Under the Super-Suit
What Superheroes Can Reveal About Inherited Properties in Conceptual Blending

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Abstract

Conceptual blending has been proposed as the cognitive machinery for concept generation. While computational approaches to conceptual blending have been implemented with some success, the automatic approaches still struggle to consistently produce concepts and blends that 'make sense' and have value. Mechanisms and optimality principles for blending have been introduced, yet their formal integration remains sparse. In this paper, we suggest to partly bypass this problem by identifying some *conceptual heuristics* for blending. This is done through a top-down analysis of three prototypical superheroes, an exemplary domain for conceptual blends and human imagination. We formalise the superheroes and backtrace their properties into their respective input spaces and from there map the inherited properties to cognitive theories for conceptualisation. It is our belief that computational blending systems could greatly benefit from conceptual heuristics for blending, identified in this top-down fashion. As a proof of concept of the identified superhero-blending heuristics, we blend the superhero 'Flowerman'.

Introduction

The nature of human creativity remains a hot topic of debate, and for research in artificial intelligence, it remains one of the most complicated of human phenomena to simulate. One theory that aims to explain the creative process is the theory of *conceptual blending* (Fauconnier and Turner, 1998). Building from a view of 'combinatorial creativity' (Boden, 1998) it proposes that it is by merging different mental spaces that novel concepts emerge. While there are other forms of creativity, this form has been given particular interest in the artificial intelligence community as it provides a concrete starting point to approach the complex research field of creativity (e.g., Kutz et al. (2014); Pereira and Cardoso (2006)).

One area in which conceptual blending is particularly perceptible is in comic books and the generation of *superheroes*. Comic books capture a range of human imagination and demonstrate conceptual blending as characters, settings and plots are heavily influenced by combinations of different conceptual domains. For instance, superheroes are often conceptual blends between humans and animals (e.g., Spiderman, Catwoman, and Antman) or humans and non-animated domains (e.g., Elastigirl, Aquaman, and The Human Torch). While there are many different kinds of superheroes, there seems to be a intuitive understanding (amongst humans) on which combinations of human and non-human attributes will "work;" i.e., be satisfactory in the context of superheroes, and which will not. For instance, there is no guarantee that, in the somewhat unlikely case that you are bitten by a radioactive spider, you remain a humanoid practically indistinguishable from your original form, only now enhanced with abilities such as 'wall climbing' and 'spider web shooting'. Without any 'blending control' it is equally likely that such a *Spiderman*-blend would encompass a creature with eight legs, a generously endowed bottom and with a taste for flies. An acquired-taste superhero that may not appeal to the average comic book reader (judge for yourself in Figure 1). This is a pivotal problem since in compu-

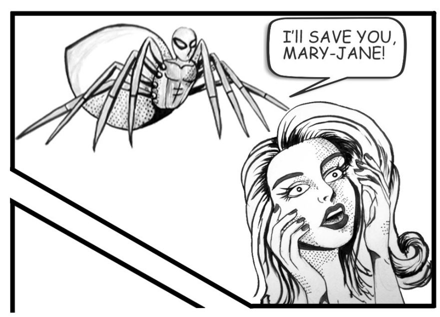

Figure 1: An alternative 'Spiderman' universe.

tational conceptual blending the number of possible blends grows exponentially in relation to the size, or detail, of the input spaces, in the context of which most of these blends will make little to no sense. The underlying rules for this intuitive understanding of what "works" have been introduced by Fauconnier and Turner (1998) as *optimality principles*. These are five[1] mental mechanisms that, when a person is "running the blend", automatically tweak the outcome to the most suitable blend for that context. While the work on formalising the rules behind these principles has been initiated

[1] Later, Fauconnier and Turner (2002) introduced three additional principles.

(Pereira and Cardoso, 2003b), they have also been deemed to be computationally difficult to capture as they are principles for certain structural patterns rather than concrete processes (Goguen and Harrell, 2010). For humans, these rules are more or less automatic. However, for computational conceptual blending, they are still a bottleneck that requires serious attention.

This paper aims to bypass this problem by identifying, in a top-down fashion, some of the blending heuristics for superheroes that tell us something about the essence of 'super', what it is that those heroes have in common. By formally exploring a few prototypical superheroes, we assess their most prominent features, backtracing them from the blended spaces into the conceptual spaces from which they were merged (or emerged). We believe that identifying such, sometimes domain-dependent, inherent mechanisms will provide useful information to increase the performance of state-of-the-art computational approaches to conceptual blending.

The paper is structured as follows: First, conceptual blending and a number of theories that help to uncover the underlying mechanisms behind conceptualisation are introduced. Second, a few well-established superheroes are dissected into their input spaces and inherited properties from each input space, followed by identifying and introducing the derived conceptual heuristics for the blending process. Third, a 'proof of concept' superhero is generated using the heuristics. The paper ends with a discussion and related work as well as speculations on the potential impact of, and interconnections between, uncovering the underlying mechanisms in computational blending vis a vis an analysis of these mechanisms in the light of formal ontologies and design patterns.

Setting the Scene

Conceptual Blending and 'Running the Blend'

Inspired by the principles of analogical reasoning, in which one domain carries information over to another less information-rich domain, Fauconnier and Turner (1998) introduced conceptual blending. The gist of the framework is that information stored in conceptual spaces are blended into a novel blended space through selective projection. During blending certain emergent features in the blend may appear without direct transfer from either input space, but rather develop as a consequence of the blended spaces particular properties. This emergence is the result of the mechanisms behind 'running the blend'.

While the mechanisms that underlay these principles for emergence are largely unknown, the principles have been specified to some extent. For our current purposes we limit ourselves to report on three such mechanisms: First, *composition* ensures, for instance, that certain part-whole relationships are maintained in the blend regardless of what information was transferred, e.g., in the case of animal blending that a head is attached to a neck or that a stomach is on the inside of the body. Second, *completion* is the principle of 'filling in the blanks', i.e. the blend might inherit insufficient information from the input spaces for the 'blend' to make sense and therefore emergent properties arise. Third, *elaboration* develops the blend through imaginative mental simulation given the already accepted rules and principles of the blend space. The emergence process might go on indefinitely with new completion structures, as well as with new laws and principles, emerging through the continuation of elaborative processes (Pereira and Cardoso, 2003b; Fauconnier and Turner, 1998).

In humans, these processes appear to be without much mental effort. Rich conceptual understanding provides excellent grounds for novel concepts to emerge, and contextual awareness ensures that the novel conceptual blends also are 'appropriate' and valuable, defining the blending process as a creative process as it is both novel and valuable (Runco and Jaeger, 2012). For computational creativity, the conceptual blending process has several issues in need of attention. One major problem is directly related to the richness of human conceptual knowledge and its intuitive understanding for appropriate combinations. While computer systems are ever increasing in data capacity, the progress in producing systems that consistently make sense is slow. In fact, as the amount of information in the input spaces grows richer, the number of generated blends grows exponentially. Any computational system dealing with conceptual blending needs to apply a series of rules and heuristics to avoid this. Some of the contributions to computational conceptual blending that outline paths towards addressing this issue include Hedblom, Kutz, and Neuhaus (2016); Eppe et al. (2018); Pereira and Cardoso (2003b).

Another important aspect to note is that it is tempting to assume that all (complex) concepts are the result of conceptual blending. While this might be true on a deeper level, it is not a fruitful assumption for most common day scenarios. Take the superhero 'Batman' from the DC Universe. Initially, one could argue that Batman is the blend of the input spaces Bats and Man. However, on closer inspection, Batman has inherited a rather limited number of properties from Bats. The only major influence is a visual analogy between his suit and a bat, and additionally a few wordplays like 'Batcave' and 'Batmobile'. On a conceptual level, Batman does not have any pertinent attributes associated with bats. Compare this to Marvel's Spiderman, a man who after being bitten by a radioactive spider is 'enhanced' with characteristics and abilities found in spiders.

So while it might be tempting to immediately assume conceptual blending rules all superheroes, there seems to be a significant quality distinction that needs to be addressed.

Identifying the Superhero through Cognitive Theories

Another difficult question involved with computational conceptual blending has little to do with the blending process itself, but rather with the structure of knowledge and conceptualisation. Human conceptual knowledge is vast and not only is it difficult to capture its span but it is uncertain how the mind structures it in the first place. Here, we present a few theories addressing how humans are thought to identify the meaning of things and which, we argue, are particularly relevant for conceptual blending of superheroes.

Conceptual Metaphor Theory: Related to conceptual blending is the research field on conceptual metaphors[2] (Lakoff and Johnson, 1980). Similar to conceptual blending, conceptual metaphor theory aims to undress analogous expressions to the conceptual core and transfer essential information from one domain to another. The theory rests on the basis that there exists a limited number of conceptual skeletons that humans use to structure their knowledge (Kövecses, 2010). A prototypical conceptual metaphor is: "DARK is BAD", which is a common method to depict the villains in comic books. For instance, how Spiderman's outfit turns black when he is infused by the supervillain Venom[3].

Image Schemas: One theory that aims to ground the conceptual metaphors into conceptual building blocks is the theory of image schemas (Johnson, 1987; Lakoff, 1987). Building from the idea of embodied cognition, the theory presupposes that there exists a limited number of spatio-temporal relationships learned from the sensorimotor processes in early infancy that are used to reason about events and the surroundings (Mandler, 2004). For instance, a table offers the image schema of SUPPORT and a house CONTAINMENT. This information then can be transferred to increasingly abstract scenarios through metaphors and associations. In the conceptual metaphor "UP is GOOD," VERTICALITY, or its dynamic version UP_DOWN, is the image schema at work. Image schemas are also suggested to be one of the core components in analogical reasoning and conceptual blending (Hedblom, Kutz, and Neuhaus, 2016). In comic books, both image schemas and conceptual metaphors are key components in encouraging particular interpretations such as who is good and who is evil as well as representing movement and sounds that are not possible in the static comic book format (Potsch and Williams, 2012).

Affordances: The hypothesis that image schemas construct the smallest conceptual building blocks is further supported by the theory of affordances[4] as image schemas have been suggested to be categorised as clusters of affordances (Galton, 2010). Affordance theory was introduced by Gibson (1977) and suggests that the meaning of objects, and concepts as a whole, can be described through the affordances that they offer to an agent. For example, a bed is a bed because you can 'sleep in it,' and a coffee cup is a coffee cup because you can 'drink coffee from it.' In relation to image schemas, the bed has the SUPPORT image schema and the cup has CONTAINMENT. This point of view provides a straightforward method to look at the essential properties of concepts. Within the affordance framework, a hero would be a hero because they offer the affordance of 'rescue' and a superhero would simply be a hero that offers rescue through some 'supernatural' means.

[2]Also called cognitive metaphors, or more specifically image schema metaphors (Kövecses, 2010).

[3]There are plenty of counterexamples for this. For instance, the villains in Batman are generally a rather colourful bunch, whereas Batman himself is rather grim.

[4]In this paper, we exclusively view affordances in the Gibsonian sense.

Recognition-by-parts: While affordances have lots to offer as a theory to the essential core of objects and concepts, there are naturally other characteristics that are of importance for the essence of objects. For instance, for all CONTAINMENT, there needs to be an inside, an outside and some sort of border. This naturally translates to a set of visual and physical characteristics. Recognition-by-parts was introduced as a means to break visual features into smaller geometric blocks called geons (Biederman, 1987). Hence, we can identify a cup because it is composed of the geons a 'hollow cylinder' and a 'handle'. Regarding superheroes and other roles, the visual features might not be as easy to core down to visual components as simple as geons, but there are visual cues of such importance that they are seen as part of the hero's essence. For instance, most would be able to identify a rough silhouette of a superhero based on the physical shape, the cape, the inside-out underwear and boots.

Prototype Theory: This leads to another important theory for the nature of things, namely prototype theory (Rosch, 1973). It suggests that for all categories (e.g., superheroes) there is a prototype to which more or less all members of that group should show some resemblance. A prototypical superhero like 'Superman' ensures that all members are similar to his properties. Superheroes that venture too far from the prototype do not qualify as members of that category.

Essentialism: From the point of view of essentialism, Neuhaus et al. (2014), while blending monsters, argue that one essential criterion is that the resulting blend needs to be 'scary.' For superheroes, a corresponding essential property is that of 'being (morally) good.'[5] This means that based on conceptual metaphors and stereotypes associated with goodness such as "GOOD is BEAUTIFUL", a superhero gains some (if not all) the conceptual information we attach to 'goodness.' This includes attributes such as beauty, generosity, wisdom, and a range of other 'generally positive' features that in reality might have little to do with goodness in itself. Arguably, it could be the case that the features associated with goodness in themselves do not need to be inherited, but rather that their conflicting attributes are unwelcome. For instance, a superhero (that follows the conventional 'goodness' model) *may not* be ugly, selfish, or stupid, rather than imposing that they *have to* be beautiful, generous and wise.[6] In fact, according to a historical analysis of the physical appearance of comic superheroes, attractiveness appears to not only be important but pivotal (Avery-Natale, 2013).

Following the presented theoretical framework for the conceptualisation of things and roles and in the light of conceptual blending we proceed to ask: *How is a superhero created?*

[5]There are unconventional cases in which superheroes are not, in the classic sense, intrinsically good, e.g., Hellboy and Deadpool. For now, we focus on the most prototypical superheroes, where this property holds.

[6]Naturally, there are counterexamples to this as well, where the attractiveness of the hero is somewhat questionable, e.g., Thing and Man-Bat, but often these are already somewhat 'dehumanized' by their names.

Heuristics for Blending Superheroes

Carving the 'Superhero Mould'

There are several attributes and requirements that guide the selection of the properties while performing blending. In the setting of this paper, the blend is by definition required to be a 'hero that is super,' hence the outcome is required to follow a hero template. One definition of a hero is "a person noted for courageous acts or nobility of character."[7] This means that any hero is an animated entity (i.e., a person) who needs to at a minimum have the attributes 'courage' and 'goodness'. As the blended space is intended to be a superhero, further distinctions are needed. A superhero can be defined as "a hero, especially in children's comic books and television cartoons, possessing extraordinary, often magical powers."[8] The relevant distinction between a hero and a superhero is the addition of 'extraordinary powers.' This distinction is of vital importance as it ensures that at least one for-humans unconventional power is inherited from the non-human input space. However, note that this is not necessarily a non-human ability such as flight, or x-ray vision; it can also take the expression of a human ability blown out of proportions, e.g., *The Flash*, who inherits 'superspeed' from the input space lightning or in the case of *Spiderman*, 'super-strength' as spiders are assumed to carry up to 20 times their own bodyweight. Note that this kind of treatment of already existing human powers is done through the image-schematic transformation of SCALING.

As we have argued that superheroes are blends we need to define the mould by which superheroes are blended. Based on the definitions above and the ideas behind essentialism we can infer that the superhero mould needs to have the following characteristics: 'Courage' and 'Goodness;' and the ability: 'at least one extraordinary power.'

When looking at prototype theory and recognition-by-parts, the visual attributes of a superhero appear equally important. Superheroes tend to be attractive, their outfits are typically made in tight spandex, have both capes and inside-out underwear and are generally colourful with symbols representing their 'core identity'. Spiderman has a spider, Superman has a big S and Batman has an outfit that is entirely bat-inspired. Therefore, the prototype hero also requires the visual attributes: 'attractive' and 'wears suit with emblem.'

Identifying the prototype superhero, or the superhero mould, is of great importance as it is used to evaluate and eliminate conflicting attributes in the blended superhero. This means that the blended superhero will most often (if not always) be forced to fit into the superhero mould. If it does not fit, it might not be considered a 'true' superhero. Based on this reasoning we define the minimum requirements for a prototype hero in the following, using DL syntax:

$$\begin{aligned}\mathsf{Superhero\_Mould} \equiv\ & \mathsf{Person} \sqcap \mathsf{Attractive} \sqcap \mathsf{Courageous} \sqcap \\ & \mathsf{Good} \sqcap \exists \mathsf{has.ExtraordnaryPower} \sqcap \\ & \exists \mathsf{wears.Suit} \sqcap \exists \mathsf{has.Emblem}\end{aligned}$$

[7] http://www.dictionary.com/browse/hero. Retrieved February 14, 2018

[8] http://www.dictionary.com/browse/superhero, Retrieved February 14, 2018

Conceptual Modelling of A Few Prototypical Superheroes

As we are verging on uncovering what lies underneath the superhero costume, our method for analysing the blending process is by backtracing from a few well-established superheroes, to identify the input spaces and the attributes and abilities that they have inherited from each space. We look closer at the Marvel Comics' heroes Spiderman, Black Panther and The Human Torch. Below, each superhero is formalised.[9]

Spiderman: Under Spiderman hides Peter Parker, an intelligent science student who after being bitten by a radioactive spider acquires several abilities associated with affordances that particular characteristics of spiders offer. Some of the most prominent ones are that he can climb walls, he shoots spider webs, and has increased senses that provide him with a 'spider sense' to perceive his surroundings.[10] In addition, his human strength and speed are through SCALING blown up to that of a spider in human size. Using description logics, we can formalise Spiderman as:[11]

$$\begin{aligned}& \mathsf{YoungMan} \sqcap \mathsf{Intelligent} \sqcap \mathsf{Good} \sqcap \mathsf{Courageous} \sqcap \\ & \exists \mathsf{climbs.Wall} \sqcap \exists \mathsf{expells.Web} \sqcap \mathsf{SuperStrong} \sqcap \\ & \mathsf{has.SpiderEmblem}\end{aligned}$$

The Black Panther: The Black Panther is T'Challa who, by a shamanistic connection to a Panther God, acquires several catlike characteristics. Some prominent ones are acute senses, enhanced strength, speed, agility, stamina, durability, healing, and reflexes. In addition he has the claws of a cat which affords him the ability of climbing VERTICALITY and using them as weapons in direct combat.

$$\begin{aligned}& \mathsf{Man} \sqcap \forall \mathsf{hasColour.Black} \sqcap \forall \mathsf{hasWeapon.Claws} \sqcap \\ & \mathsf{Good} \sqcap \mathsf{Courageous} \sqcap \mathsf{Agile} \sqcap \\ & \exists \mathsf{needs.Oxygen} \sqcap \forall \mathsf{eats.}(\mathsf{Meat} \sqcup \mathsf{Vegetable}).\end{aligned}$$

The Human Torch: Johnny Storm from the Fantastic Four is an example of a non-animal blended superhero. He gains his 'superpowers' from the inanimate input space Fire. The Human Torch is able to envelop his body in flames (i.e. CONTAINMENT) which also gives him the power to fly, motivated through the physics behind 'how flames rise' (the, from the 'just-human' point of view, 'supernatural' combination of the image schemas VERTICALITY and SOURCE_PATH_GOAL). Additionally, he can produce balls of fire. Simultaneously he reacts weak to the same things

[9] We acknowledge both the male-dominance and their limited formalisations but argue that we have captured some of the most relevant features that make each particular superhero unique.

[10] This might actually not be a spider skill in itself, however, it could be interpreted as the result of sensing the surroundings as a spider senses activity in their nets.

[11] Note that we also specify:

$$\begin{aligned}\mathsf{YoungMan} &\equiv \mathsf{Man} \sqcap \mathsf{hasAge.}(\leq 25) \\ \mathsf{Person} &\equiv \mathsf{Man} \sqcup \mathsf{Woman}\end{aligned}$$

that fire is, as water 'extinguishes' him and lack of oxygen hinders his powers.

$$\mathsf{YoungMan} \sqcap \exists \mathsf{needs.Oxygen} \sqcap \mathsf{Good} \sqcap \mathsf{Courageous} \sqcap \exists \mathsf{hasCapacity.Empathy} \sqcap \exists \mathsf{hasWeapon.FireBall} \sqcap \exists \mathsf{diesFrom.}(\mathsf{Suffocation} \sqcup \mathsf{Freezing} \sqcup \mathsf{Drowning})$$

The input spaces

Man: By the definition presented above, a hero was required to be a person. In the three examples above, all heroes were male so we require that input space to be described in more detail. A human male is an animated creature with a humanoid form, with two arms, two legs, a torso and a head, which walks upright (SOURCE_PATH_GOAL). It has high levels of intelligence and is capable of empathy (which we treat as a prerequisite for developing courage and goodness while running the blend based on the optimality principles). It requires oxygen to breathe and food to eat.

$$\mathsf{Man} \equiv \mathsf{Person} \sqcap \mathsf{Male} \sqcap \exists \mathsf{hasShape.Humanoid} \sqcap (=2.\mathsf{hasLegs}) \sqcap \exists \mathsf{hasCapacity.Empathy} \sqcap \exists \mathsf{needs.Oxygen}.$$

Spider: A spider is an eight-legged arachnoid, capable of carrying 20 times its own weight and through its characteristics affords the ability of wall-climbing. Additionally, it is able to expel webs and it injects venom into its victims. To many humans, spiders are perceived as malicious animals potentially due to them being cannibalistic predators, their alien visual appearance or their physical threat to humans.

$$\mathsf{Spider} \equiv \mathsf{Arachnoid} \sqcap (=8.\mathsf{hasLegs}) \sqcap \mathsf{Malicious} \sqcap \exists \mathsf{climbs.Wall} \sqcap \exists \mathsf{expels.Web} \sqcap \forall \mathsf{injects.Venom} \sqcap \mathsf{Strong}$$

Panther: A black panther is a particular kind of felid, characterised by its black colouring, speed, grace, and strength. It is a carnivorous quadruped, which hunts larger prays for survival. They are capable of jumping very high, and can maintain a high speed for a long period of time. They are dangerous to humans and can be considered fearsome.

$$\mathsf{Panther} \equiv \mathsf{Felid} \sqcap \forall \mathsf{hasColour.Black} \sqcap (=4.\mathsf{hasLegs}) \sqcap \mathsf{Fearsome} \sqcap \exists \mathsf{needs.Oxygen} \sqcap \forall \mathsf{eats.Meat}$$

Fire: Fire is the result of combustion, releasing heat, light, and various chemical components. It is enabled by the presence of oxygen in the environment, and can die through suffocation, freezing, or drowning. It is a chemical reaction, which can burn, but also stimulate growth.

$$\mathsf{Fire} \equiv \mathsf{ChemicalReaction} \sqcap \mathsf{Hot} \sqcap \exists \mathsf{needs.Oxygen} \sqcap \forall \mathsf{rise.Flames} \sqcap \exists \mathsf{diesFrom.}(\mathsf{Suffocation} \sqcup \mathsf{Freezing} \sqcup \mathsf{Drowning})$$

This leads us to uncover the inherited properties that are unique to the individual superhero. In the next section, we look closer at what this means.

Inherited Properties

By separating the input spaces from the blended superheroes we can identify the nature of which properties are inherited from each input space.

What can be determined is that all three superheroes inherit the personality characteristics from the human input spaces. They all remain the same people with their intelligence and their morals intact, but they are enhanced by being provided with increased strengths and inhuman abilities. Spiderman inherits properties that affords him with abilities to be able to attach himself to walls, and cast webs to capture enemies in and to be able to move around in three-dimensions. Basically, the SOURCE_PATH_GOAL image schema found in ordinary human behaviour has been enhanced to include also a vertical dimension. Similarly, Black Panther is enhanced with the gracious strength and agility found in large cats from the cat input and is provided with claws. The optimality principles for blending ensures that the presence of such characteristics are also translated into affordances and abilities, meaning that Black Panther's preferred weapon is martial art with a bit of claw. Notable also is that the generic space here ensures that the 'black' identity of the superhero is preserved. The Human Torch has been awarded the ability of flight when he is enclosed in flames. This is inspired from the input space Fire based on the idea that flames rise (the VERTICALITY image schema). Moreover, interestingly he also inherits handicaps as a consequence of this blending process. While both humans and fires require oxygen to function, a fire cannot be lit under water, which is transferred to The Human Torch and is often used as a weapon against him. Regarding their visual appearance, it is obvious that the essence of being human is preserved based on the Superhero prototype requiring them to remain "people", however, their outward appearances are heavily influenced by the non-human input space. Spiderman's suit carries a spider emblem, Black Panther's suit is heavily cat inspired and The Human Torch wears a red and yellow suit resonating with the colours of burning flames.

Based on these observations we proceed to build conceptual heuristics concerned with how to create a superhero of our own making.

The Superhero Recipe

1. Choose Input space 1 (I_1): a 'human' conceptual domain and define characteristics e.g., female, male, age, ethnicity, etc.
2. Choose Input space 2 (I_2): a conceptual domain of interest; e.g., an animal, an element, etc.
3. Specify the superhero prototype and form the mould for the blended space. Identify and generalise:[12]
   (a) Visual features: e.g., wears colourful cape and suit, muscular etc.
   (b) Characteristics: e.g., good, patient/impulsive etc.

[12]Note that the superhero mould's characteristics are examples of 'slots to be filled' and not criteria. Any kind of superhero could be built that does not need to follow the prototypical goodness-model used in this article.

(c) Abilities: e.g., speed, strength, flight, ex-ray vision etc.

4. Cross-identify visual features, characteristics and abilities between I_1 and I_2. Generate the generic space based on this.
5. Identify personality traits and characteristics from I_1 and transfer it to the blend.
6. Identify abilities based on affordances and image schemas in I_2 and transfer those abilities to the blend.
7. Remove all attributes that are in conflict with the identified superhero prototype, e.g., 'evil' cannot be present if 'goodness' is part of the prototype.
8. Run the blend through the blending optimality principles to maximise the success of the blend.

Based on our general analysis and the workflow presented above, it is now possible to 'build' new superheroes following these heuristics.

Proof of Concept: Introducing 'Flowerman'

In the previous sections, the blending process of superheroes was backtraced to identify some underlying blending heuristics guided by a number of theories on concept formation and meaning generation. In this section we introduce *Flowerman*, a proof-of-concept hero based on these heuristics.

Step 1: we choose to build an adult 'male' superhero, hence Input space 1: Man.

$$\mathsf{Person} \sqcap \mathsf{Male} \sqcap \exists \mathsf{hasShape.Humanoid} \sqcap (=2.\mathsf{hasLegs}) \sqcap \exists \mathsf{hasCapacity.Empathy} \sqcap \exists \mathsf{needs.Oxygen} \sqcap \exists \mathsf{eats.Food}$$

Step 2: we choose the complementary conceptual domain, input space 2, based on Flower.

$$\mathsf{Plant} \sqcap \mathsf{Beautiful} \sqcap \mathsf{MorallyNeutral} \sqcap \exists \mathsf{has.Petals} \sqcap \exists \mathsf{hasCapacity.ejectSeeds} \sqcap \mathsf{Grows} \sqcap \exists \mathsf{needs.CarbonDioxide} \sqcap \exists \mathsf{eats.Sunlight}$$

Step 3: we identify the prototypical goodness-model superhero as defined in the superhero mould above. This means the superhero must wear a suit with emblem, be attractive, be good and courageous as well as have an extraordinary power.

Step 4: by mapping and generalising the structure in Man and Flower the following generic structure appears. The generic space is as follows:

$$\exists \mathsf{hasCapacity.Y} \sqcap \exists \mathsf{needs.Z} \sqcap \exists \mathsf{eats.X}$$

Steps 5 and 6: From the Man we preserve the human attributes, and from Flower abilities based on affordances are preserved so that together they construct the blended space. The blended space is thus *Flowerman*:[13]

$$\mathsf{Person} \sqcap \mathsf{Attractive} \sqcap \mathsf{hasCapacity.Empathy} \sqcap \exists \mathsf{hasCapacity.ejectSeeds} \sqcap \exists \mathsf{wears.petalsSuit} \sqcap \exists \mathsf{has.FlowerEmblem} \sqcap \exists \mathsf{eats.}(\mathsf{Sunlight} \sqcup \mathsf{Food}) \sqcap \exists \mathsf{needs.}(\mathsf{Oxygen} \sqcup \mathsf{CarbonDioxide})$$

[13]Note that beautiful and attractive are treated as synonyms.

Step 7-8: The blended concept *Flowerman* is matched to the prototype Superhero in order to inherit the human form and the 'hero' attributes such as goodness and courage from the input space Man which is acquired when running the blend based on the capacity for empathy. From the Flower he inherits the abilities to eject seeds, which turns into a "Seed-Gun" of some sort through elaboration. The suit from the superhero mould is merged with the 'petal-dress' of the flower to generate a 'suit of petals.' Additionally, *Flowerman* has the ability to 'eat' sunlight, potentially through chlorophyll present in green skin, a feature that would be developed as an emergent property through *composition* and *elaboration* and he can choose to breathe either oxygen or carbon dioxide.

Whether *Flowerman* will be the next big thing in the comic book world is up for time to tell. However, the procedure by which he was made could help to advance the computational conceptual blending scene. Here we have taken potential aspects of blending superheroes into account and manually used the identified heuristics to create a novel superhero. If a computer system that handles logical rules such anti-unification as seen in the analogy engine and conceptual blender Heuristic-Driven Theory-Projection (HDTP) Schmidt et al. (2014); Guhe et al. (2011) and Structure Mapping Engine (Forbus, Falkenhainer, and Gentner, 1989), or the computational conceptual blender Divago (Pereira and Cardoso, 2006) provided with a similar script the blending outcome may be shown to be improved.

Discussion and Related Work

Comic books have been shown to be a good playground for identifying conceptual blends. In comparison to looking at individual superheroes, as done in this article, Szawerna (2012) makes an in-depth analysis of the complete blended universe in the comic book *Watchmen* by studying cross-domain parallels between the real US politics and foreign affairs in the fictive world with superheroes. Similarly, Forceville (2016) presents the role of conceptual blending in cartoons and comic strips to illustrate how meanings not directly present in the comic strips are transferred through conceptual metaphors and conceptual blending mechanisms. His work also strengthens the hypothesis this paper identified, namely, that the role of affordances and image schemas plays a central role when inheriting valuable information from the non-human input space. This is also the conclusion found by Potsch and Williams (2012) who points out how image schemas are directly related to how conceptual information regarding movement is depicted in the still frames of the comic format and the work on computational conceptual blending by Hedblom, Kutz, and Neuhaus (2016).

Another bottom-up approach to analysing the blending process is the work by Neuhaus et al. (2014). By looking at formal conceptual blending they investigate the automatic generation of monsters by merging OWL formalisations of animals together. Their work rests on the foundation that the blended monster needs to satisfy the criterium of being 'scary'. This relates to the initial criteria of superheroes having 'courage' and having 'extraordinary' abilities of some sort. Similarly, the work by Pereira and Cardoso (2003a) demonstrates how the computational blender Divago can blend the concept of 'horse' with 'bird' to generate a pegasus. The Divago system is particularly interesting as it has initiated the work on formalising the optimality principles.

These studies differ from this article by either simply analysing the state of blending in comics, or by approaching the blending processes in a bottom-up fashion. Our attempts to identify some blending heuristics for superheroes took the opposite direction, by first analysing the superheroes top-down to identify some criteria and based on this generate a new superhero bottom-up. While the approach does show promise in identifying some core heuristics for conceptual blending that could be used in computational approaches, the work here suffers from two major disadvantages. First, as the formalisation for both the input spaces and the superhero blends are handcrafted, they are subject to errors and favourable interpretations that might not be present in a more natural scenario. Second, the superhero blending is based on the notion of a prototypical superhero based on the goodness-model. As has been discussed, there are several superheroes that venture out from the norm, with questionable morals, visual appearance that verges on being inhuman, and characteristics that do not fit the here identified superhero mould. That said and within that prototypical domain, an interesting find is that blended superheroes often gain the abilities, based on affordances and image schemas, from the non-human input and the characteristics from the human input. The inherited visual appearance is something that is partly based on the superhero prototype, namely that they have to be attractive with strong humanoid bodies while the non-human input space offers less intrusive characteristics to be inherited, such as colour schemes for the Super-Suit or icons and symbols that are associated with that particular superhero, e.g., Spiderman's spider logo on his suit, or Black Panther's catlike suit.

As argued in Neuhaus et al. (2014), the steering of the automatic construction of blends requires a mix of requirements: (ontological) constraints/consistency requirements and consequence requirements. These are heavily domain-specific, and we have here presented the core of a requirement theory for the automation of the superhero mould.

The Road Ahead: Conceptual Blending from an Ontological Perspective

In this paper, we assume that the concepts (representing monadic types or unary predicates) that participate in blending operations all stand in the same ontological footing. However, as discussed in Guizzardi (2005), from an ontological perspective, different categories of concepts classify entities in completely different manners. For instance, if we take a particular individual named *Peter Parker*, he can be (at the same time or across time) classified under the concepts Person, Adult Man, Reporter, and Physical Object, among others. However, it is not the case that all these concepts classify *Peter Parker* in the same manner. First of all, Person is a **Kind** (or **Substance Sortal**) and, as such, it captures the essential properties of the entities it collects and provides principles of individuation, cross-world identity and persistence for them (see Guizzardi (2005)). In contrast, Physical Object is an example of a **Non-Sortal** concept and, as such, one which cannot provide a uniform principle of identity for its instances and, hence, which represents properties that occur in individuals of multiple **Kinds**. Furthermore, concepts like Adult Man, Student or Reporter represent **Anti-Rigid Sortals**, i.e., concepts that represent contingent properties of entities of a particular **Kind** (in this case, Person). Nonetheless, still under this category, we have concepts that capture *intrinsic and contingent properties* of entities of a given **Kind** (e.g., being an Adult Person is being a Person who has the intrinsic contingent property of being in a certain developmental phase). These are called **Phases**. On the other hand, we have concepts that capture *contingent but relational properties* of entities of a given **Kind** (e.g., being a Reporter is being a Person who has the contingent and relational property of working for a news organization). These concepts are called **Roles**.

Now, the conceptual blending operations discussed in this article seem to follow a particular ontological recipe: (1) select two **Kinds** (e.g., Person and Spider); (2) one of these **Kinds** will be preserved as the **Kind** of the resulting concept (e.g., Person) and the other one will be used to abstract a **Non-Sortal** concept capturing the characteristics that are necessary for the intended blending (e.g., Arachnoid-Entity). Notice that Arachnoid-Entity is indeed a **Non-Sortal** as it classifies entities of multiple **Kinds** (i.e., entities of the **Kind** Person and of the **Kind** Spider). Moreover, it is an example of a semi-rigid **Non-Sortal** (i.e., a so-called **Mixin**, see Guizzardi (2005)), as it defines properties that are essential for some of its instances (i.e., for Spider, which are necessarily Arachnoid-Entities), while being contingent for other instances (i.e., instances of people are only contingently Arachnoid-Entities). In other words, for example, Peter Parker existed without having those properties and can still survive maintaining its identity (i.e., exist as the same *Person*) in case he loses these properties; (3) create a concept that specialises by intersecting the **Kind** selected in (1) with the **Mixin** produced by abstraction in (2). The result will typically be an **Anti-Rigid Sortal** (e.g., a **Phase**, if we think of the concept Man-with-Spider-Powers, or **Role**, if we think of Spider-Man, i.e., as Man-with-Spider-Powers who acts as a hero, bearing certain responsibilities w.r.t. a community, etc.).

For future work, we intend to systematically investigate the connection between the conceptual blending operations discussed here with the rich literature on categories of concepts/types as proposed in the area of formal ontology. This will establish a connection between theories of blending and those of *Ontology Design Patterns* as discussed in, for example, Kutz et al. (2016); Ruy et al. (2017). For doing that, we will also need to extend our formal characterisation of these operations, since the characterisation of these different categories of types necessarily requires the treatment of modal notions (e.g., rigidity or relational dependence).

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