Kinds of Physical Features

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Abstract. Physical features are parasitic on a host entity and emergent from it. Representative examples include a smile on a face, a bend in a river, an ocean wave, and a hole in an object. While such features are quite widespread in reality, their ontological analysis is evolving with some important kinds of features still unidentified or under-characterized. To advance the ontological representation of physical features, this paper proposes a structure for such features grounded in multiple ontological dependencies, as well as an informal taxonomy that expands on existing kinds and introduces several new distinctions. Examples are drawn from many domains including the geosciences.

Keywords. physical feature, ontological dependence, hosting, emergence, geoscience

1. Introduction

Physical features are object-like entities (i.e. endurants or continuants) that are parasitic on some host, in addition to being emergent from the host. As physical entities they occupy some physical space and exist wholly at any one time. As parasitic entities they ontologically depend on some other physical entity - their host - such that they could not exist essentially without it. As emergent entities their identity is distinct from their host, but is drawn from a focus on specific aspects of the host, thus emerging from the host. Representative examples include smiles, river bends, mountaintops, ocean waves, and holes. Smiles are hosted by a face and emerge from a configuration of lips, eyes, and other facial parts. River bends emerge from river segments having a particular shape. Mountaintops emerge from being certain material parts of a mountain. Ocean waves emerge from physical disturbances in the height and material of the ocean, and holes are empty spaces that emerge from depressions or cavities in a physical object. Additional notable examples include landscape features such as mountains and valleys, as well as geological features such as earthquake waves and epicenters. As these examples illustrate, physical features are plentiful and meaningful to a wide range of human endeavour, from the everyday to the highly technical and scientific.

Despite this proliferation, physical features are relatively scarce in ontological representations. While some physical features have been analyzed extensively, such as holes, places and boundaries [2,3,4,5,8], others are in comparatively early stages of characterization, such as ocean waves [9,14] or landscape features [14,15]. Representation of

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features in upper-level ontologies is also limited to a relatively small number of feature kinds, primarily boundaries [7,16]), immaterials [10,16], or parts [10]. Potential additions are complex features (features with feature parts) and shape-based features, with the latter possibly extended to features derived from any quality [12,11]. This then raises the prospect of physical features arising from any aspect of a host, which is a step toward a broader notion of emergence for features.

This paper contributes to the characterization of physical features for applied ontology. It proposes an ontological structure for physical features founded on multiple ontological dependencies combined with a relational notion of emergence. It also develops a taxonomy of physical features grounded in this structure, one that expands upon some existing characterizations and introduces several new kinds. The structure and taxonomy are described informally, leaving formal representation to future work. Section 2 introduces the structure of physical features, Section 3 describes each feature in the taxonomy, Section 4 compiles various examples, and Section 5 concludes with a brief summary.

Note that kinds and categories are used interchangeably in this paper to refer to generalizations such as types, universals, properties, and classes; instances are entities that instantiate kinds, and individuals cannot be instantiated. Relations refer to associations held between entities in the world, and not to their expressions in propositional statements. Physical feature and feature will also be used interchangeably throughout the paper.

2. Structure of Physical Features

Physical features are characterized in this paper via the hosting relation, which holds between a feature individual, which is a physical endurant, and at least one other distinct physical endurant individual, its host. The hosting relation encompasses the two vital attributes of features: (1) physical features are ontologically dependent on their host [10], and (2) they emerge from their host with distinct identity [9]. Ontological dependence includes specific and generic dependence [13], such that the dependence is on a particular entity (specific) or some entity of a particular kind (generic). Emergence is then required in tandem with such ontological dependence to form a necessary and sufficient condition for hosting, insofar as ontological dependence on its own does not always imply hosting. For example, a person might be considered to be ontologically dependent on their brain [10], but not hosted by it. Hosting, comprised of such dependence and emergence, then uniquely defines a feature: to be a feature is to be hosted, and anything hosted is a feature. However, emergence criteria are difficult to recognize leaving the hosting relation under-determined.

2.1. Feature Emergence

To augment the hosting relation, feature emergence begins here with a focus on certain individuals, called focals, in a specific relation with a host. For example, in features such as a stain [10], the focus is on a localized colour that inheres in a shirt. The relation might also be n-ary: e.g. shadows are features with a ternary relation, comprised of a light source, an obstructing body, and a surface onto which the shadow is projected, with focus on the projected surface. Critically, each such relation has three important traits: (1) it exists independent of the feature, (2) it is essential to the feature, and (3) it identifies the feature.

For the relation to be independent of the feature, it must be possible for it to hold without the feature existing, e.g. a shirt can have different colours in distinct parts without them being stains. It is only when focus is brought to a specific colour in a certain part that a stain emerges. Likewise, the components of a shadow can be appropriately arranged independent of the shadow. Such independence then implies the feature is not a relata in the relation, primarily to enable the feature to emerge from it. Conversely, the second trait implies the relation must hold for the feature to exist and to be the way it is, though the host might exist without the relation holding. For example, carrying a certain localized colour is necessary for the stain to exist and be as it is, but it is only accidental for the shirt despite being carried by the shirt too. The second trait thus establishes an existence condition for the feature, as the relation must hold for the feature to exist. It also implies an essential condition for the feature, as the relation holding is a characteristic of the feature without which it could not be as it is. In this sense, the relation is an essential relation for the feature. Note the relation is not necessarily an essential relation in itself, but is only essential to the feature, as the relation does not necessarily exist if its relata exist. The third trait indicates the relation is an identity condition for the feature: a different relation would yield a different feature, and features with different relations differ in identity.

Emergence is then manifest through relations between the feature, its host, and its focals. The host and feature are related via ontological dependence, and the host and focals are related via the essential relation. The remaining relations, between the feature and each focal, are also claimed here to be ontological dependence. Take for example a knot on a string: it emerges from a focus on the arrangement of string segments, such that the feature is the knot, the host is the string, the focals are the string segments, and the essential relation involves the arrangement of the segments. If the identity of the knot does not change as the knot is shifted along the string [9], that is, if it retains identity while different string segments are used to arrange the knot, then the knot generically depends on the segments and specifically depends on the string. Likewise for shadows: the surface of projection can change without affecting the identity of the shadow. Unlike such knots and shadows, an ocean wave is specifically dependent on its focal: the wave feature emerges from the ocean, its host, participating in a specific flow, its focal (a perdurant, which is a process-like entity), and not in any other flow, otherwise it would be a different wave. Features are thus either specifically or generically dependent on focals.

Due to the possible generic dependence of a feature on a focal, the essential relation can now more accurately be characterized as being a relation pattern, because some relata could be replaced by others over time. Essential relations should therefore be understood to be such patterns throughout this paper. The existence, essence, and identity conditions for a feature then require the relation pattern to hold.

More broadly, a feature is then ontologically dependent on each host or focal in the essential relation. In particular, a feature is constantly ontologically dependent on them, such that the feature must exist co-temporally with them in an essential and non-accidental way: if the feature exists at a time, then the relation involving certain hosts and focals must hold at that time. Such co-existence in time not only makes sense for emergence - it is difficult to emerge, and remain emergent, from something that is not present - it also excludes unintended cases in which features are historically dependent on relata for their origins. For example, excluded are cases such as some material artifacts, which are dependent on a maker and some matter (e.g. a statue emerging from a sculptor and some clay). Ontological dependence should therefore be understood to be of this constant variety [18] in the context of features.

In addition to such temporal co-location, a feature is also spatially co-located with the sum of its focals at any time the feature exists. Such spatial co-location is the maximal and exact spatial congruence at a time, i.e. the same physical space is occupied by the feature and its focals. Then a stain is spatially co-located with a colour, a knot with its string segments, a shadow with the projection surface, and a wave with the flow, or more specifically with the ocean parts participating in the flow at a time. This effectively constrains focals to being individuals that can be spatially located, either directly or indirectly. Indirectly located individuals are exemplified by perdurants, which are positioned at the spatial location of their participants at a time. Other noteworthy examples are qualities (e.g. colour) and their quales (e.g. red), which are either directly or indirectly located depending on certain ontological choices. It is difficult to imagine a physical feature emerging from entities that are neither spatially nor temporally co-located with the feature, at least as construed herein.

2.2. Feature Hosting

A related concern is the nature of the ontological dependence between a feature and its host: is it specific dependence, generic dependence, or does it vary across features? As proposed in Figure 1 and Table 1, the dependence relation between a feature and its host is specific dependence only. One empirical reason for this choice is the lack of good counter examples. This includes the river [9] and whirlpool [10] cases, initially thought to be hosted via their generic dependence on some water matter amount, though subsequent ontological analysis of water entities [1] suggests rivers are not physical features at all, but are physical objects instead. This is mainly because such water entities have another entity, a water object, as an essential part, though not host, one that unifies the changing water matter amounts into an integral whole. For other water entities, such as a whirlpool, cloud, or rainfall, the situation is less clear. On the one hand they might also be physical objects (as per [1]), and on the other hand they might instead be physical features specifically dependent on, and hosted by, a water object, as well as generically dependent on amounts of water matter as focals. Regardless, these suggested counter-examples are either not features, or if they are features then they are specifically dependent on their host.

Apart from such empirical considerations, there is a good analytical reason to claim features are universally specifically dependent on their host. If this were not the case, then some features might be generically dependent on all relata in the essential relation, enabling all relata to be replaced, thus leaving the relation pattern itself as the only subject of focus for feature emergence. But such a relation pattern is not an individual - it is more akin to a kind - and features emerge from individuals (possibly of a certain kind) held in an essential relation, and not from such patterns. So the generic dependence of a feature on a host would lead to a structure that accommodates non-features. Features are thus specifically dependent on hosts, and a feature's essential relation has at least one host.

Remaining concerns about the structure of a feature revolve around the nature of the host: (1) how many hosts can a feature have, and (2) what constitutes a host? In answer to the first concern, a feature can have multiple hosts: e.g. the midpoint between two objects is a feature hosted by the objects, and the spatial location centered between them is the focal, one that changes as the objects move. Shadows also have multiple hosts, namely the obstructing body and the light source. Because the shadow is spatially co-located with the projection surface, and not the light source, the light source cannot be a focal and so must be a host. Replacement of the obstructing body or light source would then produce a different shadow, and multiple light sources illuminating the same body would produce distinct shadows due to distinct essential relations.

To begin to address the second concern, about the nature of a host, consider this: if hosts are any relata in an essential relation upon which a feature is specifically dependent, then focus could be lost for some features. For example, a wave would then be hosted by both the ocean and a particular flow, and thus lack focals. One way to retain a sense of focus, adopted here, is to restrict hosts to being physical endurants. This makes eminent sense: being physical endurants, features should be anchored by physical endurants only and not by other kinds of things. A host is then some physical endurant in the essential relation on which a feature specifically depends, a focal is some spatially located individual in the essential relation on which the feature ontologically depends, and the focals are in sum spatially co-located with the feature at any time the feature exists. A feature's essential relation can now be further clarified to be a relation pattern in which the host relata are fixed, and the remaining focal relata might be either fixed or variable.

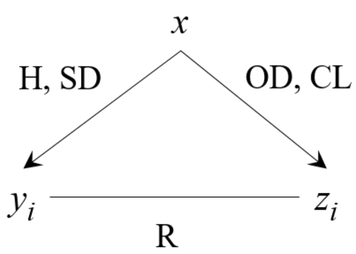

Figure 1. Essential structure of physical feature x. See Table1 for details.

Table 1. Physical feature components, from Figure 1.

Physical Feature - x	parasitic and emergent individual that is a physical endurant
Host - y_i	physical endurant individuals on which a feature constantly specifically depends; relata in the feature's essential relation
Focal - z_i	spatially located individuals on which a feature constantly ontologically depends; relata in its essential relation
Essential Relation - R	relation pattern with hosts and focals as relata; provides existence, essence and identity conditions for a feature
Hosting - H	relation between a feature and its hosts accounting for the feature's parasitic and emergent nature
Co-Location - CL	full spatial co-location of a feature with the sum of its focals, at a time
Specific Dependence - SD	essential existential constant dependence of a physical feature on a host or focal
Generic Dependence - GD	essential existential constant dependence of a physical feature on a focal of a certain kind
Ontological Dependence - OD	either specific or generic dependence from above

However, these conditions are insufficient to identify a host, because features can also be specifically dependent on focals that are physical endurants too. Consider if a knot changes identity when relocated along a string: then the knot is specifically dependent on each string segment. Features can also be spatially co-located with both hosts and focals, such as a fist co-located with a hand, its host, and its various parts, the focals. Consequently, as it stands, these conditions are necessary, but not sufficient, for determining whether a relata in the essential relation is a host or focal. They do, nonetheless, enhance the characterization of a feature, and tentatively constitute a jointly necessary and sufficient condition for the feature itself: a feature must jointly meet these conditions, and anything that jointly meets these conditions is a feature.

Although this characterization has emphasized their essential structure, features can also have non-essential aspects, such as necessary or accidental qualities. Hosts can also be ontologically dependent on focals without undermining feature structure. Consider a host that is an integral whole with focals as its essential parts, for example, a face with lips and eyes as essential (ontologically dependent) parts, but also hosting a smile. Lastly, while the proposed feature structure has potential to be adapted to non-physical features, it has only been explored in the context of certain physical features and is limited to them for the purposes of this paper.

3. Kinds of Physical Features

As illustrated in Figure 2, features are organized herein according to their essential relation, specifically the *inheres in*, *part of*, and *participates* relations, as well as various spatial relations. Inherent features are then structured around a certain aspect, such as a quality, inhering in a host; integral features are structured around the feature emerging as an integral whole with aspects of the host as its proper parts; part features are structured around the feature emerging from a proper part of the host; dynamic features are structured around the host participating in a perdurant; and spatial features are structured around the host involved in an essential spatial relation. Immaterial features are a notable specialization of spatial features and include things such as holes and places.

Significantly, the non-spatial feature kinds in the taxonomy are disjoint, such that if a feature individual is an instance of one of these kinds then it cannot be an instance of another. In contrast, the spatial feature kind is not disjoint from them. For example, some spatial parts are part features and spatial features, such as the bottom half of some hole.

It remains an open question whether the feature kinds are covering, that is, whether every physical feature instantiates a kind in the taxonomy? This primarily devolves to the question of whether there are additional kinds of essential relations not encompassed by the taxonomy? Temporal relations are an obvious omission, but as they would lead to temporal features such as the beginning, ending or midpoint of some event or process, they are out of scope. Reaching an understanding about the type of relations leading to featurehood is thus an open task, one likely to somehow rely on a general categorization of relations (e.g. [6]). Consequently, with its completeness still very much in question, the taxonomy is largely utilitarian in covering the range of examples examined for this paper.

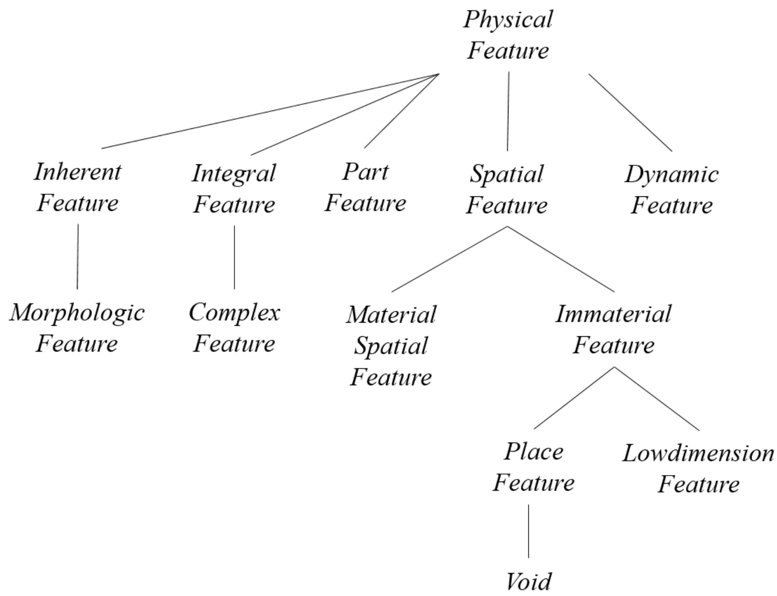

Figure 2. Taxonomy of physical features.

3.1. Inherent Features

Inherent features emerge from their host due to an aspect, its focal, that inheres in its host, with *inheres in* being the essential relation. For example, zebra stripes or leopard spots are features that emerge from certain colours inhering in specific locations on the coat of a zebra or leopard, respectively. Shirt stains [10], birthmarks, and tattoos are analogous. Notably, the aspect inheres in both the host and the feature, e.g. a certain colour (the discolouration) inheres in both the stain and the shirt, but this aspect is essential to the feature and not necessarily essential to the host, e.g. it is essential for a stain to be discoloured, but only accidental for the host shirt. Note, it is assumed in this paper that if a quality (e.g. colour) inheres in a host at some time, then its quale (e.g. red) also inheres in the host at the time, so both qualities and quales can be focals.

Morphologic features are a specialization of inherent features, for which the focal is a specific shape [11]. Bends in rivers, folds in rock bodies, and protrusions or depressions in the landscape [14,15] are all morphologic features. Somewhat surprisingly, corners and edges are also morphologic features in this sense. Specialized morphologic features will typically possess additional essential aspects, e.g. landscape features such as eskers (edges) and volcanoes (corners) are often further refined by their constituent materials and genetic processes.

3.2. Integral Features

Integral features are exemplified by knots, smiles, and fists. They have proper parts, their focals, that are some aspect of a host, and these parts are arranged in a specific way to make an integral whole, which is the feature: knots have parts of a string tied together, smiles have parts of a face uniquely configured, and fists have fingers clenched together. In this, the essential relation is the composition of the relation between hosts and focals, plus the relation arranging the focals into an integral whole. For example, the essential relation for a knot is the composition of the *part of* relation between a string and its segments, plus the topologic relation arranging the segments into a knot. Having parts specifically arranged in this way is then essential to the feature, but may not be essential to the host, as strings do not necessarily have knots, faces do not necessarily have smiles, nor hands have fists. Integral whole features also differ from integral wholes by virtue of being hosted. For example, a pair of eyeballs is a distinct whole composed of left and right eyeballs, with the pair being part of a face, but not hosted by it - they are not ontologically dependent on the face and do not emerge from it, hence they are not integral features.

Integral features are not limited to an arrangement of host parts, as other host aspects can be arranged for a feature to emerge. For example, wood grain is a feature of the wood in which wood fibers (constituents of the wood) are arranged, and a surf is an arrangement of ocean waves (dynamic features) hosted by an ocean. Indeed, any aspect of the host can be arranged to form an integral feature. Cases where features emerge from aspects of other other features to form wholes, such as a surf from ocean waves, are examples of complex features [11]. Complex features have other features as parts.

3.3. Part Features

Part features emerge from focus on a proper part of their host (after [10]). For example, foreheads emerge from upper parts of heads, and mountaintops, mountainsides, and bases of mountains emerge from various parts of mountains. Boundaries that are material entities are also part features, if understood to be the thin exterior-facing material of some material body, one that can be dented and have edges [5]. A particular *part of* relation is essential to the part feature, but not necessarily to the host: it is not essential for all heads to have foreheads, e.g. in some crushed skulls. Part features also differ from parts via hosting, e.g. a forehead is hosted by a head, but eyeballs are not.

3.4. Dynamic Features

Dynamic features [9,14] are disturbances in the physical aspects of a host over time, due to the host participating in a perdurant, its focal. An iconic example is any flowing wave, such as an ocean wave or earthquake wave. Unlike perdurants, which have only temporal parts, dynamic features are physical endurants having physical parts, such as the crest of an ocean wave.

The notion of disturbance is central to dynamic features, and it can be understood as any change in some host aspect over time, including changes of parts, constituents, qualities, other features, as well as their locations. For example, an ocean wave is simply a bump in the ocean surface - an inherent feature - if changes in time to surface shape and location are ignored. However, change in feature location is not essential for a dynamic feature: consider a feature emerging from colours changing over time in the same location.

3.5. Spatial Features

Spatial features have essential relations that are spatial in nature, such as adjacency, containment, intersection, or contact.

3.5.1. Material Spatial Features

Material spatial features are spatial features in which at least the feature is material. Examples include my front yard or backyard, if both are understood to be a piece of ground rather than a chunk of space, and both are structured around the ground being adjacent to my house. If my house then expands or moves, my front yard will consist of a different piece of ground, while still being my front yard: the yard is specifically dependent on my house, its host, and generically dependent on some frontally adjacent ground, its focal.

3.5.2. Immaterial Features

Immaterial features are spatial features in which at least the feature is immaterial - it is not constituted by any matter whatsoever. Immaterial features include place features, voids, and low dimensional features. Immaterial features might, or might not, spatially overlap their host: a hole or shadow is never co-located with its material host, unlike the midpoint of a self-connected and materially-solid object, which does spatially overlap its host.

3.5.3. Place Features

Place features are immaterial features that are chunks of physical space, the focal, adjacent to or containing some material entity, its host, at a time, hence they are a form of relative place [4]. They are analogous to sites in [16] and dependent place features in [10]. Place features are only hosted by material entities, and cannot be hosted by immaterial entities. Being relative to a material entity, they are not fixed in space over time, and thus the chunk of physical space they occupy can change over time, if the location of its material host changes in time. Place features are exemplified by any downtown, the outside of my house, the space along the stem of a wine glass, and my personal space.

3.5.4. Voids

Voids are immaterial features that are chunks of physical space adjacent to some material feature and surrounded by it. They can be subdivided into holes [2], such as valleys, canyons, and caves, as well as gaps [8], such as the space between my knees, with self-connectedness of the host as the distinguishing criteria [8].

3.6. Lowdimension Features

Low dimensional features are immaterial features that do not occupy physical space, but are spatially located. They are typified by lower dimensional spatial subdivisions of a host, including a point such as the North Pole, a linear edge (a line) such as the Equator, a flat slice through it (a plane) [16], or a bumpy slice through it (a surface) such as the Earth's surface. While the host is a physical endurant, the focal is a spatial location that changes as the host moves. Midpoints of any physical endurant are common examples of low dimensional features, such as the center of: a town, my body, a hole, and an earthquake. An earthquake epicenter is an interesting midpoint, because it is hosted by the ground surface instead of the earthquake; as a perdurant, the earthquake cannot host a physical feature. Boundaries that are not material parts of their host are often considered lower dimensional features [16,17].

4. Examples

Table 2 lists some examples of physical features discussed in this paper. Included are everyday examples as well as geographical and geoscientific examples. Most examples specialize the noted feature kind, though the list also contains some individuals.

Table 2. Physical feature examples.

Feature Kind	**Example**
InherentFeature	zebra stripe, stain, birthmark, tattoo
MorphologicFeature	edge, corner, river bend, mountain
IntegralFeature	knot, smile, fist, wood grain
ComplexFeature	ocean surf
PartFeature	forehead, mountaintop, base of mountain
DynamicFeature	ocean wave, earthquake wave
SpatialFeature	*any example below*
MaterialSpatialFeature	backyard, front yard
ImmaterialFeature	*any example below*
PlaceFeature	downtown, outside of my house, my personal space
Void	valley, canyon, cave, space between my knees
LowdimensionFeature	town center, North Pole, Equator, earthquake epicenter

5. Summary

Physical features are elusive things. Though their parasitic character is partially captured by the ontological dependence of a feature on some host, this in itself is not enough to determine physical featurehood - not all things so dependent are features. This paper proposes emergence as the missing ingredient that jointly with ontological dependence determine featurehood. Features then not only ontologically depend on some host, they emerge by way of focus on a relation holding between the hosts and some other spatially-located things. This leads to a proposed structure for a physical feature consisting of: (1) its constant specific dependence on one or more physical endurant hosts, (2) its constant ontological dependence on the other related things, as well as (3) its co-location in space with the sum of the other things. A taxonomy is derived from the relation and consists of features that are: inherent (from *inheres in*), integral (the whole from *part of*), part (the part from *part of*), dynamic (from *participates*), and spatial (having spatial relations). In this way, the structure and taxonomy contribute to the ontological representation of physical features. Remaining work includes formalization and taxonomy expansion to account for other varieties of relations. Consequently, questions remain about the completeness and generality of the approach, especially its applicability to other kinds of features, such as temporal or social features.

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