The Minimal Cognitive Grid^{+}, Universal Cognition and Perceptual Performance

(extended abstract)

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Abstract

Lieto's Minimal Cognitive Grid (MCG) for assessing artificial agents, augmented as the method MCG^{+}, has two implications: (1) MCG^{+} can advance the mathematical science of universal intelligence/cognition. (2) (a) pre-Lieto, this science lacks of coverage of perception; (b) heralded artificial agents of today are devoid of human-level perceptual intelligence.

In *Cognitive Design for Artificial Minds*, Lieto (2021) introduces the Minimal Cognitive Grid (MCG); applied to artificial agents[1] produced by either computational cognitive science (CCS) or AI it returns verdicts regarding the intelligence and explanatory power of these agents. Lieto e.g. applies MCG to the Watson system and AlphaGo; in both, MCG reveals acute deficiencies.[2] MCG applies three sub-metrics to a given artificial agent $\mathfrak{a}$: (i) **ratio** of functional to structural components; (ii) level of **generality** (higher the more cognitive faculties meaningfully present in the agent); and (iii) how well the agent **performs**, as determined by tests in line with Psychometric AI (Bringsjord & Schimanski 2003).[3]

We have augmented and formalized MCG, to produce a method for determining, precisely, what can be viewed as the overall cognitive power of an artificial agent. The method is MCG$^+$; its application to the agents Lieto has analyzed with MCG yields formal outcomes concordant with his. A glimpse of the method's anatomy is afforded by Table 1 in Appendix A, but it suffices for our present purpose to suggestively write

$$\text{MCG}^+[\mathfrak{a}] = \Pi_{\mathfrak{a}}$$

to indicate the overall cognitive power Π of an artificial agent.[4] That purpose is to put into discussion in CCS and AI two implications of Lieto's framework, and MCG$^+$.

The first implication is that while hitherto no scholars to our knowledge have noticed that Lieto's framework relates directly to the mathematical science of universal intelligence and cognition, it does, in a substantive, consequential way. E.g., the formal theory of *universal artificial intelligence* given by Hutter (2005) and elaborated in (Legg & Hutter 2007), identifies the intelligence of an artificial agent $\mathfrak{a}$ with the level of reward maximization achievable by that agent across environments,

$$\Upsilon[\mathfrak{a}] = \sum_{\mu \in Envs} weight \cdot reward(\mathfrak{a}, \mu)$$

which completely ignores the rich, nuanced, and illuminating information returned by the application of MCG$^+$ to some agent $\mathfrak{a}$. Put starkly and simply, it's entirely possible for the cognitive power of some agent by MCG$^+$, $\Pi_{\mathfrak{a}}$, to be vanishingly small, while Hutter's framework Υ declares the agent maximally intelligent. This profound divergence surely must be investigated.

The second implication is that if MCG or MCG$^+$ adopted, one sees that AI agents of today receiving much attention display a serious deficiency: they are devoid of one of the chief cognitive faculties that make human agents cognitively powerful: the ability to, in an environment, attend to and perceive objects therein ways that enable and inform other cognitive faculties (such as reasoning and decision-making).[5]

[1] One could also refer to artificial *systems*, but the term 'agent/s' is the established, orthodox one, and we employ it.

[2] In this pair of cases, use of MCG e.g. yields the verdict that the system, despite pronouncements that they bring an age of "cognitive computing," do nothing of the sort, since cognition is nowhere to be seen in either case; see Chap. 4 of (Lieto 2021). Subsequent to the book, Lieto (2022) has applied MCG to bionic systems, work that from the standpoint of the history of CCS science is quite interesting — but likewise beyond the present document.

[3] And as set out and explored in subsequent papers, e.g. (Bringsjord & Licato 2012, Bringsjord 2011).

[4] In the fuller description of our research, we marry cognitive power as gauged by MCG/MCG$^+$ with *universal cognitive intelligence*, set out in (Bringsjord, Govindarajulu & Oswald 2023).

[5] E.g. the often-praised GPT-k series of artificial agents from OpenAI are unable to answer the sample questions we give momentarily regarding the scene in Fig. 2 — yet these are questions many humans, even very young ones, have little trouble with.

To concretize this second implication, we can employ the performance-by-test part of MCG/MCG$^+$: Imagine an agent spends a minute trying to memorize the objects shown in Figure 2.

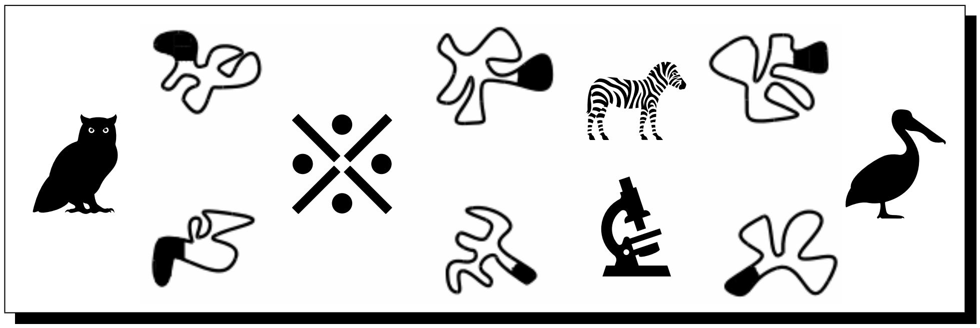

Figure 1: A Visual Scene for Memorization. *Our agent studies this visual scene in an attempt to memorize the objects therein over the course of one minute. (Scene is a variant of those used on the STB test at Johns Hopkins University; see next figure.*

Many cognition-probing questions (or — the psychometric term — 'stems') can be asked about the scene. For instance, without looking back at it: Were there less than seven birds? Was there a zebra right of a bird? Was there an artifact commonly used to enhance human vision below at least two objects? There are also questions used on the test from which we draw; e.g., see Figure 2.

In the larger paper summarized here, the perception lacuna revealed by Lieto's work is addressed by turning to the ARCADIA cognitive architecture (Lovett, Bridewell & Bello 2019), which places perception at the heart of the cognitive faculties.

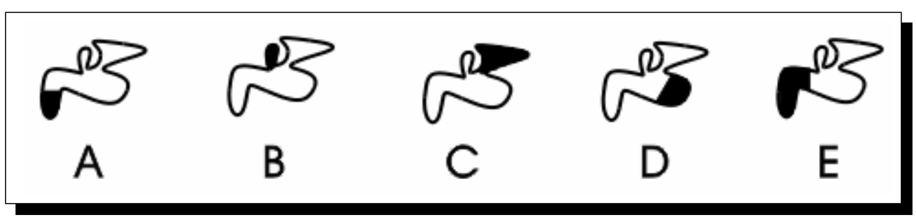

Figure 2: A Set of Options for a Sample Item on the Spatial Test Battery (STB). *Without looking back, which object appeared in the scene you sought to memorize? (STB, was developed by CTY at Johns Hopkins University for human agents; for info, go to https://cty.jhu.edu/testing/stb.)*

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A A Glimpse of the Minimal Cognitive Grid$^+$

Functional/Structural Ratio	Generality	Performance
$F:T, c_1^{\mathfrak{a}}; F:T, c_2^{\mathfrak{a}}, \ldots, F:T, c_k^{\mathfrak{a}}$	$\lvert\{\text{cog-fac}_1, \ldots, \text{cog-fac}_m\}\rvert$	$\sum_1^n \sigma_i$, where $\langle T_1(\mathfrak{a}) = \sigma_1, \ldots, T_n(\mathfrak{a})\rangle = \sigma_n$

Table 1: Simplified, Partial View of MCG$^+$, An Augmented and Formalized Version of Lieto's MCG. *We let '$\mathfrak{a}$' denote an arbitrary artificial agent. Given a certain level L of description from which to view $\mathfrak{a}$, certain components of the agent are visible and analyzable; these components are $c_1^{\mathfrak{a}}, c_2^{\mathfrak{a}} \ldots$, and each has a ratio. We use $|X|$ in customary fashion to denote the cardinality of set X. (The sheer presence of a cognitive faculty in a given agent provides data inadequate for a meaningful measure. The full version of MCG$^+$ treats each cognitive faculty as the node in a hypergraph $\mathscr{H}$, with directed edges/links from cog-fac$_i$ to cog-fac$_j$ indicating data flow from the former to the latter, and bidirectional edges indicating interoperability between such a pair. We then use arithmetic functions over standard measures (e.g. see Berge 1989) of $\mathscr{H}$, e.g. over its number of nodes and edges, to give a formal measure of Lieto's conception of generality.) Each σ_i is a score; the simplified view shown here leaves aside the composite function mapping scores to combined on. The end result is that given any artificial agent $\mathfrak{a}$, the application of MCG$^+$ to that agent, MCG$^+[\mathfrak{a}]$ yields a single, all-encompassing natural-number value.*