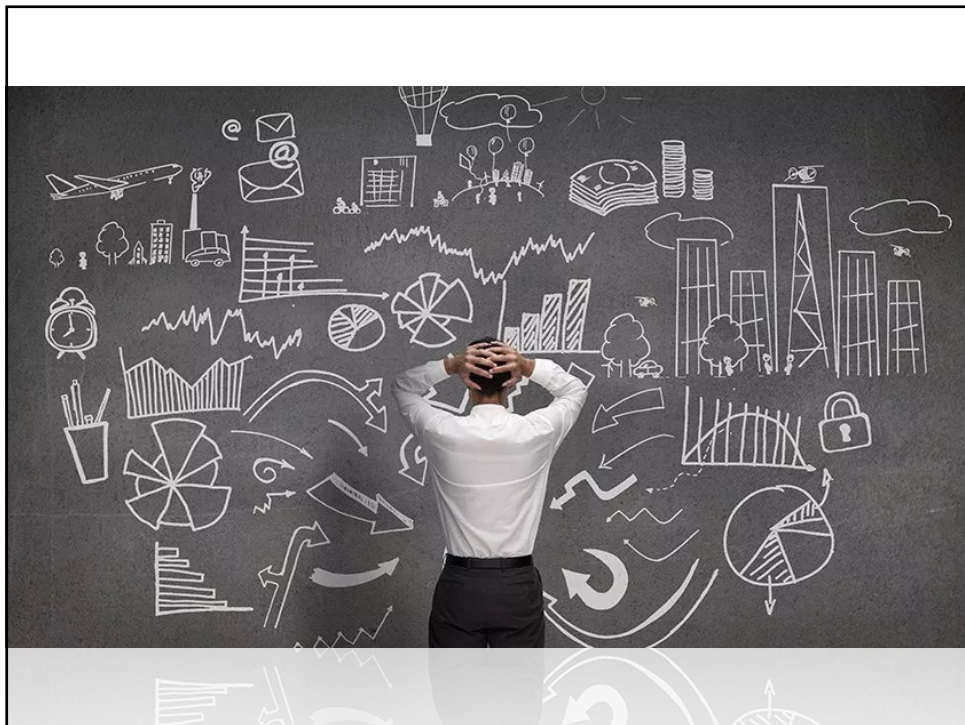
114



115



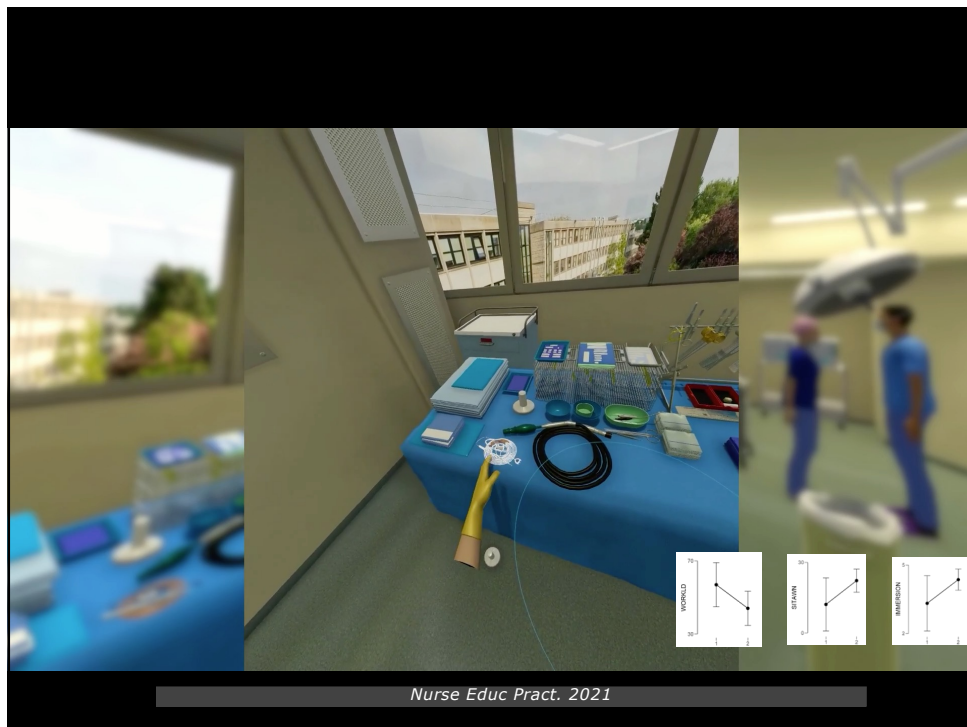
116



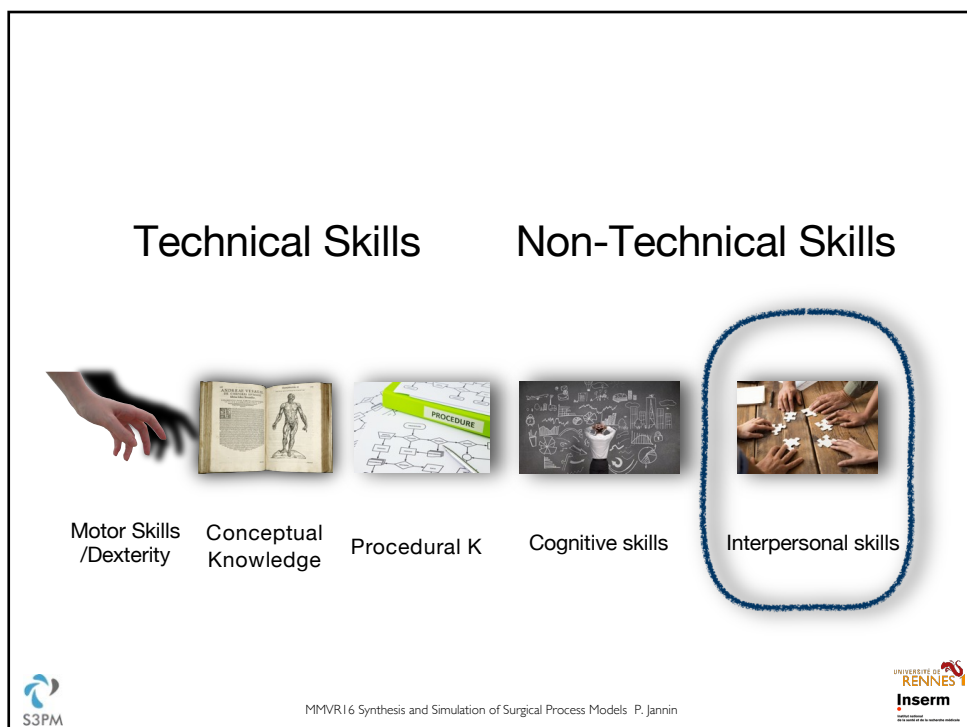
117



118



119



121

Communication



Clin Simul Nurs. 2021.

122



[IJCARS 2023]

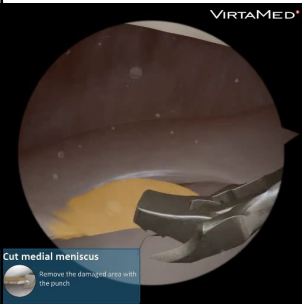
123

Limits of simulators for dexterity skills


NOVICE	CONFIRMÉ	EXPERT																																																																																																																																																																																				
<p>Résumé Guided meniscectomy II</p> <p>Date du rapport : 21/05/2023, 13:00</p> <p>Simulation overview</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Procedure time</td><td>01:51</td><td>≤ 03:00</td><td>20/20</td></tr> </table> <p>Meniscus cutting</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Optimal medial region</td><td>99%</td><td>≥ 95%</td><td>10/10</td></tr> <tr><td>Healthy medial region</td><td>0%</td><td>≤ 5%</td><td>10/10</td></tr> </table> <p>Safety</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Arthroscopy instruments movement observed</td><td>75%</td><td>≥ 70%</td><td>10/10</td></tr> <tr><td>Misalignment time of scope horizon</td><td>11%</td><td>≤ 5%</td><td>10/10</td></tr> <tr><td>Scratching of femur cartilage</td><td>1%</td><td>≤ 8%</td><td>10/10</td></tr> <tr><td>Scratching of tibia cartilage</td><td>0%</td><td>≤ 4%</td><td>10/10</td></tr> </table> <p>Economy</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Camera path length</td><td>22.8 cm</td><td>≤ 25 cm</td><td>10/10</td></tr> <tr><td>Probe path length</td><td>11.7 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Punch path length</td><td>36 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Shaver path length</td><td>18.8 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> </table> <p><i>Un Geste peu maîtrisé</i></p>	Nom	Mesure	Valeur de l'objectif	Score	Procedure time	01:51	≤ 03:00	20/20	Nom	Mesure	Valeur de l'objectif	Score	Optimal medial region	99%	≥ 95%	10/10	Healthy medial region	0%	≤ 5%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Arthroscopy instruments movement observed	75%	≥ 70%	10/10	Misalignment time of scope horizon	11%	≤ 5%	10/10	Scratching of femur cartilage	1%	≤ 8%	10/10	Scratching of tibia cartilage	0%	≤ 4%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Camera path length	22.8 cm	≤ 25 cm	10/10	Probe path length	11.7 cm	≤ 50 cm	10/10	Punch path length	36 cm	≤ 50 cm	10/10	Shaver path length	18.8 cm	≤ 50 cm	10/10	<p>Résumé Guided meniscectomy II</p> <p>Date du rapport : 17/06/2023, 08:38</p> <p>Simulation overview</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Procedure time</td><td>01:31</td><td>≤ 03:00</td><td>20/20</td></tr> </table> <p>Meniscus cutting</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Optimal medial region</td><td>100%</td><td>≥ 95%</td><td>10/10</td></tr> <tr><td>Healthy medial region</td><td>1%</td><td>≤ 5%</td><td>10/10</td></tr> </table> <p>Safety</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Arthroscopy instruments movement observed</td><td>75%</td><td>≥ 70%</td><td>10/10</td></tr> <tr><td>Misalignment time of scope horizon</td><td>6%</td><td>≤ 5%</td><td>10/10</td></tr> <tr><td>Scratching of femur cartilage</td><td>1%</td><td>≤ 8%</td><td>10/10</td></tr> <tr><td>Scratching of tibia cartilage</td><td>0%</td><td>≤ 4%</td><td>10/10</td></tr> </table> <p>Economy</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Camera path length</td><td>9 cm</td><td>≤ 25 cm</td><td>10/10</td></tr> <tr><td>Probe path length</td><td>12.8 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Punch path length</td><td>34.4 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Shaver path length</td><td>14 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> </table> <p><i>Un Geste non reconnu par le simulateur</i></p>	Nom	Mesure	Valeur de l'objectif	Score	Procedure time	01:31	≤ 03:00	20/20	Nom	Mesure	Valeur de l'objectif	Score	Optimal medial region	100%	≥ 95%	10/10	Healthy medial region	1%	≤ 5%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Arthroscopy instruments movement observed	75%	≥ 70%	10/10	Misalignment time of scope horizon	6%	≤ 5%	10/10	Scratching of femur cartilage	1%	≤ 8%	10/10	Scratching of tibia cartilage	0%	≤ 4%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Camera path length	9 cm	≤ 25 cm	10/10	Probe path length	12.8 cm	≤ 50 cm	10/10	Punch path length	34.4 cm	≤ 50 cm	10/10	Shaver path length	14 cm	≤ 50 cm	10/10	<p>Résumé Guided meniscectomy II</p> <p>Date du rapport : 04/05/2023, 08:07</p> <p>Simulation overview</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Procedure time</td><td>01:07</td><td>≤ 03:00</td><td>20/20</td></tr> </table> <p>Meniscus cutting</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Optimal medial region</td><td>99%</td><td>≥ 95%</td><td>10/10</td></tr> <tr><td>Healthy medial region</td><td>3%</td><td>≤ 5%</td><td>10/10</td></tr> </table> <p>Safety</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Arthroscopy instruments movement observed</td><td>68%</td><td>≥ 70%</td><td>10/10</td></tr> <tr><td>Misalignment time of scope horizon</td><td>2%</td><td>≤ 5%</td><td>10/10</td></tr> <tr><td>Scratching of femur cartilage</td><td>1%</td><td>≤ 8%</td><td>10/10</td></tr> <tr><td>Scratching of tibia cartilage</td><td>0%</td><td>≤ 4%</td><td>10/10</td></tr> </table> <p>Economy</p> <table border="1"> <tr><td>Nom</td><td>Mesure</td><td>Valeur de l'objectif</td><td>Score</td></tr> <tr><td>Camera path length</td><td>11.5 cm</td><td>≤ 25 cm</td><td>10/10</td></tr> <tr><td>Probe path length</td><td>17.1 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Punch path length</td><td>31.2 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> <tr><td>Shaver path length</td><td>24.2 cm</td><td>≤ 50 cm</td><td>10/10</td></tr> </table> <p><i>Un Geste sûr</i></p>	Nom	Mesure	Valeur de l'objectif	Score	Procedure time	01:07	≤ 03:00	20/20	Nom	Mesure	Valeur de l'objectif	Score	Optimal medial region	99%	≥ 95%	10/10	Healthy medial region	3%	≤ 5%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Arthroscopy instruments movement observed	68%	≥ 70%	10/10	Misalignment time of scope horizon	2%	≤ 5%	10/10	Scratching of femur cartilage	1%	≤ 8%	10/10	Scratching of tibia cartilage	0%	≤ 4%	10/10	Nom	Mesure	Valeur de l'objectif	Score	Camera path length	11.5 cm	≤ 25 cm	10/10	Probe path length	17.1 cm	≤ 50 cm	10/10	Punch path length	31.2 cm	≤ 50 cm	10/10	Shaver path length	24.2 cm	≤ 50 cm	10/10
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Procedure time	01:51	≤ 03:00	20/20																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Optimal medial region	99%	≥ 95%	10/10																																																																																																																																																																																			
Healthy medial region	0%	≤ 5%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Arthroscopy instruments movement observed	75%	≥ 70%	10/10																																																																																																																																																																																			
Misalignment time of scope horizon	11%	≤ 5%	10/10																																																																																																																																																																																			
Scratching of femur cartilage	1%	≤ 8%	10/10																																																																																																																																																																																			
Scratching of tibia cartilage	0%	≤ 4%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Camera path length	22.8 cm	≤ 25 cm	10/10																																																																																																																																																																																			
Probe path length	11.7 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Punch path length	36 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Shaver path length	18.8 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Procedure time	01:31	≤ 03:00	20/20																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Optimal medial region	100%	≥ 95%	10/10																																																																																																																																																																																			
Healthy medial region	1%	≤ 5%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Arthroscopy instruments movement observed	75%	≥ 70%	10/10																																																																																																																																																																																			
Misalignment time of scope horizon	6%	≤ 5%	10/10																																																																																																																																																																																			
Scratching of femur cartilage	1%	≤ 8%	10/10																																																																																																																																																																																			
Scratching of tibia cartilage	0%	≤ 4%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Camera path length	9 cm	≤ 25 cm	10/10																																																																																																																																																																																			
Probe path length	12.8 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Punch path length	34.4 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Shaver path length	14 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Procedure time	01:07	≤ 03:00	20/20																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Optimal medial region	99%	≥ 95%	10/10																																																																																																																																																																																			
Healthy medial region	3%	≤ 5%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Arthroscopy instruments movement observed	68%	≥ 70%	10/10																																																																																																																																																																																			
Misalignment time of scope horizon	2%	≤ 5%	10/10																																																																																																																																																																																			
Scratching of femur cartilage	1%	≤ 8%	10/10																																																																																																																																																																																			
Scratching of tibia cartilage	0%	≤ 4%	10/10																																																																																																																																																																																			
Nom	Mesure	Valeur de l'objectif	Score																																																																																																																																																																																			
Camera path length	11.5 cm	≤ 25 cm	10/10																																																																																																																																																																																			
Probe path length	17.1 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Punch path length	31.2 cm	≤ 50 cm	10/10																																																																																																																																																																																			
Shaver path length	24.2 cm	≤ 50 cm	10/10																																																																																																																																																																																			

124


Limits of simulators for dexterity skills



LE NOVICE (SCORE 90/90)
Un Geste peu maîtrisé



LE CONFIRMÉ (SCORE 89/90)
Un Geste non reconnu par le simulateur



L'EXPERT (SCORE 90/90)
Un Geste sûr

125

Perception
Capteurs

✓Heart rate Belt ✓RGB-D cameras ✓EMG sensors ✓Eye tracking

Stress Ergonomie Effort, Fatigue Eye gaze

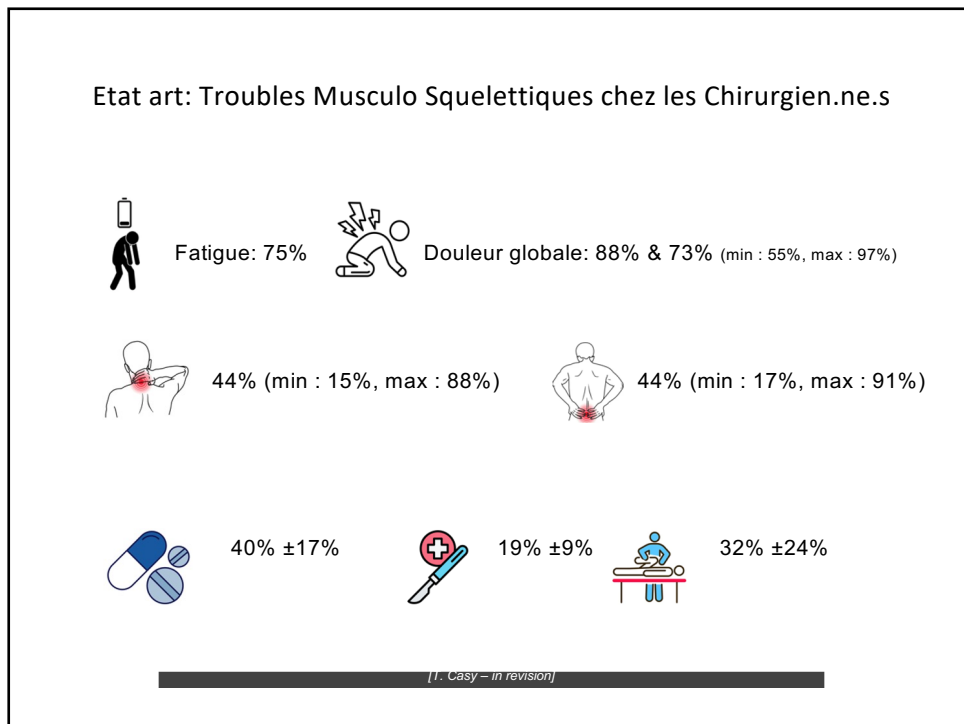
126

✓Heart rate Belt ✓RGB-D cameras ✓EMG sensors

Indirect measure of stress Ergonomie Fatigue and effort

82

128



129

“Stand-up straight !”: Human pose estimation to evaluate postural skills during orthopedic surgery simulations

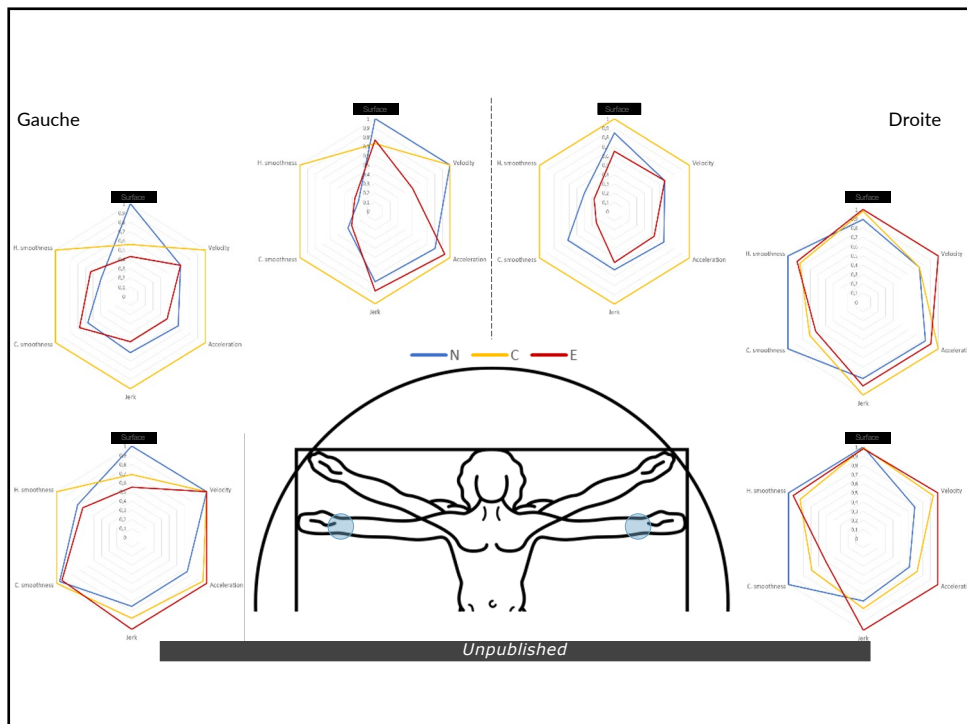
Tiphaine Casy, Alexandre Tronchot, Hervé Thomazeau, Xavier Morandi, Pierre Jannin, Arnaud Huaultmé

Supplementary material

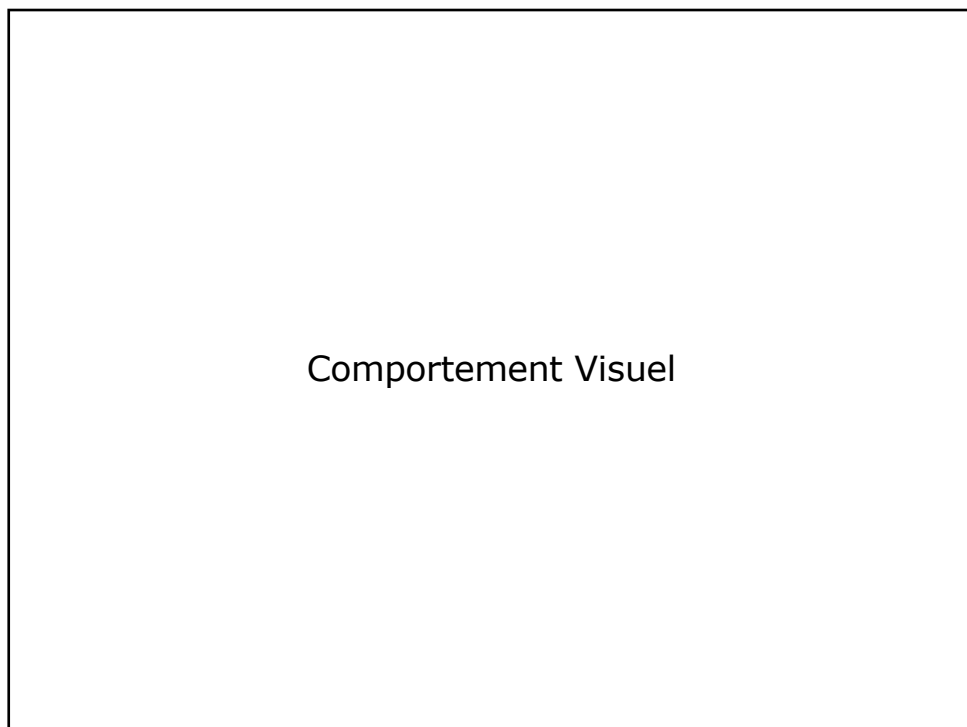
Dots and lines representation of human pose estimation of one surgeon during orthopedic simulation with a modified OpenPose algorithm

IJCARS 2022

130

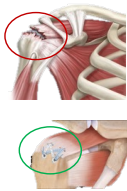


131

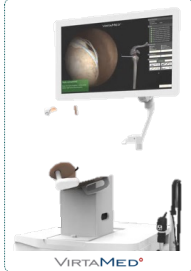


132

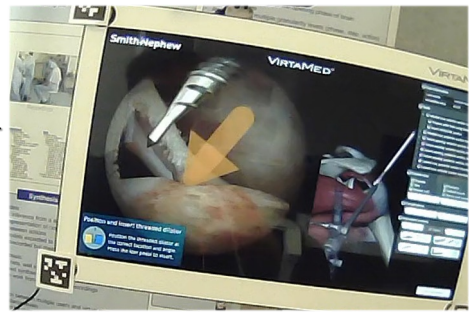
Arthroscopie




1 double row cuff repair




VIRTAMED®






30 fps



120 fps




PupilLabs

[IJCARs 2023]

133

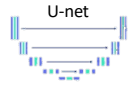
Arthroscopie



3,608 annotated frames

- Training : 622
- Validation : 266
- Test : 2,720

} 2 sessions
→ 23 sessions



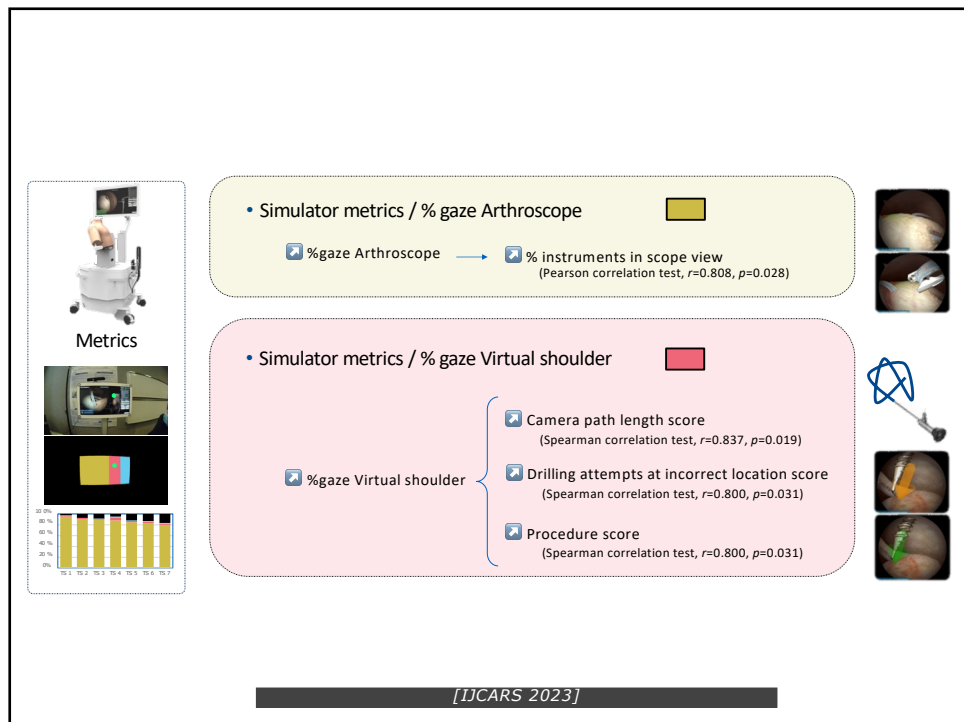
U-net

Average IoU on the test dataset:

	Arthroscope	97.5 %
	Virtual shoulder	93.7 %
	Information	95.5 %

[IJCARs 2023]

134



135

Impact IA sur l'apprentissage: Simulation

- **Compétence ciblée – Public ciblé**
- **Scénario d'apprentissage**
- **Réalisme visuel, haptique, procédural, immersif**
- **Métriques d'évaluation**
- **Retour**
- **Schéma pédagogique**
- **Validité/Validation/Evaluation**
- ...

136

136

Impact IA sur l'apprentissage: Autres

- **Outils**
 - RV
 - IAG
 - Capteurs
- **Formation initiale et continue**

137

137

Oui, Mais ...

138

138

