

Three Facets of Roles in Foundational Ontologies

Fumiaki TOYOSHIMA ¹

Graduate School of Advanced Science and Technology, JAIST, Japan

Abstract. Roles remain such a nebulous concept notwithstanding its ubiquity in a wide variety of domains, including conceptual modeling, that no clear consensus exists over the nature of roles in the foundational ontology research. In this paper I argue that there are three closely intertwined, but conceptually separate role-related notions: a *role specification*, a *role position*, and a *role performance*. I further contend that different accounts of roles might depend on which of the three concepts takes priority over the other two. Additionally I propose that there be three possible interpretations of the ontological nature of roles, each of which requires careful cost-benefit analysis: a family resemblance concept, a functionally definable concept, and a practically unifiable concept.

Keywords. role, foundational ontology, grounding, specification, family resemblance

1. Introduction

The notion of role is present in a number of different domains, ranging from knowledge representation [1] and conceptual modeling [2] to cognitive science and linguistics. Accordingly there is a high demand for a common definition of role that would help us address the problem of semantic interoperability among information systems [3]. To meet this need, roles have been extensively researched in formal ontology for the last few decades and virtually all foundational ontologies nowadays have the role category. The role concept nonetheless remains so elusive that the understanding of role can vary greatly from one foundational ontology to another.²

Intimately connected to this topic is the extant issue of whether a single definition of role is possible [3]. Despite some attempts to define roles explicitly (e.g., [2,6]), for instance, Loebe [7, p. 144] says: “there is no single kind of roles, and no unique kind of entities on which roles depend.” If the answer to this question is no, then the challenge to be met is (how to build a model for specifying) how roles are to be individuated or

¹Corresponding Address: Graduate School of Advanced Science and Technology, Japan Advanced Institute of Science and Technology (JAIST), 1-1 Asahidai, Nomi, 923-1292, Japan; E-mail: fumiaki.toyoshima@jaist.ac.jp, fumiakit@buffalo.edu.

²For instance, Guarino [4, p. 14] says: “I have been always fascinated by the subtle aspects of this notion [role], and by its ubiquitous relevance for practical applications. (...) It is not a surprise therefore to see roles appearing in BFO [Basic Formal Ontology [5]], but their characterization as realizable specifically-dependent continuants reflects a very peculiar understanding of the role notion which, although useful, would require a broader framework.” Note that we will later look at the BFO conception of role.

classified. Some noteworthy related studies (e.g., [8]) notwithstanding, it is still largely unexplored how a certain theory of role is connected to the *meta-ontological choices* [9] behind the general ontological background against which the theory is constructed.

In this paper I endeavor to investigate the nature of role from the perspective of foundational ontology. To do so, I leverage the notion of *grounding* that has been recently developed in the field of philosophical ontology. As we will see below, grounding is supposed to specify how some phenomena (e.g., a table exists) hold *in virtue of* more fundamental phenomena (e.g., subatomic particles are ‘arranged table-wise’) and, quite importantly, to be closely linked to the notion of explanation (which may be called ‘ontological explanation’) in philosophical ontology.³

More specifically, I consider what grounds the concept of *role-playing* that is central to the general discussion on role. This work amounts to an attempt to seek an adequate explanation of role-playing, thus leading to a better understanding of role. It is found on close examination that there are three notions (which I call the ‘role triad’) that ground role-playing: a *role specification*, a *role position*, and a *role performance*. Defying easy analysis, each of the role triad is to be elucidated by analogy and with examples.

Then I hypothesize that different accounts of role might hinge on which of the role triad is ontologically prior to the other two concepts. To illustrate this, I explore three theories of roles and which element of the role triad each theory take to be primary. I further clarify that and how each theory’s ‘role choice’ is conceptually firmly glued to the (meta-ontological choices of) foundational ontology on which the theory is based.

I finally suggest that there be three possible interpretations of the nature of role: a family resemblance concept, a functionally definable concept, and a practically unifiable concept. As will be detailed below, each of them has both advantages and disadvantages. For instance, a family resemblance conception of role lacks practical virtue while it is arguably most theoretically tenable. All these findings will contribute to bridging the gulf between foundational investigation into the nature of role and modeling processes associated with roles in various application domains.

The paper is structured as follows. Section 2 offers some preliminary knowledge on basic ontological assumptions and grounding. Section 3 presents and elucidates each of the role triad. Section 4 illustrates, with three selected accounts of roles, the relationship between meta-ontological choices in foundational ontologies and their ‘role choices’. Section 5 proposes three possible understandings of the nature of role. Section 6 concludes the paper with some brief remarks on future directions of research.

2. Preliminaries

2.1. Basic Ontological Assumptions

Since this paper is partly devoted to comparative analysis of foundational ontologies, I assume only the basic categories and relations that are relatively widespread in foundational ontologies. Concrete individuals (which exist in space and/or time) fall into two types: *continuants* (aka endurants) such as *objects* and *occurrents* (aka perdurants). Characteristically, continuants can persist, whereas occurrents extend through time. Continuants (e.g., a stone) can *participate in* occurrents (e.g., a fall of the stone).

³I borrow the expression of the form ‘arranged X-wise’ from van Inwagen [10].

I stipulate throughout the paper that roles are continuants, since roles are most frequently taken to be a special kind of properties (in the broad sense of the term) in the relevant literature on role (e.g., [6,11]). I also assume that a role is a continuant *to be played* by something (*player*), since the notion of role-playing is generally thought to be a key to a deeper understanding of the nature of role.⁴

2.2. Grounding as a Conceptual Tool

As a conceptual tool for my investigation, I exploit the notion of grounding that is supposed to provide ontological explanation.⁵ In particular, I employ its most standard version: *fact-grounding* [16,17]. According to this doctrine, grounding is a relation between the more fundamental fact and the less fundamental fact. For instance, the fact that a table exists is grounded in the fact that some subatomic particles are arranged table-wise.

This theory is typically coupled with the claim that the notion of grounding *is* (a kind of) ontological explanation (e.g., [17]). In the example of the table, the latter fact grounds, and *ipso facto* explains ontologically, the former fact.⁶ In addition, the grounding relation is strict partial ordering (i.e. irreflexive and transitive), as the received view [18] goes.

To be concrete, I will examine which fact grounds the fact that Mary is a student, given that a student is paradigmatic example of a role. For the sake of simplicity I introduce the notation '<>' to refer to facts: e.g., <Mary is a student>. More specifically, I will consider which fact grounds <Mary plays a student role>, which is plausibly taken to ground <Mary is a student>. The gist of my argument is that there are three candidate facts which correspond to the role triad and which ground <Mary plays a student role> and, by the transitivity of grounding, <Mary is a student>.

3. Three Facets of Roles

3.1. Role Specification

What grounds <Mary plays a student role>? In order to be a student, Mary *must* gain admission to the university (say 'ABC-U') of her choice. To attain this goal, she *needs* to read and understand the admission policy and then make an effort to satisfy all its requirements. Mary's role-playing has, in this respect, a deontic or normative dimension.

This observation may lead us to interpret role-playing as meeting the constraints or conditions that are 'embedded' in the role. In my terminology, role-playing in this sense is *meeting a role specification*, or the specification that is determined by the role. Therefore <Mary plays a student role> is grounded in <Mary meets a role specification>.

I appeal to the notion of specification to capture the above-mentioned normative feature of role. The ontological nature of a specification remains obscure, but Turner [19] argues that a specification is something that has "correctness jurisdiction over an arte-

⁴As we will see in Section 4, however, Basic Formal Ontology [5] exceptionally specifies the *role-having* relation, but not the role-playing one [12, p. 58].

⁵For an introduction to the general notion of grounding, see e.g., Schneider and Correia [13], Trogden [14], and Raven [15].

⁶The proponent of this view might argue that, just as *some* kind of causal explanation is given merely by stating the causal relation (what causes what), so *some* kind of ontological explanation is given merely by stating the grounding relation (what grounds what) [15].

fact” [19, p. 147]. By ‘correctness jurisdiction’ Turner means that the specification places “empirical demands on the physical device” [19, p. 144]. If an artifact is not built to a specification, then the artifact is defective with respect to that specification.⁷

A role specification is thus well understood with an analogy with artifacts (cf. [21]). In the U.S., for instance, an aircraft has to satisfy the strict specifications laid down by the Federal Aviation Administration (FAA). This means that an aircraft-like aggregate of mechanical parts is not an aircraft unless it is built exactly to the FAA specifications. Similarly, Mary fails to play a student role (and to be a student) unless she meets the role specification (admission requirements) given by ABC-U.

Not surprisingly, the specification view of role-playing fits well with the notion of *social role* (e.g., president) because a specification is determined by our intentionality.⁸ To paraphrase in my framework, <Mary plays a student role> is grounded in <Mary meets a role specification>, which is in turn grounded (via a complex chain of grounding relations) in some relevant social facts: e.g., <ABC-U is nationally authorized>.

3.2. Role Position

There is nevertheless another candidate for what grounds <Mary plays a student role>. As an ABC-U student, Mary can use various facilities and enjoy educational opportunities (e.g., taking classes). Seen from another perspective, she locates herself, in playing a student role, in a specific *situation* where she can do something role-related.

Following this intuition, one may think that Mary’s role-playing consist in her *occupying* the kind of special place (which I call a ‘*role position*’) that allows her to do something that is associated with the role. For this reason one may say that <Mary plays a student role> is grounded in <Mary occupies a student role position>.

A role position can be elucidated by an analogy with a *relative place* [22]. Given the Newtonian conception of absolute space, both *absolute* places and *relative* places persist and may be occupied by various (material) objects at various times. Unlike absolute places (which are parts of absolute space that are independent of objects), relative places stand in fixed spatial relations with one or more objects (*reference objects* [22]). Examples include places in and around a ship whose reference object is the ship.

A role position is like a relative place. Role positions stand in a fixed conceptual relation towards one or more entities (which I call ‘*role reference entities*’ and which are sometimes called ‘context’ in the literature [7,23]).⁹ In playing a student role, Mary occupies the student role position that exists relative to ABC-U.

The analogy between role positions and relative places offers an interesting interpretation of the alleged relational nature of roles [3,6,11]. One salient feature of relative places is that they may move relative to one another when their reference objects move relative to one another. Using Donnelly’s [22] example, when a ship moves relative to the

⁷Duncan [20, pp. 16-17] illustrates this point: “For example, if I build a physical implementation of a stack and the device does not allow me to add and remove items from the top of the device, my device is defective relative to the specification of a stack.” It is also well worth noting his ontological interpretation (which I do not present owing to spatial limitations) of Turner’s conception of specification based on some categories taken from Basic Formal Ontology [5].

⁸Turner [19, p. 147] says: “Our intentional stance determines what we take to be the specification: something is a specification if we give it normal force over the construction of an artefact.”

⁹I am using the term ‘conceptual’ in the very broad sense of the term. It may be argued that the partisan of role positions is responsible for clarifying the relationship between them and their role reference entities.

earth, places with the ship as their reference object (e.g. the ship's hold) move relative to places with the earth as their reference object.

Similarly, role positions may 'conceptually move' (e.g., changes their related functions) relative to one another when their role reference entities 'conceptually move' relative to one another, although the notion of conceptual movement is currently a placeholder and it is to be further clarified. For instance, when a human resource department changes its importance with respect to its company, personnel director role positions (whose role reference entity is the human resource department) change their relationship with executive role positions (whose role reference entity is the company).

The positional view of role-playing has two characteristics. First, it would lead to a classification of roles according to what role reference entities are and what the 'occupiers' of role positions are (e.g., [24]). Second, and reasonably, it meshes with the notion of *relational role* (e.g., the *lover* and the *lovee* in a love relationship). This is supported by the observation that an ontological commitment to relational roles presupposes *positionalism*, according to which "the distinction between the claims made in, for example, 'Abelard loves Eloise' and 'Eloise loves Abelard' is explained by differences in the *roles* (or *positions*) attributed to the relata" [25, p. 80, my emphasis added].¹⁰

3.3. Role Performance

There is yet another possibility for what grounds <Mary plays a student role>. As said above, Mary *can do* many things (e.g., getting a student discount) because she is an ABC-U student. A clearly visible difference between Mary and non-ABC-U students is, for instance, that she is *able* to acquire a degree from ABC-U, whereas they are not.

This consideration may result in the idea that Mary's role-playing resides essentially in her role-related performance, or rather her 'power' to do something role-related.¹¹ I say that, generally speaking, role-playing in this sense is *giving a role performance*. Thus <Mary plays a student role> is grounded in <Mary gives a student role performance>.

It is important to note that a player of a role (performance) has only to possess the role-related 'power' instead of actually demonstrating it, although I use the phrase 'give a role performance' for the sake of simplicity. In playing a student role, Mary does not need to use any facility or take any class; she only needs to be able to do them.¹² In this sense, the notion of a role performance may be intimately related to *deontic powers* [28,29] in the context of social ontology.

On the one hand, the performance view of role-playing would be easier to understand than the other two approaches discussed above, since it is explicable in terms of an analogy with the intuitively less complicated notion of 'power' than a specification or a relative place. On the other hand, the onus is on the proponent of this view to pin down

¹⁰See Marmodoro and Yates [26] for an introduction to ontology of relations. See Fine [27] for a critique of positionalism (which he formulates). See also Donnelly [25] for a revised version of positionalism.

¹¹Boella, Torre and Verhagen [3, p. 5] say: "(...) behavior should not be disregarded as a main feature of roles."

¹²Strictly speaking, Mary would have to comply with the rules and regulations imposed by ABC-U in order to play a student role. It could be therefore argued that, in general, a player of a role needs to give some sort of role performance, however trivial it may be.

precisely the interrelationship between a role performance and its intimately related concepts: e.g., dispositions, functions, and capabilities.¹³

4. Case Studies

4.1. A Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)

Masolo et al. [6] propose a general formal framework for social roles in compliance with a Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) [37]. The basic idea is that social roles are (social) *concepts* which are defined by *descriptions* and which, in virtue of those descriptions, classify in a time-relative way continuants (other than concepts; which I will henceforth omit to mention). In other words, a social role is a concept that classifies continuants at time t in such a way that they satisfy at t ‘all the constraints stated in the description’ of that concept.

A concept and a description both fall into the DOLCE category of *non-agentive social concept*: “an endurant that: (i) is not directly located in space and, in general, has no direct spatial qualities; (ii) has no intentionality; (iii) depends on a community of intentional agents, e.g., a law, an economic system, a currency, an asset ...” [6, p. 272]. Furthermore, some basic features of descriptions are offered as follows [6, p. 271]:

- descriptions are created by (communities of) intentional agents at the time of their first encoding in an expression of a ‘public’ (formal or informal) language
- different expressions (possibly in different languages) can be associated to the same description, provided they have the same semantic content. I.e., descriptions have a unique semantic content
- descriptions must be encoded on (possibly multiple) physical supports [Original footnote: “Printed or recorded texts obviously count as physical support, but memory or other cognitive processes should probably be considered as well (think of orally transmitted tales, rules and contracts)”]
- descriptions are usually accepted (adopted) by (communities of) intentional agents, but a description can exist even if no one accepts it, as long as it remains encoded; acceptance can change in time
- descriptions cease to exist when their last physical support ceases to exist

It is not hard to see that the approach by Masolo et al. to social roles pivots around a role specification in the role triad. My notion of role specification coincides with the DOLCE notion of description. Both of them are based on agents’ intentionality and aim to specify how continuants *should* be like by satisfying the constraints provided by the role specifications and the descriptions, respectively.

On my view, the choice by Masolo et al. of a role specification is not only because they focus primarily on social roles but also because they take DOLCE as a general

¹³On dispositions: see e.g., Mumford [30] and Molnar [31] for a general introduction to dispositions. See Röhl and Jansen [32] for a formal application of dispositions to the (biomedical) ontology research. On functions: see Röhl and Jansen [33] for a survey of theories of functions in philosophy as well as in formal ontology. On capabilities: see Daniel [34] and Smith [35] for an ontological (dispositional) approach to capabilities in accordance with Basic Formal Ontology [5]. It is interesting to note Wahlberg’s [36] claim that deontic powers may be sometimes mistakenly identified with dispositions (causal powers).

ontological setting. DOLCE claims to represent the categories with a clear cognitive bias that are associated with, e.g., human cognition and socio-cultural artifacts.¹⁴ In the role triad, a role specification is arguably the most cognitive and linguistic element.

4.2. General Formal Ontology (GFO)

Loebe [7] provides a general account of roles in alignment with General Formal Ontology (GFO) [38]. According to his basic role model, an entity (player) plays a role such that that role bears the *role-of* relation with a *context*. This view of role centers on a role position in the role triad, as evidenced by his explicit reference to the notion of context, which I take to be a role reference entity as a key term for a role position.

Loebe also offers a classification of roles according to the kinds of the player, role-playing relation, the role-of relation, and the context. This is, as said above, characteristic of the positional view of role-playing. Roles fall into *social roles* and *abstract roles*, the latter being in turn classified into *relational roles* and *processual roles*.¹⁵ Processual roles are, roughly, roles that are participated in (played) by objects and that bear the parthood (role-of) relation with occurrents (context).¹⁶ For instance: “When John moves his pen, he and the pen form participants of that process, and the processual role which John plays captures what John does in that participation” [7, p. 135].

The GFO theory of role would deal better with abstract roles than social roles.¹⁷ This can be seen as a consequence of GFO’s choice of a role position in the role triad. As was above pointed out, relational roles are well treated with a role position, whereas social roles with a role specification.¹⁸ Processual roles are sufficiently characterized in terms of a role position because they consist in having occurrents as role reference entities.

Finally, part of the reason why the GFO account of role is committed to a role position may lie in GFO’s meta-ontological choice of what it calls ‘integrative realism’.

¹⁴“Regarding the content of the ontology, the aim of DOLCE is to capture the intuitive and cognitive bias underlying common-sense while recognizing standard considerations and examples of linguistic nature. DOLCE does not commit to a strong referentialist metaphysics (it does not make claims on the intrinsic nature of the world) and does not take a scientific perspective (it is not an ontology of, say, physics or of social sciences). Rather, it looks at reality from the mesoscopic and conceptual level aiming at a formal description of a particular, yet fairly natural, conceptualization of the world” [37, pp. 279-280].

¹⁵Loebe [7, p. 137] explains abstract roles as follows: “Due to their similarity, relational and processual roles are subsumed by a role type called *abstract roles* which is contrasted with social roles. Abstract roles can be functionally characterized in a uniform manner, namely as a mechanism of viewing some entity - namely the player - in a defined context, i.e., in a more complex entity with interrelated other “notional components”. Put differently, players of abstract roles are looked at in an *external* manner in contrast to viewing them as self-contained entities focusing on their *internals* like their properties or parts.”

¹⁶I am using the word ‘roughly’ because, assuming the type level, a player of a processual role is the GFO notion of *persistant* and its context is the GFO notion of *process*. See Herre [38] for details on those GFO categories. This does not have much bearing on my argument, however.

¹⁷Loebe [7, p. 136] says: “Social roles appear to be the least understood role type in our model. For instance, switching to *role-of*, we must admit that contexts remain fairly obscure for social roles.”

¹⁸Loebe [7, pp. 137-138] says: “(...) encouraged by the diverging ontological categories of contexts, we believe that it will be hard to find further commonalities, especially between abstract and social roles. It may thus be difficult to add much more to a general theory of roles, at least as long as a similarly broad range of examples is to be covered.” Loebe [7, p. 154] also says: “In our opinion, it turns out that the aspects of abstract and social roles are intermingled in the literature, especially concerning relational and social roles.” I would submit that the same roles (e.g., student roles and professor roles) are interpretable in terms of a role specification as well as in terms of a role position.

Herre [38, pp. 303-304] elucidates this doctrine by comparing it with what he calls ‘Smithian realism’ [40] (which I will below discuss): “No definition for *reality representation* is provided. This fundamental gap can never be closed without the use of concepts, i.e. there is no representation of reality without concepts.”¹⁹ By my lights, one advantage of a role position would be to afford us a moderate stance on ontology, disentangling us from a forced choice between pure conceptualism (cf. [39]), which would lead to a role specification, and robust realism, which would lead to a role performance.

4.3. Basic Formal Ontology (BFO)

Basic Formal Ontology (BFO) defines a role as follows: “A realizable entity that (1) exists because the bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be, and (2) is not such that, if this realizable entity ceases to exist, then the physical make-up of the bearer is thereby changed. A role is thus always optional” [5, p. 184].

A realizable entity is: “A specifically dependent continuant entity that has at least one independent continuant as its bearer, and whose instances can be realized (manifested, actualized, executed) in associated processes of specific correlated types in which the bearer participates” [5, p. 183]. A specifically dependent continuant is then: “A continuant entity that depends on precisely one independent continuant for its existence. The former is dependent on the latter in the sense that, if the latter ceases to exist, then the former will as a matter of necessity cease to exist also” [5, p. 185].

The BFO conception of role clearly focuses on a role performance in the role triad. An entity *a* plays a role because, for an external reason, *a* has a BFO-role which is unique to *a* and which can be realized in the kind of occurrents (typically *a*’s behaviors) in which *a* participates. For instance, Mary is a student in virtue of her student role that can be realized in, for instance, her behavior of taking classes.

BFO’s ‘role choice’ would be primarily motivated by its meta-ontological adoption of *ontological realism*: “The realist methodology is based on the idea that the most effective way to ensure mutual consistency of ontologies over time and to ensure that ontologies are maintained in such a way as to keep pace with advances in empirical research is to view ontologies as representations of the reality that is described by science. This is the *fundamental principle* of ontological realism” [40, p. 139]. In the role triad, a role performance is arguably most likely to be the object of empirically scientific inquiry.

I make two further comments on BFO-roles that would help us understand better the relationship between meta-ontological choices and their related ‘role choices’. First, BFO specifies the *role-having* relation, but not the role-playing relation: “An entity is sometimes said to play a role, as when a passenger plays the role of a pilot on a commercial plane in an emergency, or a pyramidal neuron plays the role occupied by a damaged

¹⁹Herre [38, p. 305] further elucidates integrative realism as follows: “the nodes in an ontology are labeled by terms that denote concepts. Some of these concepts, notably natural concepts, are related to invariants of material reality. Concepts are represented in individual minds and are founded in society. The same is true for individuals to which individual concepts correspond. The interrelations between universals, concepts, symbols and society are realized by various relations, including the relation of correspondence (between concepts and universals, and individual concepts and real individuals), the relation of representation (between concept and individual mind), the relation of foundedness (between concept and society), and the instantiation relation. We summarize that the restricted view of Smithian realism cannot be an ontological-philosophical foundation for the field of conceptual modeling and, in particular, for computer-science ontologies.”

stellar neuron in the brain; but neither the person nor the pyramidal neuron *have* those roles. BFO 2.0 only specifies the **has_role** relation” [12, p. 58].

Seen from the viewpoint of grounding, the former ‘pilot-role fact’ and the latter ‘neuron-role fact’ are better grounded in <A passenger *meets* the pilot *role specification*> and <A pyramidal neuron *occupies* the stellar neuron *role position*> than <A passenger gives the pilot role performance> and <A pyramidal neuron gives the stellar neuron role performance>, respectively.

BFO’s specification of the role-having (but not role-playing) relation implies that BFO-roles focus primarily on a role performance, but neither a role specification nor a role position. Using the Mary-student example, <Mary plays a student role> is grounded in <Mary gives a student role performance>, which is in turn grounded, within the BFO framework, in <Mary’s student role is (can be, more precisely) realized>.

Second, it is suggested that some usages of the term ‘role’ be covered in another way than BFO-roles: “The term “role” can, however, be used in a different sense in contexts such as Jane’s being the seventh person to fill the role of director of this institute, or Joe’s being the third person to play a particular role in a play. “Role” in this sense is being used to designate what BFO calls a *generically* dependent continuant” [5, pp. 100-101].

A generically dependent continuant is: “A continuant that is dependent on one or other independent continuants and can migrate from one bearer to another through a process of copying. We can think of generically dependent continuants as complex continuant patterns either of the sort created by authors or designers or (in the case of DNA sequences) brought into being through the processes of evolution” [5, p. 179].

It is not hard to see a close conceptual affinity between the BFO notion of generically dependent continuant and the DOLCE notion of description. It could be argued that a DOLCE-description is the sort of BFO-generically dependent continuant that is connected to agents’ intentionality. In this respect, BFO attempts to ground, e.g., <Jane fills the role of director of this institute> and <Joe play a particular role in a play> in <Jane meets the director role specification provided by this institute> and <Joe meets a role specification provided in a play>, respectively.

5. Three Conceptions of Roles

5.1. Family Resemblance Concept

All the arguments given above would reveal the ontological nature of role: roles are *family resemblance concepts* [41, Section 3]. As shown above, there are *equally plausible* facts in which <Mary plays a student role> could be grounded. This means that there is no single privileged concept of role; the role notion is merely partly unified by the role triad. Moreover, different meta-ontological choices in foundational ontologies lead to different choices in the role triad. Granted that those meta-ontological choices are equally reasonable from a theoretical perspective, so are the associated ‘role choices’.

The family resemblance view of role is a direct consequence of the present work and it is arguably most convincing. It lacks practical virtue, however. As said, there is considerable need for formalizing this cross-disciplinary notion in order to conceptualize the world coherently. However theoretically tenable it may be, it would be of little help for actual modeling processes to say just that roles are family resemblance concepts.

5.2. *Functionally Definable Concept*

I said that <Mary plays a student role> is grounded in either <Mary meets a student role specification>, <Mary occupies a student role position>, or <Mary gives a student role performance>. Instead of taking a family resemblance view of role, one may then attempt to offer a *functional definition* [42] of the role-playing concept.

The core part of my argument over role can be simplified as follows:

For any an (individual) entity x , if x plays a role, then either x meets a specification determined by that role; x occupies a position determined by that role; or x gives a performance determined by that role.²⁰

Replace the term ‘role’ with a variable R , and then existentially quantify it, as follows:

$\exists R$ (if x plays R , then either x meets a specification determined by R ; x occupies a position determined by R ; or x gives a performance determined by R).

Then define the role-playing notion as follows:

x plays a role =def. $\exists R$ [(if x plays R , then either x meets a specification determined by R ; x occupies a position determined by R ; or x gives a performance determined by R) and x plays R].

The view of role as a functionally definable concept may be a practical advance from its family resemblance conception. Even if there may some room for improvement in the formalization of the term ‘specification’ (e.g., [43]) and perhaps other relevant terms, however, it does not seem that the functional definition of role will be practically usable enough to help domain-specific modeling processes.

5.3. *Practically Unifiable Concept*

One may still wish to provide a unified concept or definition of role even at the price of theoretical rigor. This task requires considering carefully which ‘role choice’ is practically appropriate. For instance, one may choose a role specification, based on the intuition that <Mary meets a student role specification> grounds <Mary gives a student role performance>. For another example, one may take a role position because it fits well with an apparently widely acceptable, moderate stance on ontology. This line of investigation is to be pursued together with careful cost-benefit analysis.

6. Conclusion

I have argued for three claims. First, there are three role-related concepts (the role triad): a role specification, a role position, and a role performance. Second, different accounts of role might depend which notion in the role triad is ontologically prior to the other two, as illustrated with close examination of three theories of role which are based on (the meta-ontological choices of) DOLCE, GFO, and BFO, respectively. Third, there are

²⁰To simplify matters, I am setting aside the issue of whether logical entailment fully captures the notion of grounding that I have exploited so far.

three possible understandings of the ontological nature of role: a family resemblance concept, a functionally definable concept, and a practically unifiable concept.

This work on role will bring us to many future directions of research and, in particular, there are many thorny questions to be answered regarding various associated modeling processes. For instance, the topic of *qua-individuals* [44] (e.g., *Mary-qua-student*) has wide implications for a representation of roles.²¹ The idea of the role triad will shed light on *qua-individuals*, contributing possibly to a novel approach to them.²²

References

- [1] J. Fan, K. Barker, B. Porter and P. Clark. Representing Roles and Purpose. In *Proceedings of the 1st International Conference on Knowledge Capture (K-CAP'01)*, Victoria, British Columbia, Canada, October 22–23, 2001, ACM Press, 38–43.
- [2] F. Steimann. On the representation of roles in object-oriented and conceptual modelling. *Data & Knowledge Engineering* 35(1): 83–106, 2000.
- [3] G. Boella, L. van der Torre and H. Verhagen. Roles, an interdisciplinary perspective. *Applied Ontology* 2(2): 81–88, 2007.
- [4] N. Guarino. BFO and DOLCE: So Far, So Close.... In L. Zaibert (ed.), *The Theory and Practice of Ontology - Festschrift for Barry Smith*, Palgrave / Macmillan, 2016, 10–18.
- [5] R. Arp, B. Smith and A. D. Spear. *Building Ontologies with Basic Formal Ontology*. MIT Press, 2015.
- [6] C. Masolo, L. Vieu, E. Bottazzi, C. Catenacci, R. Ferrario, A. Gangemi and N. Guarino. Social Roles and Their Descriptions. In D. Dubois, C. Welty and M. A. Williams (eds.), *Principles of Knowledge Representation and Reasoning, Proceedings of the Ninth International Conference (KR 2004)*, Whistler British Columbia, Canada, June 2–5, 2004.
- [7] F. Loebe. Abstract vs. social roles Towards a general theoretical account of roles. *Applied Ontology* 2(2): 127–158, 2007.
- [8] V. Genovese. Towards a General Framework for Modelling Roles. In G. Boella, L. van der Torre and H. Verhagen (eds.), *Normative Multiagent Systems*, number 07122 in Dagstuhl Seminar Proceedings. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany.
- [9] S. de Cesare, F. Gailly, G. Guizzardi, M. Lycett, C. Partridge and O. Pastor. 4th International Workshop on Ontologies and Conceptual Modeling (Onto.Com). In O. Kutz and S. de Cesare (eds.), *Proceedings of the 2nd Joint Ontology Workshops (JOWO 2016)*, CEUR Workshop proceedings, vol.1660, 2016.
- [10] P. van Inwagen. *Material Beings*. Cornell University Press, 1990.
- [11] J. F. Sowa. *Knowledge Representation: Logical, Philosophical and Computational Foundations*. Brooks/Cole, 2000.
- [12] B. Smith et al. Basic Formal Ontology 2.0 - Specification and User's Guide, 2015. Available online at: <https://github.com/BFO-ontology/BFO> (Last accessed on July 8, 2018).
- [13] B. Schnieder and F. Correia. Grounding: an opinionated introduction. In B. Schnieder and F. Correia (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, Cambridge University Press, 2012, 1–36.
- [14] K. Trogdon. An Introduction to Grounding. In M. Hoeltje, B. Schnieder and A. Steinberg (eds.), *Varieties of Dependence: Ontological Dependence, Grounding, Supervenience, Response-Dependence (Basic Philosophical Concepts)*, Philosophia Verlag, 2013, 97–122.
- [15] M. J. Raven. Ground. *Philosophy Compass* 10(5): 322–333, 2015.
- [16] K. Fine. The Question of Realism. *Philosophers' Imprint* 1(2): 1–30, 2001.
- [17] K. Fine. Guide to Ground. In B. Schnieder and F. Correia (eds.), *Metaphysical Grounding: Understanding the Structure of Reality*, Cambridge University Press, 2012, 37–80.
- [18] K. Fine. The Pure Logic of Ground. *Review of Symbolic Logic* 5(1) :1–25, 2012.
- [19] R. Turner. Specification. *Minds & Machines* 21(2): 135–152, 2011.
- [20] W. D. Duncan. Ontological distinctions between hardware and software. *Applied Ontology* 12(1): 5–32, 2017.

²¹Synonyms for 'qua-individual' include 'role holder' [23].

²²I thank Adrien Barton and the reviewers for some helpful comments of the paper.

- [21] L. Vieu, S. Borgo and C. Masolo. Artefacts and Roles: Modelling Strategies in a Multiplicative Ontology. In C. Eschenbach and M. Grüninger (eds.), *Proceedings of the Fifth International Conference (FOIS 2008)*, Saarbrücken, Germany, October 31 - November 3, 2008, IOS Press, 121–134.
- [22] M. Donnelly. Relative Places. *Applied Ontology* 1(1): 55–75, 2005.
- [23] R. Mizoguchi, E. Sunagawa, K. Kozaki and Y. Kitamura. A Model of Roles within an Ontology Development Tool: Hozo. *Applied Ontology* 2(2): 159–179, 2007.
- [24] R. Mizoguchi, A. Galton, K. Kozaki and Y. Kitamura. Families of roles: A new theory of occurrent-dependent roles. *Applied Ontology* 10(3-4): 367–399, 2015.
- [25] M. Donnelly. Positionalism Revisited. In A. Marmodoro and D. Yates (eds.), *The Metaphysics of Relations*, Oxford University Press, 2016, 80–99.
- [26] A. Marmodoro and D. Yates. Introduction: The Metaphysics of Relations. In A. Marmodoro and D. Yates (eds.), *The Metaphysics of Relations*, Oxford University Press, 2016, 1–18.
- [27] K. Fine. Neutral relations. *Philosophical Review* 109(1): 1–33, 2000.
- [28] J. Searle. *The Construction of Social Reality*, Penguin, 1995.
- [29] J. Searle. *Making the Social World: The Structure of Human Civilization*, Oxford University Press, 2010.
- [30] S. Mumford. *Dispositions*. Oxford University Press, 1998.
- [31] G. Molnar. *Powers: A Study in Metaphysics*. Oxford University Press, 2003.
- [32] J. Röhl and L. Jansen. Representing dispositions. *Journal of Biomedical Semantics* 2(Suppl 4), S4, 2011.
- [33] J. Röhl and L. Jansen. Why functions are not special dispositions: an improved classification of realizable for top-level ontologies. *Journal of Biomedical Semantics* 5, 27, 2014.
- [34] D. Daniel. Resilience as Disposition. In P. Garbacz and O. Kutz (eds.), *Proceedings of the 8th International Conference of Formal Ontology in Information Systems (FOIS 2014)*, Rio de Janeiro, Brazil, September 22–25, 2014, IOS Press, 171–182.
- [35] B. Smith. [Barry Smith]. (2017, 09, 12). Are there Capabilities on Mars? Retrieved from: <https://www.youtube.com/watch?v=1IPg2bGJSzE> (Last accessed on July 8, 2018).
- [36] T. H. Wahlberg. Causal powers and social ontology. *Synthese*, 2018. <https://doi.org/10.1007/s11229-018-1763-2>.
- [37] S. Borgo and C. Masolo. Ontological Foundations of DOLCE. In R. Poli, M. Healy and A. Kameas (eds.), *Theory and Applications of Ontology: Computer Applications*, Springer, 2010, 279–295.
- [38] H. Herre. General Formal Ontology (GFO): A Foundational Ontology for Conceptual Modelling. In R. Poli, M. Healy and A. Kameas (eds.), *Theory and Applications of Ontology: Computer Applications*, Springer, 2010, 297–345.
- [39] B. Smith. Beyond Concepts: Ontology as Reality Representation. In A. C. Varzi and L. Vieu (eds.), *Proceedings of the 4th International Conference on Formal Ontology in Information Systems (FOIS 2004)*, Torino, Italy, November 4–6, 2004, IOS Press, 31–42.
- [40] B. Smith and W. Ceusters. Ontological realism: A methodology for coordinated evolution of scientific ontologies. *Applied Ontology* 5(3–4): 139–188, 2010.
- [41] M. Carrara, P. Garbacz and P. E. Vermaas. If engineering function is a family resemblance concept: Assessing three formalization strategies. *Applied Ontology* 6(2): 141–163, 2011.
- [42] D. Lewis. How to Define Theoretical Terms. *Journal of Philosophy* 67(13): 427–446, 1970.
- [43] R. Turner. The Foundations of Specification. *Journal of Logic & Computation* 15(5): 623–663, 2005.
- [44] C. Masolo, G. Guizzardi, L. Vieu, E. Bottazzi and R. Ferrario. Relational Roles and Qua-individuals. In G. Boella, J. Odell, L. van der Torre and H. Verhagen (eds.), *Proceedings of the AAAI Symposium on Roles, an interdisciplinary perspective*, AAAI Press, 2005, 103–112.