

ALMA MATER STUDIORUM Università di Bologna

Human-centric Al foundations: grounded feature engineering

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Al's double-clutching

Al double-clutching (lack of sync in gear shifting) AI lacks grounding! #1 No tacit knowledge representable propositionally: semantics misses the real thing Polanyi's paradox, Dreyfus, Searle, Harnad, ... "our tacit knowledge of how the world works often exceeds our explicit understanding" (Polanyi 1966) "how can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads?" (Harnad 1999) Al lacks grounding! #2 No explicit knowledge represented in learning from signal: no semantics at all Gary Marcus and many others **DOUBLE CLUTCHING** 6677

Is SYMbolic/SUBsymbolic integration a possible solution to resync AI gear shifts? What is grounding, after all? A few operational clarifications













vector spaces, embeddings, attention networks)

Google Translate



Universal Dependencies:

	PRON	ensubj	PRON
1	I	love	you

In a symAl system, a representation might be a primitive, an expression, an axiom set, etc., which has possible interpretations/models

aime .03 .95



In a subAl system, a representation is typically a <u>distributed pattern of activation</u> over a set of nodes (e.g.







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Symbol grounding: the background of meaning processing

Extensional/Externalist grounding (things, not strings!) Intensional/Internalist grounding (cognition as naming, or as sensorimotor theories? cf. Harnad)

- Perceptual, experiential, sensorimotor grounding (cognition is grounded in content: sensory experiences, cf. Harnad, Barsalou's simulators)
- Embodiment (cognition is grounded on schematic embodiment, cf. cognitive semantics, image schemas, conceptual blending, ...)

Multimodal grounding: how to get a *sensorium closure* in SYM, SUB, or SYMSUB paradigms?



Descartes, Traité de l'homme, 1664



And it is happening :)

2012)

Judea Pearl's causal grounding, example paper

Deb Roy's robotic grounding work

Grounded machine reading, e.g. the <u>FRED/Framester</u> integration

Mirella Lapata's experientialist NLP <u>manifesto</u>

Deep Mind's symbolic behaviour <u>manifesto</u>

<u>Traincrease</u> project on the grounding of abstract concepts

Yejin Choi's Allen Institute <u>Unicorn commonsense model</u>

Knowledge graphs as an infrastructure for the Web (cf. Google's Amit Singhal "things, not strings",

A lot is still on arXiv ...



Pearl' causal grounding

"Current machine learning systems operate, almost exclusively, in a statistical, or model-free mode, which entails severe theoretical limits on their power and performance ... To achieve human level intelligence, learning machines need the guidance of a model of reality"



Roy's grounded robot communication

"Generalized Grounding Graphs represent the grounding for a linguistic constituent ... to find the most probable groundings $y_1 \dots y_N$ given a parsed natural language command Λ and the robot's model of the environment, Λ "

 $\operatorname*{argmax}_{\gamma_1} p(\gamma_1 \dots \gamma_N | \Lambda, M)$

 $\gamma_1...\gamma_N$

each γ_i is a tuple (g, p, t), where

g is a three-dimensional shape

 $p \in R^{T \times 7}$ is a sequence of a trajectory *T* points in *g*, It consists of a tuple ($\tau, x, y, z, roll, pitch, yaw$) representing the location and orientation of *g* at time τ (with location interpolated linearly across time). The combination of the shape *g* and the trajectory *T* defines a three-dimensional region in the environment corresponding to the object at each time step. *t* is a set of pre-defined textual tags { *tag1*, ..., *tagM* }, output of perceptual classifiers, such as object recognizers or scene classifiers. For example, noun phrases map to objects; prepositional phrases map to places or paths; verb phrases map to events



$$p(\gamma_1 \dots \gamma_N | \Lambda, M) = rac{1}{Z} \prod_m \psi_m (\lambda_m, \gamma_{m_1} \dots \gamma_{m_k})$$

Kollar et al., Generalized Grounding Graphs, JAIR, 2013



FRED/Framester automated grounding of knowledge graphs extracted from text





Hybrid feedback loop



TAILOR H2020 Network of AI Excellence Centres H2020 SPICE Project





Geometrical semantics

Model-theoretical semantics

owl:Thing

cis:CulturalEntity or dul:Quality or vir:IC9_Representation or PartOf some cis:CulturalEntity) or cis:CollectionCulEnt or xpression or frbr:Manifestation or cis:CulturalEvent

cc:CuratorialContext



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