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Characterising Computational Creativity

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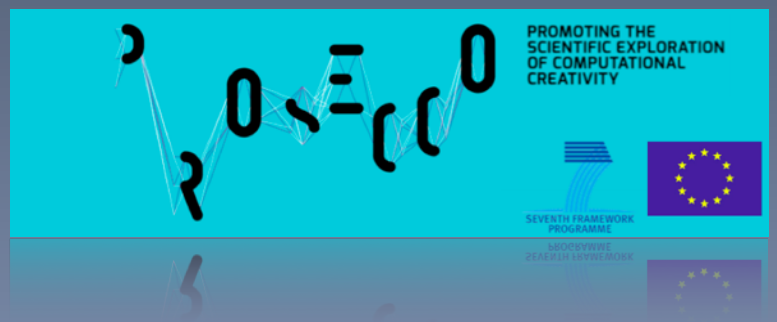

Overview of Lecture

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- Aims
  - to motivate the scientific study of creative behaviour
  - to give a framework within which to consider the rest of the course
- Contents
  - Some computational creativity
  - Background – Boden's model of creativity
  - Formalising exploratory creativity
  - The relationship between exploratory and transformational creativity
  - Classifying the failure to be creative
  - Motivating transformational creativity

Claim

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- Creativity is one of the things that makes humans human
- If we are to understand ourselves, we need to understand creativity, both as a cognitive and a social phenomenon
- Enabling computers to create will
  - make them more useful
  - help us to understand ourselves

History

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- For the past five decades, we have been engaged in the study of Artificial Intelligence (AI)
- Weak AI aims to study and simulate behaviours which, in humans, are called intelligent
- Strong AI aims to create intelligence itself

Anecdote

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- For many computer scientists, (even weak) AI is anathema
  - sometimes because it involves formally incomplete and/or unsound approaches
  - sometimes because intelligent behaviour is "just too human" to be copied or created by machine
- Nevertheless, AI technology is to be found working in many practical scientific and commercial computer systems

Anecdote

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- And many staunch believers in (at least weak) AI do not believe in the simulation of creativity
- When I have asked such people why computers cannot be creative, the only answer has been "because they just can't!"

Anecdote

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- In other words, creativity seems to be too close to the nature of humanity even for some AI-believers
- Computational Creativity is to AI-people what AI is to CS-people!

Definitions?

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- Perhaps this is simply a matter of definition: “creativity =def something done by humans”
- But if we look at what seems to constitute creativity in humans (viz. novelty and value in context) there is no apparent a priori reason why a computer cannot be creative

Double standards?

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- So it seems that we are aiming at a moving target when we use the word "creative"
- In particular, both value and novelty are relative concepts, relative to
  - the creator
  - the observer
  - the context

So what are we doing?

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- My preferred definition of our field is (Wiggins, 2006):
  - "The support, study and simulation, by computational means, of behaviours which would be deemed creative if exhibited by a human"
    - NB this does not imply that creativity is limited to things that can be done by a human!
- Updated by Colton and Wiggins (2012):
  - "The philosophy, science and engineering of computational systems which, by taking on particular responsibilities, exhibit behaviours that unbiased observers would deem to be creative."

An AI model of creativity

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- Margaret Boden was the first artificial intelligence (AI) researcher to approach creativity seriously
  - in *Artificial Intelligence and Natural Man*, Boden, 1977
- Her 1990 book, *The Creative Mind*, outlines a broad characterisation of creative behaviour
- However, the characterisation is rather vague, since the discussion is more philosophical than scientific
- The aim here is to cast Boden's characterisation in more precise terms

The conceptual space

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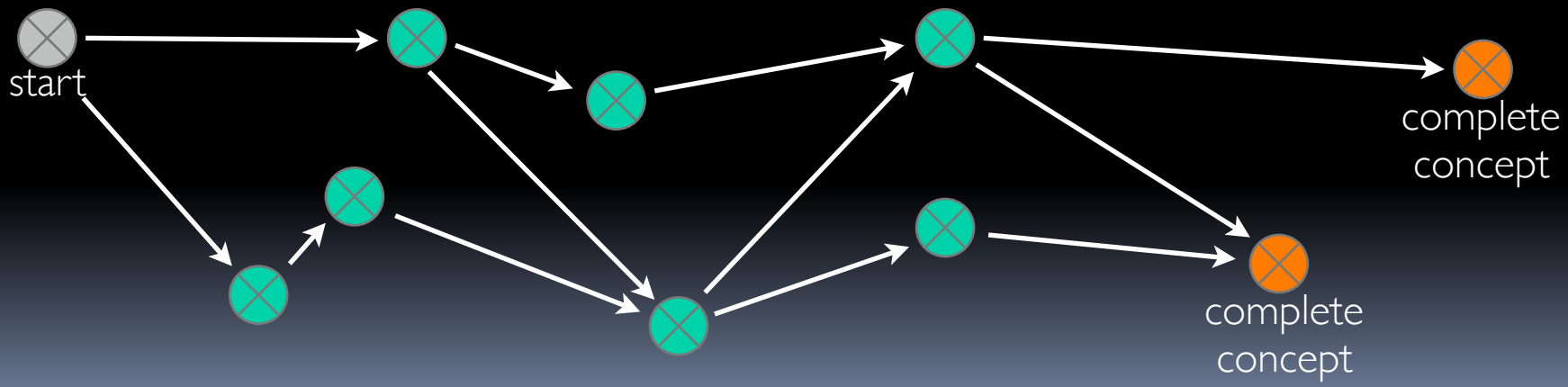
- Creative activity is cast as the discovery of *concepts* in a *conceptual space*
- The conceptual space contains all the possible concepts available to the creative agent
- The space is defined/constrained by rules
- *Exploratory creativity* is defined as the action of searching the conceptual space for a new concept
- This is an *abstraction* - no strong claim that it works this way in minds/



Transformational creativity

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- An alternative kind of Boden creativity is *transformational creativity*
- This is where the rules defining the conceptual space are changed so as to create a different (but presumably related) space
- Boden suggests that transformational creativity is more significant than exploratory creativity, because it is in a sense "bigger thinking"
- Bundy (1998) and Wiggins (2006b) argue against this, as an overly simple definition

Reasons why not

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- "A symbolic system cannot create new concepts"
  - weighted semantic networks allow us freely to define new concepts in terms of old ones
  - conceptual blending allows us to create new semantic structures directly
  - geometrical representations of meaning allow arbitrary interpolation between concepts (e.g., Gärdenfors, 2000)
    - though we do need to think carefully about what the resulting representations mean!!

Reasons why not

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- "A system which is exploring a search space defined by a representation is not being creative"
  - not necessarily true: it depends on the expressive power of the representation
  - creating an artefact by *explicit mechanistic inference* doesn't make doing so any less creative
  - cognitively speaking, creative insight does not "feel" like enumeration
    - but such introspection is almost always misleading

Reasons why not

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- "Non-symbolic systems generalise via a simple mathematical process, which is not creative"
  - There is no evidence that the human mind does not create in this way
  - There are suggestions (e.g., Kanerva's sparse distributed memory) that this is exactly how the human mind creates
  - Anyway, interpolation and generalisation may be a perfectly good model of creativity

Formalising Boden's model

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- Let us represent the conceptual space as a multidimensional (possibly metric) space
- Partial and complete concepts are represented as points in the space
- Each dimension of the space represents a feature of the domain
- (So each point denotes a set of property/value pairs)

Defining a conceptual space

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- Suppose now that we have a set of rules, **R**, which defines a conceptual space, **C**
- The existence of transformational creativity implies that there must be a larger set, **U**, containing **C**
- So **R** is a set of rules which picks the elements of **C** from **U**
- $\mathbf{C} \subset \mathbf{U}$

Defining a conceptual space

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- In order to give our rules, **R**, we need a language, **L**, and an interpreter for it
- Let $[\![.]\!]$ be an interpreter which maps its argument (a set of rules in **L**) to an effective procedure for selecting elements of **U**
- $\mathbf{C} = [\![\mathbf{R}]\!](\mathbf{U})$
- We also need a null concept, $\top$

Exploring a conceptual space

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- Let us also allow another set of rules, **T**, describing our creative agent's method for exploring **C**
- One more ingredient of Boden's model remains: it is necessary to be able to choose the better concepts from the less good ones
- We introduce a set of rules, **E**, written in **L**, which may be used to accept or reject concepts in terms of their quality
- We will need a more complex interpreter, $\langle\!\langle .,.,. \rangle\!\rangle$, which, given three sets of rules in **L**, will return an effective procedure for computing an ordered set of (partial) concepts, $\mathbf{c}_{out}$, from another, $\mathbf{c}_{in}$

$$\mathbf{c}_{out} = \langle\!\langle \mathbf{R}, \mathbf{T}, \mathbf{E} \rangle\!\rangle (\mathbf{c}_{in})$$

Exploring a conceptual space

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- It will be useful to add the operator $^\diamond$ which will allow us to compute the set defined by repeated applications of a function

$$F^\diamond(X) = \cup_{n=0,\infty} F^n(X)$$

- We can now define the enumeration of the conceptual space, **C**, by our creative agent:

$$ec = \langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E} \rangle\!\rangle^\diamond(\{\top\})$$

Exploring a conceptual space

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- Note that e_C may be a subset of **C**
- This is because a creative agent's exploratory technique, as captured by **T**, need not be strong enough to discover all the concepts which are actually admissible under **R**
- Or e_C may intersect **C**, producing some acceptable and some unacceptable concepts

An exploratory creative system

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- We are now able to describe an exploratory creative system with the following septuplet:

$$\langle \mathbf{U}, \mathbf{L}, [\![.]\!], \langle\!\langle .,.,.,. \rangle\!\rangle, \mathbf{R}, \mathbf{T}, \mathbf{E} \rangle$$

U	The universe of all concepts
L	A language for expressing rules and concepts
$[\![.]\!]$	A testing interpreter (for **R**)
$\langle\!\langle .,.,.,. \rangle\!\rangle$	An enumerating interpreter (for **R**, **T** and **E**)
R	A set of rules defining a conceptual space, **C**, in **U**
T	A set of rules allowing traversal of **U** (around **C**)
E	A set of rules evaluating concepts found using $\langle\!\langle .,.,.,. \rangle\!\rangle$

Transformational creativity

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- Boden describes *transformational creativity* as changing the rules, **R**, which define the conceptual space
- In our formulation, there are two sets of rules which can be transformed
- Transforming **R** is transforming what is allowed as the output of the creativity process
- Transforming **T** is transforming the creative agent's personal method

Transformational creativity

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- There is a search space of rule sets, which is itself a conceptual space
- That search space is the power set of the language, **L**: **L***
- So **L*** is now the universe in which we are searching
- We can describe **L** (and **L***) with a metalanguage $\mathbf{L}_{\mathbf{L}}$

Transformational creativity

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- To capture the exploration of the rule space, we need some constraints on what is syntactically well-formed, $\mathbf{R}_L$
- We also need to define the search strategy, $\mathbf{T}_L$
- If we use the metalanguage $\mathbf{L}_L$ as before for these specifications, we can use the same interpreters as before, $[\![.]\!]$ and $\langle\!\langle .,.,. \rangle\!\rangle$

Transformational creativity

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- The only thing outstanding is the evaluation of the transformation, which can be done with a set of rules, $\mathbf{E}_L$
- We now have another *exploratory* septuple:

$$\langle\ \mathbf{L}^*, \mathbf{L}_L, [\![.]\!], \langle\!\langle .,.,.,. \rangle\!\rangle, \mathbf{R}_L, \mathbf{T}_L, \mathbf{E}_L\ \rangle$$

- So transformational creativity is exploratory creativity at the meta-level of conceptual spaces
- $\mathbf{E}_L$ may be characterised in terms of $\mathbf{E}$ (see Wiggins, 2006a, for how)

On failing to create...

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- We are now in a position to examine the behaviour of creative systems
- The different components of the descriptions interact, and how they interact can tell us useful information
- Now, we discuss ways in which a system can fail to create
- Therefore, a creative system can introspect about how to improve itself

Uninspiration

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- *Uninspiration* is the inability to produce valued outputs
- There are three kinds of uninspiration:
  - Hopeless
  - Conceptual
  - Generative
- It is useful to know about uninspiration, because it can act as
  - a "well-formedness" check
  - a trigger to transform a creative system in one way or another

Hopeless Uninspiration

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- The simplest case of uninspiration is where there are no valued concepts in the universe:

$$[\![\mathbf{E}]\!](\mathbf{U}) = \varnothing$$

- This means that no creative agent in this universe can ever produce anything valued
- It is a property which we should attempt to disprove of any creative system, *a priori*

Conceptual Uninspiration

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- *Conceptual uninspiration* is where there are no valued concepts in a given conceptual space:

$$[\![\mathbf{E}]\!](\mathbf{C}) = [\![\mathbf{E}]\!]([\![\mathbf{R}]\!](\mathbf{U})) = \varnothing$$

- This means that no creative agent exploring this conceptual space can ever produce anything valued
- It is a property which we should attempt to disprove of any exploratory-creative system, *a priori*
- Conceptual uninspiration can be used as a cue to encourage *aberrant* behaviour

Generative Uninspiration

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- *Generative uninspiration* is where a creative agent's technique, **T**, causes it to miss the valued members of the conceptual space:

$$[\![\mathbf{E}]\!](\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E}\rangle\!\rangle^{\diamond}(\{\top\})) = \varnothing$$

- This means that the agent will never produce anything valued
- It is a property which we should attempt to disprove of any exploratory-creative system, *a priori*
- It can act as a trigger for transformation of **T** (or **R**)

Aberration

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- *Aberration* is the production of new concepts which are not in the existing conceptual space (that is, deviation from the expected)
- There are three kinds of aberration:
  - Perfect
  - Productive
  - Pointless

Aberration

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- Aberration happens when a creative agent finds concepts which are valued, but which are not in the conceptual space
- This is why value (**E**) needs to be represented distinctly from acceptability (**R**)
- In the CSF, this means that

$$\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E} \rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U}) \neq \emptyset$$

Perfect Aberration

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- Perfect aberration is the case where

$$\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E} \rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U}) = [\![\mathbf{E}]\!](\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E} \rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U}))$$

  that is, where all the aberrant concepts are valued

- This, in most cases, will be a cue to transform **R** so that it includes the new concepts

Productive Aberration

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- Productive aberration is the case when

$$[\![\mathbf{E}]\!](\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E} \rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U})) \neq \varnothing$$

  that is, where some aberrant concepts are valued

- This, in many cases, may be a cue to transform **R** or **T** or both

Pointless Aberration

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- Pointless aberration is characterised by

$$[\![\mathbf{E}]\!](\langle\!\langle \mathbf{R},\mathbf{T},\mathbf{E}\rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U})) = \varnothing$$

  that is, where no aberrant concepts are valued

- This is a cue to transform **T** but not **R**

Reflection and transformational creativity

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- These ideas pave the way towards creative agents which can reason about their own performance, in terms of both value and productivity
- In particular, these analyses, which were not possible in Boden's original framework, allow a system which is essentially exploratory to cue occasional transformational behaviour
- Is this what artists/musicians/scientists do when they (eg) consciously change style?
- Just because we can use the CSF to model creative systems, it doesn't mean that all creative systems have to work by search
- We can usefully conceptualise/model a process as a search mechanism in the abstract *even if that is not how it actuallyworks*

An important question

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- What is the difference between Good Old-Fashioned AI Search and Computational Creativity based on the Boden/Wiggins model?

GOFAI Search

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- Given an agenda **S** (a sequence of states):
  1. If **head(S)** is a solution, stop.
  2. Remove **head(S)** from **S** giving remainder **S'**
  3. **expand(head(S))** giving **S''**
  4. **merge(S'',S')** giving (new) **S**
  5. Repeat from 1
- For Depth-First Search, **merge = prepend**
- For Breadth-First Search, **merge = append**
- For Best-First Search, Hill-climbing, A, A*, **merge = append+sort**

GOFAI Search

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- Key Features:
  - Representation: can represent all and only output configurations of problem (closed world)
  - Solution detector: Boolean test for (a representation of) a solution
  - Heuristics allow control of search for best one(s)
    - calculate "quality" of solutions
    - calculate "distance" from nearest solution
    - combination of these

Similarities

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- GOFAI search vs. CSF
  - Representation syntax ≃ Rules of **R**
  - Search space ≃ Conceptual space
  - Algorithmic framework ≃ Algorithmic framework
  - Heuristics ≃ Traversal (**T**) and/or Value (**E**) Rules
  - Agenda (**S**) ≃ Current expansion of space ($\mathbf{c}_{in}$)

Differences

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- Representation: closed vs. open world (**C** vs **U**)
  - admits "discovery" of solutions not envisaged by system designer
- Algorithmic framework: single vs. multiple operands
  - admits more complex (powerful?) search algorithms, e.g., GA, blending

CSF > GOFAI Search

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- GOFAI search can be implemented in the CSF
- The CSF cannot be implemented as GOFAI search
  - (unless, in both cases, we disingenuously jump to a meta-level)
  - The CSF is therefore more expressive than the GOFAI search framework
  - So Boden's notion of creativity is not "just AI search"

Summary

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- Introduced Creative Systems Framework
  - Conceptual Space and Rule Set **R**
  - Traversal of Space to find Concepts and Rule Set **T**
  - Evaluation and Rule Set **E**
- Transformational Creativity is Exploratory Creativity at the meta-level
- The CSF is more expressive than the standard search framework of AI
- We can use the CSF to help conceptualise creative systems