Part, Slot, Ground:
Foundations for Neo-Aristotelian Mereology

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It is a widespread Neo-Aristotelian idea that a material object is structured by a certain arrangement of *slots*, and that the fillers of these slots are the object's proper parts.[1] Consider, for instance, a typical car, at a given time. Among its proper parts, at this time, are its engine, its chassis, and its wheels.[2] According to slot mereology, as I shall understand it, the engine is a proper part of the car, at that time, in virtue of filling a slot in the car, at the time. Likewise for the other proper parts. Each of them is a proper part of the car by filling a slot in the car. In general, for any material objects x and y, and any time t,

(Proper Part) x is a *proper part* of y, at $t =_{\text{def}} x$ *fills* one of y's *slots*, at t.[3]

With proper parthood in play, additional mereological notions, including parthood, overlap, and composition, can be defined in the usual way.

Slot mereology reduces parthood to slot-filling. My aim in this essay is to go further and reduce slot-filling to essence and grounding. In combination, the reduction of parthood to slot-filling, championed by slot mereologists, and the reduction of slot-filling to essence and grounding, to be developed here, yields the reduction of parthood to essence and grounding. If this overarching reduction succeeds, it promises new metaphysical foundations for Neo-Aristotelian mereology, formulated in terms of well-understood notions with powerful applications far beyond the field of mereology. My aim is exploratory. I do not intend to present these foundations as superior to its alternatives, but

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[1] The slot ideology is invoked, *inter alia*, by Bennett (2013), Harte (2002: chapter 4), and Koslicki (2008: 115-6; 235-7).

[2] This description of the car's parts is temporally relativized because the car can change in its proper parts over time.

[3] Cf. Bennett (2013: section 6). If material objects persist by perduring, then the basic notion of proper parthood need not be temporally relativized, in order to allow for mereological change. If material objects persist by enduring, the basic notion requires temporal relativization. I invoke the relativized notion, since Neo-Aristotelians commonly hold that material objects persist by enduring—see, *inter alia*, Fine (1999).

merely to present them as a new kind of approach that merits serious consideration.

I shall give a reductive account of filling a slot in a material object in three steps. The first step—to be undertaken in Section 1—is to give a rough, initial characterization of the slots to be reduced. This characterization will take the form of seven principles about slots and slot-filling. These principles are chosen to profile slots because they support a number of intuitions about the proper parts of material objects, via definition (Proper Part), and hence give some plausibility to the slot-mereologist reduction of parthood to slot-filling. The second step—to be undertaken in Section 2—is to define several slot-notions in terms of the notions of *grounding* and *essential kind*. The third step—to be undertaken in Section 3—is to complete the reduction of the initially characterized slots by showing that the seven principles from Section 1 are supported by the definitions of Section 2 together with reasonable assumptions about grounding and essence in the domain of material objects. In Section 4, I shall add two clarifications of the proposed reductive account.

1   Principles

The first step in my reductive account of filling a material object's slots is to give a rough, initial characterization of these slots. This characterization will take the shape of a list of seven principles. These principles characterize the target of the attempted reduction. The principles do not appeal to the parts of material objects. They connect to these parts via definition (Proper Part). They earn their keep as reference points because they support a number of intuitions about the proper parts of material objects, as will be shown briefly. While my immediate aim is the reduction of slot-filling to essence and grounding, my mediate aim is the reduction of parthood to essence and grounding. Therefore, it will be necessary to link the initial picture of slots to the mereological structure of material objects in a sensible fashion. To be sure, the initial picture of slots to be sketched is only one among several possible pictures. For reasons of length, I shall not attempt to review alternative approaches and compare them to the present one. [4] Moreover, I shall not attempt to develop a slot mereology axiomatically. The picture to be presented leaves room for a range of different axiomatic slot mereologies that characterize aspects of slots and their interrelations in greater detail.

The principles are the following:

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[4] See, *inter alia*, the contemporary Neo-Aristotelian mereologies of Bennett (2013), Fine (1999), and Koslicki (2008). The slot-picture to be sketched relies heavily on the work of these authors.

(P1) All slots of a material object are kind-sensitive.
(P2) A material object can have monadic slots and polyadic slots.
(P3) A material object can have immediate slots and mediate slots.
(P4) A material object can change with respect to which objects fill its slots.
(P5) A material object can change with respect to which slots it has.
(P6) A material object's range of potential slots is restricted by the object's kind.
(P7) A material object's slot-fillers are exactly located at spatial subregions of the object's exact location.

In the remainder of this section, I shall elaborate on these principles and show that they match various mereological intuitions about material objects.

(P1): All slots of a material object are kind-sensitive. A typical car has an engine, a chassis, wheels, doors, and so on. These things belong to the car, in the sense that they fill slots in the car. The engine fills the engine-slot in the car, the chassis fills the chassis-slot, each wheel fills a wheel-slot, and so on.[5] These slots are *kind-sensitive*. A wheel-slot is sensitive to the kind being a wheel—I shall also say that the slot *encodes* this kind—in the sense that only a wheel can fill the slot. It will be assumed that all slots in a material object are kind-sensitive.

This principle captures the mereological intuition that whether a thing, x, is a proper part of a given material object depends on what kind of thing x is. For instance, each wheel of a given car has the same microphysical parts as a wheel-shaped lump of matter. Intuitively, however, the wheel-shaped lumps of matter are not parts of the car because they are not of the right kind.[6] By (P1) and definition (Proper Part), this is so because the car has wheel-slots but lacks lump-of-matter slots.

(P2): A material object can have monadic slots and polyadic slots. A car's slots combine to form the car's *slot-structure*. The car's slot-structure is not only sensitive to certain kinds of object, but also to a certain arrangement of objects. Roughly, the car's slot-structure encodes an automotive arrangement, in the sense that the objects filling the car's slots must be arranged in an automotive fashion. More precisely, a material object has *monadic K-slots*, for some kind K, and *polyadic R-slots*, for some relation R. A K-slot, such as a wheel-slot, encodes kind K, in the sense that it can only be filled by an object that is a K. While K-slots are simple slots, R-slots are complex slots. An R-slot, for a dyadic relation R, is built from a K-slot, a K*-slot, for some K and K*, and a dyadic relation R, such as the spatial relation of being in contact with. This dyadic slot has both the K-slot and the K*-slot as components, and therefore it encodes kinds K and K*. In addition, the dyadic slot encodes relation R, in the sense that it can only be filled by objects that stand in R, where one is required to be a K and the other

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[5] These examples are helpful to get us started, but they will later turn out to be mere first approximations, especially in light of the second clarification in Section 4.
[6] Cf. Fine (1999: 73).

a K*. An object's slot-structure is the plurality of an object's K-slots and R-slots. The reason for assuming that a car has polyadic R-slots in addition to monadic K-slots is that R-slots make the car's slot-structure relation-sensitive. This is how an automotive arrangement gets to be encoded in the car's slot-structure. Moreover, the reason for assuming that R-slots are built from K-slots, rather than being independent from K-slots, is that, by (P1), slot-filling in general—that is, both completely filling a monadic slot and partially filling a polyadic slot—is kind-sensitive.

This principle captures the mereological intuition that whether some things, the xs, compose a given material object depends on how the xs are arranged, in addition to depending on what kinds the xs belong to. For instance, an engine, a chassis, wheels, doors, and so on, compose a given car only if they are arranged in an automotive fashion. A wheel on the backseat of the car is of a suitable kind but fails to be suitably related to the car's engine, its chassis, and so on, to be a part of the car. By (P2) and (Proper Part), this is so because the car has an automotive slot-structure that holds no slot for a rogue wheel.

(P3): A material object can have immediate slots and mediate slots. Each of the fillers of the mentioned K-slots in the car itself has slots. For instance, each wheel has a tire-slot, a rim-slot, several bolt-slots, and so on. Furthermore, each of the objects filling the wheel's slots itself has slots, until we reach slot-fillers without their own slots, if such there be. It will be assumed that a material object inherits the slots of its slot-fillers and of its slot-fillers' slot-fillers, and so on. Moreover, it will be assumed that among the car's slots are *immediate* ones and *mediate* ones. The engine-slot and the wheel-slots are among the car's immediate K-slots. In addition, the car has immediate R-slots that jointly encode the carwise arrangement among the fillers of its immediate K-slots. Further, certain tire-slots and rim-slots are among the immediate slots of an object that fills an immediate wheel-slot in the car, which makes them mediate slots in the car. Moreover, the car has mediate R-slots that encode, for instance, the wheelwise arrangement of the objects filling the K-slots of the filler of an immediate wheel-slot.

This principle captures the mereological intuition that a material object has immediate parts and mediate parts—that a material object's parts are ordered hierarchically. The car's engine, its chassis, and its wheels are among its immediate parts, whereas the tires, rims, and bolts of the car's wheels are among the car's mediate parts. By (P3) and (Proper Part), this is so because the engine, the chassis, and the wheels fill immediate slots of the car, whereas the tires, rims, and bolts fill mediate slots.

(P4): A material object can change with respect to which objects fill its slots. Which material objects fill a material object's slots may be different at different times (and worlds). For instance, given two doors, x and y, x may fill a door-slot in a car, at one time, though y does not, and y may fill a door-slot in the same car, at another time, though x does not.

This principle captures the mereological intuition that a material object can change in its parts over time. For instance, a given car can have a particular door as a part, at one time, but a different door as a part, at a later time. By (P4) and (Proper Part), this is so because the car's door-slots can be filled by different doors at different times.

(P5): A material object can change with respect to which slots it has. There can be variation across times (and worlds) with respect to which K-slots and which R-slots a given object possesses. For instance, a car with a trunk may be altered to become a car without a trunk, in which case the car's automotive slot-arrangement changes as well. A trunk-slot in a car is an instance of a *variable slot* of the car, in that the car can exist without it. The engine-slot in a car, by contrast, is an instance of a *rigid slot* of the car, as the car cannot exist without it.[7] On the assumption that an object's slot-structure is the plurality of an object's slots, an object can have different slot-structures at different times, since it can have different slots at different times.

This principle captures the mereological intuition that which kinds of object a material object's mereological structure is sensitive to may change over time. For instance, while the parts of a given car must be of the right kinds to be arranged automotively, the car may have parts of different kinds at different times. By (P5) and (Proper Part), this is so because a car can have different automotive slot-structures at different times.

(P6): A material object's range of potential slots is restricted by the object's kind. While a material object can change in its variable slots over time, the range of slots, and hence the range of slot-structures, it can have is restricted. For instance, a trunk-slot is a potential slot of the car, but a hand-slot is not. What restricts the range of potential slots of this object is that it is a car. While a trunk-slot is the right sort of slot for a car, a hand-slot is not. More broadly, a car has, at each time of its existence, a slot-structure of an automotive sort, in virtue of being a car.

This principle captures the mereological intuition that which kinds of object a material object's mereological structure is sensitive to is determined by the object's kind. For instance, in virtue of being a car, an object can have a trunk as a part, but it cannot have a hand as a part. By (P6) and (Proper Part), this is so because, in virtue of being a car, an object can have a trunk-slot, but it cannot have a hand-slot.

(P7): A material object's slot-fillers are exactly located at spatial subregions of the object's exact location. A car is exactly located at a certain spatial region, at any time, t, of its existence. The objects that fill the car's slots, at t, are also exactly located at certain spatial regions, at t. It will be assumed that the exact locations of the car's slot-fillers, at t, are subregions of the exact location of the

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[7] I adapt the *rigid/variable* terminology from Fine (1999), where it is used differently.

car, at t.[8] That is, a car does not have any slots that are filled by an object exactly located at a region that is partly or completely outside of the car's exact location. This is a spatial aspect of a material object's slots.

This principle captures the mereological intuition that the exact locations of a material object's parts, at a time t, are subregions of the exact location of the whole, at t. For instance, the engine, the chassis, the wheels, and all the other proper parts of a car, at a time t, are located inside of the region, at which the car is located, at t. By (P7) and (Proper Part), this is so because the exact locations of a car's slot-fillers, at t, are subregions of the exact location of the car, at t.

The key notions in the slot-picture that emerges from (P1)-(P7) are the notion of filling a K-slot, for some kind K, and the notion of filling an R-slot, for some relation R. In the following section, I will define these notions in terms of grounding and essence. In Section 4, I will show that the definitions together with reasonable assumptions about grounding and essence in the domain of material objects support (P1)-(P7).

2   Definitions

In defining filling a K-slot and filling an R-slot, I shall rely primarily on two basic notions. The first is the notion of *grounding*.[9] I shall understand grounding as a relation among facts, or states of affairs, and I shall focus on grounding statements of the following sort: a's being ϕ and b's being ψ ground c's being ξ. (Alternative grounding ideologies are equally suited to the task at hand.) Moreover, I shall assume that grounding is a strict partial ordering—that is, an irreflexive, transitive, and asymmetric relation—between facts, or states of affairs. When a's being ϕ and b's being ψ ground c's being ξ, then c's being ξ is explained, in a non-causal sense, by a's being ϕ and b's being ψ.[10] I shall also adopt the now-common distinction between *partial* and *full* grounding. When a's being ϕ *partially* grounds c's being ξ, then a's being ϕ is relevant to explaining c's being ξ, but it is not sufficient to explain the latter fact on its own. When a's being ϕ and b's being ψ *fully* ground c's being ξ, then a's being ϕ and b's being ψ are both relevant and jointly sufficient to explain c's being ξ.

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[8] It is common to understand subregions as parts of regions: if p and p^* are regions, then p is a *subregion* of $p^* =_{def} p$ is a part of p^*. If this definition is adopted in the present context, then parts of regions are of a different type than parts of material objects, since the parthood relation that holds between regions is, presumably, not a slot-theoretic parthood relation of the type developed here. Alternatively, being a subregion may be defined set-theoretically or may be taken as primitive. For an overview of links between location and parthood, see Gilmore (2018).

[9] See Fine (2012) for an overview and the grounding-distinctions mentioned below.

[10] I am here assuming that grounding backs metaphysical explanation. Some friends of grounding reject this link. See Thompson (2016) for an overview.

The second basic notion is that of an *essential kind*. I shall make the relatively familiar assumption that necessarily each material object has a unique essential kind. An object typically falls under many kinds, but only one of them is the object's essential kind. This kind belong's to the object's nature and determines the object's persistence conditions and *de re* modal profile. An object may be a person, a mother, a teacher, and a musician, while only its personhood is essential to it and the other kinds inessential. The notion of an essential kind raises many pressing metaphysical questions. But explanation has to start somewhere. So, I shall just take this familiar notion for granted here.

Grounding and essence are vetted notions with powerful applications far beyond the field of mereology. If this portfolio yields a firm grasp of these notions, it also yields a firm grasp of the definitions to be proposed in what follows. The key idea behind the definitions is, very roughly, to understand filling a material object's slots in terms of grounding a spatio-temporal instantiation of the object's essential kind.[11]

What does it take for a material object to fill a (monadic) K-slot, for some K, of another material object? For instance, what does it take for a wheel, W, to fill a wheel-slot of a car, C? To begin with, I shall assume that a material object instantiates a kind K, *at a spatial region* and *at a time*, namely, at the spatial region at which the object is exactly located—intuitively, the region that the object fits into perfectly—at that time. This does not imply that an object can always vary from region to region and time to time with respect to K. It only means that the instantiation of K is sensitive to regions as well as times.

Now contrast the following two questions: a) What makes something a K, in general? b) What makes something a K, at a particular region and time? Question a) concerns the *nature* of being a K—that is, a) concerns those grounds of the instantiation of K that explain any spatio-temporal instantiation of K whatsoever. Question b), by contrast, concerns a *realization* of K—that is, b) concerns the grounds of a specific spatio-temporal instantiation of K.[12, 13]

In defining slot-filling in the domain of material objects, I shall focus on realizations of material-object kinds. Suppose that C is a car, at *p*, at *t*. What grounds this spatio-temporal instantiation of carhood? A natural schematic

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[11] This idea is inspired by the account of mereological structure in my framework of perspectival hylomorphism; see Sattig (2015: section 2.2).

[12] Note that a kind's nature and its spatio-temporal realizations are intimately related. To be a car, in general, is to have some automotive function. Given this nature of carhood, to ask what makes something a car, at a specific region and time, is to ask what makes something in this spatio-temporal region have that automotive function—that is, to ask how the automotive function is realized in this region.

[13] While I understand a realization of a kind as the grounding of a spatio-temporal instantiation of that kind, I do not offer this as an analysis of the notion as it is used in a variety of contexts in metaphysics and philosophy of mind. There may well be different notions of realization in play.

explanation is the following: within region p, at t, some objects are wheels, some are doors, one is a chassis, etc.—they are exactly located at subregions of p, at t—and these objects are arranged in a certain automotive fashion, such that the instantiations of the latter kinds, within p, at t, as well as the automotive arrangement of the instances of those kinds, together fully ground the instantiation of being a car, at p, at t. Accordingly, the instantiation of carhood, at p, at t, is partially grounded in the instantiation of wheelhood, at a subregion of p, at t. In brief, at this spatio-temporal region, carhood is partially realized by wheelhood.

Given that C is the subject of this spatio-temporal instantiation of carhood, and that W is the subject of the mentioned nearby instantiation of wheelhood, and given that carhood is essential to C, while wheelhood is essential to W, we get the result, concisely put, that W's essential kind partially realizes C's essential kind. I propose that this is what it means for W to fill a wheel-slot of C.

Generalizing: for any material objects x and y, any kind K, and any time t,

(K-slot) x fills a K-slot of y, at t, $=_{\text{def}}$
(i) x is a K, at some region p, at t;
(ii) there is a kind K*, such that y is a K*, at some region p*, at t;
(iii) x is essentially a K, while y is essentially a K*;
(iv) the fact that some object is a K, at p, at t, partially grounds the fact that some object is a K*, at p*, at t;[14] and
(v) p is a subregion of p*.

In addition to defining filling a K-slot, I shall define filling an *immediate* K-slot and filling a *mediate* K-slot. It is now common in the grounding-literature to distinguish between *immediate* and *mediate ground*, where mediate ground is defined in terms of chains of immediate grounds.[15] This distinction yields a ground-theoretic hierarchy. A fact's immediate ground sits at the next lower level of the grounding-hierarchy, while an immediate ground of an immediate ground (of an immediate ground ...) of the fact is a mediate ground further down in the hierarchy.

Now consider condition (iv) of (K-slot). When the fact that some object is a K, at p, at t, partially grounds the fact that some object is a K*, at p*, at t—

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[14] Note that condition (iv) is existentially quantified. It does not simply say that the fact that x is a K, at p, at t, partially grounds the fact that y is a K*, at p*, at t. I shall return to this aspect in Section 4.

Note, further, that specifying partial grounds of the fact that an object is a K*, at a given region and time—as condition (iv) in (K-slot) does—is different from specifying grounds of the fact that an object is *essentially* a K*. Specifying grounds of essentiality facts is not a part of the proposed account.

[15] See Fine (2012).

for some K and K*—then we may ask whether the former fact immediately or mediately partially grounds the latter fact. That is, we may ask whether the former fact is immediately or only mediately relevant to explaining the latter fact. Intuitively, something's being a brick is an immediate partial ground of something's being a brick wall, while something's being a clay molecule is an immediate partial ground of something's being a brick but not of something's being a brick wall. Something's being a clay molecule is merely a mediate partial ground of something's being a brick wall.

I shall define what it is for an object to fill an immediate slot and what it is to fill a mediate slot, as follows: for any objects x and y, any kind K, and any time t,

(i-K-slot) x fills an *immediate* K-slot of y, at t, $=_{\text{def}}$
              (i) x is a K, at some region p, at t;
              (ii) there is a kind K*, such that y is a K*, at some region p^*, at t;
              (iii) x is essentially a K, while y is essentially a K*;
              (iv) the fact that some object is a K, at p, at t, *immediately* partially grounds the fact that some object is a K*, at p^*, at t; and
              (v) p is a subregion of p^*.

(m-K-slot) x fills a *mediate* K-slot of y, at t, $=_{\text{def}}$
              (i) x is a K, at some region p, at t;
              (ii) there is a kind K*, such that y is a K*, at some region p^*, at t;
              (iii) x is essentially a K, while y is essentially a K*;
              (iv) the fact that some object is a K, at p, at t, *mediately* partially grounds the fact that some object is a K*, at p^*, at t; and
              (v) p is a subregion of p^*.

Moving on to relational slots, what does it take for material objects x and y to fill an R-slot, for some dyadic relation R, of a material object z, at a time? (I shall focus on the dyadic case; generalization to cases of higher adicity will be straightforward.) For instance, what does it take for x and y to fill a spatial-contact-slot of z?

In order to extend my definition of filling monadic slots, (K-slot), to filling polyadic slots, I shall start with the assumption that if material objects instantiate a relation at a time, they also instantiate the relation at a tuple of regions, at that time, namely, at the tuple of regions the objects exactly occupy, respectively, at that time. So, the instantiation of time-sensitive relations is also region-sensitive.

Suppose, again, that C is a car, at p, at t. What grounds this spatio-temporal instantiation of carhood? The schematic explanation sketched earlier is this: within p, at t, some objects are wheels, some are doors, one is a chassis, etc., and these objects are related in a certain automotive fashion, such that the instantiations of the latter kinds, within p, at t, and also the instantiation of certain

automotive relations, within p, at t, together fully ground the instantiation of being a car, at p, at t. Accordingly, the instantiation of carhood, at p, at t, is partially grounded in the instantiation of certain automotive relations, inside of p, at t. In brief, at this spatio-temporal region, carhood is partially realized by certain automotive relations.

Given that C is the subject of this spatio-temporal instantiation of carhood, carhood being essential to C, and given that door D and body B bear the spatial-contact-relation inside of this spatio-temporal region, we get the result, concisely put, that D and B's contact-relation partially realizes C's essential kind. I propose that this is what it means for D and B to fill a spatial-contact-slot of C.

Generalizing: for any material objects x, y, and z, any dyadic relation R, and any time t,

(R-slot) x and y fill an R-slot of z, at t, $=_{\text{def}}$
(i) x and y fill K-slots, for the same or different Ks, of z, at t;[16]
(ii) there is a kind K*, such that z is a K*, at some region p_1, at t;
(iii) z is essentially a K*;
(iv) x stands in R to y, at some region-pair $<p_2, p_3>$, at t;
(v) the fact that some object stands in R to some object, at $<p_2, p_3>$, at t, partially grounds the fact that some object is a K*, at p_1, at t; and
(vi) p_2 and p_3 are subregions of p_1.

By clauses (ii)-(vi), x and y fill an R-slot of z only if x and y stand in R, at a certain spatio-temporal region, and the instantiation of R, at that region, makes an explanatory contribution to z's substantial nature. By clause (i) and (K-slot), though, x and y do not get to fill a relational slot of z unless their substantial natures, in addition to their relatedness, make explanatory contributions to the substantial nature of z.

The distinction between filling an immediate K-slot and filling a mediate K-slot can be extended to R-slots in the following straightforward way: for any material objects x, y, and z, any dyadic relation R, and any time t,

(i-R-slot) x and y fill an *immediate* R-slot of z, at t, $=_{\text{def}}$
(i) x and y fill immediate K-slots, for the same or different Ks, of z, at t;
(ii) there is a kind K*, such that z is a K*, at some region p_1, at t;
(iii) z is essentially a K*;
(iv) x stands in R to y, at some region-pair $<p_2, p_3>$, at t; and

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[16] By clause (i) and (K-slot), x and y are required to belong to their kinds essentially.

(v) the fact that some object stands in R to some object, at $<p_2, p_3>$, at t, *immediately* partially grounds the fact that some object is a K*, at p_1, at t; and

(vi) p_2 and p_3 are subregions of p_1.

(m-R-slot) x and y fill a *mediate* R-slot of z, at t, $=_{def}$

(i) x and y fill mediate K-slots, for the same or different Ks, of z, at t;

(ii) there is a kind K*, such that z is a K*, at some region p_1, at t;

(iii) z is essentially a K*;

(iv) x stands in R to y, at some region-pair $<p_2, p_3>$, at t; and

(v) the fact that some object stands in R to some object, at $<p_2, p_3>$, at t, *mediately* partially grounds the fact that some object is a K*, at p_1, at t; and

(vi) p_2 and p_3 are subregions of p_1.

3   Applications

The definitions of Section 2 together with reasonable assumptions about grounding and essence in the domain of material objects support the seven principles of Section 1, (P1)-(P7). Showing this will complete the promised reduction of slots of material objects, as initially characterized, to grounding and essence.

According to (P1), all slots of a material object are kind-sensitive. By definitions (K-slot) and (R-slot), whether an object x fills any slot in an object y depends on what kind of object x is. According to the definitions, that an object x fills a slot in an object y—that x fills a monadic slot in y completely or that x fills a polyadic slot in y partially—requires, concisely put, that x's essential kind partially realize y's essential kind. Thus, all slots in y are kind-sensitive.

According to (P2), a material object can have monadic slots and polyadic slots. Let x be an engine essentially and y be a car essentially. The following scenario about x and y is possible. Given that x is an engine, at a region p, at a time t, and that y is a car, at a region p^*, at t, where p is a subregion of p^*, something's being an engine, at p, at t, partially grounds something's being a car, at p^*, at t. More concisely put, a spatio-temporal instantiation of being an engine, of which x is the subject, partially grounds a simultaneous spatio-temporal instantiation of being a car, of which y is the subject. By definition (K-slot), x fills a monadic engine-slot of y, at t.

Furthermore, let x be a door essentially, y be a body essentially, and z be a car essentially. The following scenario is possible. First, z is a car, at p_1, at t, x is a door, at p_2, at t, y is a body, at p_3, at t, where both p_2 and p_3 are subregions of p_1, and x is in spatial contact with y, at $<p_2, p_3>$, at t. Moreover, the fact that some

object is in spatial contact with some object, at $<p_2, p_3>$, at t, partially grounds the fact that some object is a car, at p_1, at t. Finally, that x is a door, at p_2, at t, partially grounds that z is a car, at p_1, at t, and that y is a body, at p_3, at t, partially grounds that z is a car, at p_1, at t. By definition (R-slot), x and y fill a spatial-contact-slot of z, at t.

According to (P3), a material object can have immediate slots and mediate slots. Let x be a tire essentially, let y be a wheel essentially, and let z be a car essentially. The following scenario about x, y, and z is possible. A spatio-temporal instantiation of the kind being a tire, of which x is the subject, immediately partially grounds the simultaneous spatio-temporal instantiation of the kind being a wheel, of which y is the subject. Moreover, the latter spatio-temporal instantiation of the kind being a wheel, of which y is the subject, immediately partially grounds the simultaneous spatio-temporal instantiation of the kind being a car, of which z is the subject. Accordingly, the mentioned spatio-temporal instantiation of the kind being a tire, of which x is the subject, mediately partially grounds the simultaneous spatio-temporal instantiation of the kind being a car, of which z is the subject. By definitions (i-K-slot) and (m-K-slot), it follows that y fills an immediate wheel-slot of z, and that x fills a mediate tire-slot of z.

According to (P4), a material object can change over time with respect to which objects fill its slots. Let x be a door essentially, let y be a door essentially, let x be non-identical with y, and let z be a car essentially. The following scenario about x, y, and z is possible. Object z is a car at different regions and times, and the different spatio-temporal instantiations of being a car, of which z is the subject, are realized by different spatio-temporal instantiations of being a door, respectively, where x is the subject of one such instantiation and y is the subject of another. By (K-slot), x fills a door-slot of z, at one time, though y does not, and y fills a door-slot of z, at another time, though x does not. Hence, there is change with respect to which objects fill the car's slots.[17]

According to (P5), a material object can change with respect to which slots it has. Let x be a trunk essentially and let y be a car essentially. The following scenario is possible. Given that y is a car, at p_1, at t, and at p_2, at t_2, where p_1 and p_2 are different regions and t_1 and t_2 are different times, x is a trunk at a subregion, p_3, of p_1, at t_1, while no object is a trunk at a subregion of p_2, at t_2. Moreover, some object's being a trunk, at p_3, at t_1, partially grounds some object's being a car, at p_1, at t, while no trunk-fact partially grounds some object's being a car, at p_2, at t_2. By (K-slot), x fills a trunk-slot of y, at t_1, while no object fills a trunk-slot of y, at t_2. The crux of this case is that what realizes the car's essential kind can vary over time (even if the nature of carhood is invariant). While the car has its

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[17] Note that I do not say that y fills the door slot of z that was previously filled by x, since my definitions do not provide means to identify K-slots and R-slots across times (or worlds). This should not be considered a limitation of the account.

essential kind everywhere and always, what makes it a car may be different at different regions and times. Carhood is multiply realizable.[18]

According to (P6), an object's range of potential slots is restricted by the object's essential kind. For instance, while a trunk-slot is the right sort of slot for a car, a hand-slot is not. The restrictedness of an object's range of potential slots by its essential kind has a clear explanation on the basis of our definitions. By (K-slot), an object fills a K-slot, for any K, of a car (at a time) only if being a K partially realizes being a car. Since being a trunk is a possible partial realizer of being a car, a car can have a trunk-slot. Since being a hand is, presumably, not a possible partial realizer of being a car, a car cannot have a hand-slot. Similarly, for kind-based restrictions on an object's R-slots. In general, kind-based restrictions of the range of an object's potential slots have their source in the kind's realizability by other kinds.

According to (P7), a material object's slot-fillers are exactly located at spatial subregions of the object's exact location. That K-slot-filling satisfies this constraint follows from condition (v) in the definitions of K-slot-filling, on the assumption that an object x always instantiates a K at the exact location of x. Moreover, that R-slot-filling satisfies this constraint follows from condition (vi) in the definitions of R-slot-filling, on the assumption that an object x and an object y always instantiate a relation at the pair of exact locations of x and y.

The case of a car may give the impression that these spatial conditions are not needed to support (P7). For it may well be the case that all kind-instantiations that ground a car-instantiation, at p, for any spatial region p, are kind-instantiations at subregions of p. If this were the case in general, then the spatial constraint in (v) of (K-slot) would follow from (iv). Consider, however, the following case.[19] Suppose that something is an island, at p_1 (at a given time). Plausibly, something's being an island, at p_1, is partially grounded in something's being surrounded by an ocean (or a lake or a river), at p_1. Moreover, something's being surrounded by an ocean, at p_1, is partially grounded in something's being an ocean, at p_2, where p_2 surrounds p_1. Supposing that o is an ocean, at p_2, and that o is an ocean essentially, it would follow by (K-slot) without condition (v) that o fills an ocean-slot of the island. Hence, (P7) would not be supported. Since (K-slot) contains (v), it does not follow that o fills an ocean-slot of the island, because p_2 is not a subregion of p_1. Hence, (P7) is supported by the definitions of K-slot-filling. Similarly for the definitions of R-slot-filling.

I conclude that the definitions of Section 3 together with reasonable assumptions about grounding and essence in the domain of material objects support each of the seven principles of Section 2, (P1)-(P7). This completes the

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[18] Accordingly, recognizing an explanatory link between x's filling a K-slot in y, for any K, and y's essential kind does not require viewing this K-slot as being essential to y—that is, it does not require viewing this K-slot as a rigid slot.

[19] Cf. Sattig (2015: 55).

third and final step of my reduction of slots, as they were initially characterized, to grounding and essence.

4   Clarifications

Let me close with two clarifications, which are needed to avoid misunderstanding of the proposed reductive account.

      The first clarification addresses an issue concerning grounding, haecceity, and necessity. The grounding relation in condition (iv) of (K-slot) and in condition (v) of (R-slot) are existentially quantified, and hence do not relate facts about particular objects:

(K-slot) x fills a K-slot of y, at t, $=_{\text{def}}$

          ...

          (iv) the fact that some object is a K, at p, at t, partially grounds the fact that some object is a K*, at p*, at t.

          ...

(R-slot) x and y fill an R-slot of z, at t, $=_{\text{def}}$

          ...

          (v) the fact that some object stands in R to some object, at $<p_2, p_3>$, at t, partially grounds the fact that some object is a K*, at p_1, at t.

          ...

Why does condition (iv) of (K-slot) (and of (i-K-slot) and (m-K-slot)) not simply read: the fact that x is a K, at p, at t, partially grounds the fact that y is a K*, at p*, at t? Analogously, why does condition (v) of (R-slot) (and of (i-R-slot) and (m-R-slot)) not simply read: the fact that x stands in R to y, at $<p_2, p_3>$, at t, partially grounds the fact that z is a K*, at p_1, at t? This is an important issue. The reason why no particular objects enter into the relevant grounding conditions—in short, why these conditions are not *haecceitistic*—concerns the relationship between grounding and necessity. The principle of *grounding necessitarianism* is widely accepted. It says that if a fact f fully grounds a fact g, then f necessitates g. Given this principle, haecceitistic versions of the grounding conditions in (K-slot) and (R-slot) are open to a certain type of counterexample.[20]

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[20] The following type of case has been discussed intensively, though it is usually encountered in a slightly different context. See, *inter alia*, Hawthorne & Gendler (2000) and Sattig (2015: 155-62). Skiles' (2015) discussion of grounding necessitarianism focuses on Theseus-style cases that are closely related to the recurrence-case discussed here.

Consider a possible world, w, with eternal recurrence, in which the same plenum of microphysical particles become arranged in the same total qualitative way at regular intervals. Some of these particles regularly become arranged carwise before they get rearranged again. So, a car is created and destroyed in each epoch, and distinct epochs contain distinct cars with the same microphysical parts. Consider times t_1, t_2, and t_3, in w, such that the universe is in duplicate states, at these times. Suppose that Cara is a car that has an electron e as a proper part, at t_2, and that Cora is a distinct but qualitatively indiscernible car that has e as a proper part, at t_3. Given that Cara and Cora differ only in the particular times at which they have their properties and relations, and given that a car could have been created at a different time, it seems plausible that Cara could have been created, at t_1, while Cora is created, at t_2. Suppose, then, that in world w^*, at t_2, Cora is composed of the same particles, including e, as Cara in w.

Since e is a proper part of Cara, at t_2, in w, it follows by the haecceitistic version of (K-slot) that e's being an electron, at t_2, partially grounds Cara's being a car, at t_2. The fact that e is an electron, at t_2, is thus a member of a collection of facts, F, whose obtaining at t_2 fully grounds Cara's being a car, at t_2. By grounding necessitarianism, the obtaining of F at t_2 necessitates the fact that Cara is a car, at t_2. In world w^*, F obtains at t_2 as well. Yet, in w^*, Cara is not a car at t_2, since in w^*, Cara does not even exist, at t_2. What is grounded by the obtaining of F, at t_2, in w^*, is the fact that Cora is a car, at t_2. We thus have a counterexample to the haecceitistic version of (K-slot) on the assumption of grounding necessitarianism.

While it is open to the haecceitistically minded slot mereologist to deal with this problem by rejecting grounding necessitarianism, compatibility with the principle is preferable, given the latter's intuitive appeal and widespread endorsement. As condition (iv) in (K-slot) was in fact formulated, it is non-haecceitistic—that is, the grounding relation does not apply to facts about particular objects. The Cara-Cora case therefore poses no threat to the account. Given that e is a proper part of Cara, at t_2, in w, it follows by clause (iv) of (K-slot) that some object's being an electron, at p, at t_2, partially grounds some object's being a car, at a nearby region, p^*, at t_2. The fact that some object is an electron, at p, at t_2, is thus a member of a collection of facts, F^*, whose obtaining at t_2 fully grounds some object's being a car, at p^*, at t_2. By grounding necessitarianism, the obtaining of F^*, at t_2, necessitates the fact that some object is a car, at p^*, at t_2. This is unproblematic. While Cara is the relevant car, at t_2, in w, and Cora is the relevant car, at t_2, in w^*, in both w and w^* the obtaining of F^*, at t_2, fully grounds the fact that some object is a car, at p^*, at t_2. (K-slot) (along with (i-K-slot) and (m-K-slot)) thus avoids the counterexample from grounding necessitarianism. (R-slot) (along with (i-R-slot) and (m-R-slot)) avoids counterexamples of this sort for analogous reasons.

The second clarification addresses an issue concerning causal-functional roles. Suppose that a given car has a window-slot. Initially, the window-slot is

filled by a piece of glass. Later, following an accident, the window-slot is filled by a plastic bag.[21] When setting up (K-slot), I stated that filling a K-slot, for any K, requires being essentially a K. But neither the piece of glass nor the plastic bag is essentially a window. They play the window-role in the car for a period of time, while they may have a window-less life before and after that period. The notion of a K-slot that is in play in this example corresponds to the notion of a *causal role* in a functional organization: a window-slot in a car, on this understanding, is filled by an object that plays the causal-functional window-role in the car.

This is *not* the notion of a K-slot intended here. On the intended understanding, the car does not have a window-slot that is first filled by a piece of glass and then filled by a plastic bag. Rather, the car first has a piece-of-glass-slot and then has a plastic-bag-slot, which are filled by a piece of glass and a plastic bag, respectively. That is, the car's slots are not individuated by causal roles in the car's functional organization. They are individuated by the essential kinds of the objects that play these causal-functional roles. In general, on the intended understanding of the notion of a slot, K-slots do not correspond straightforwardly to causal-functional K-roles, if K is a functional kind.

Notice, however, that the causal-functional roles in the car's automotive organization may be appealed to in specifying how the substantial nature of the proper part partially grounds the substantial nature of the car. In virtue of what they are, the two proper parts of the car play the causal role of a window in the car, at different times. Something's being a piece of glass, at a certain region and time, partially grounds something's being a car, at a nearby region, at that time, because an object's being a piece of glass realizes the window-role in the car's automotive function, at that region and time. Similarly, something's being a plastic bag, at a certain region and time, partially grounds something's being a car, at a nearby region, at that time, because an object's being a plastic bag realizes the window-role in the car's automotive function, at that time.[22]

Where does the proposed reduction of slot-filling to essence and grounding leave us? While this reduction is the immediate aim of this essay, its ultimate aim is the reduction of parthood to essence and grounding. If the envisaged reduction of parthood succeeds, then slots might retain a role in Neo-Aristotelian mereology, or they might lose any role at the end of the day. The former is the more conservative approach. It consists in continuing to do Neo-Aristotelian mereology with slots, viewing the notion as a valuable theory-building device that we have now come to understand thoroughly. The latter is a more radical approach. It consists in abandoning slots, viewing the notion as a

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[21] Thanks to Claudio Calosi for the example.

[22] While causal-functional roles clarify the realization of functional kinds, the proposed slot-definitions do not appeal to causal-functional roles, in order to cover slots in non-functional kinds of material object as well.

mere enabler in the explanation of parthood, and doing Neo-Aristotelian mereology exclusively in terms of essence and grounding.[23]

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