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RESEARCH

The Complexity of Human Space: Multi-layered Networks and the Relativity of Distance

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Abstract

This article characterizes the human space as reflecting the architecture of interdependencies within it, which may generate alternative identifications of external boundaries and internal divisions. After introducing how human actors and activities are arranged according to relative positions belonging to different dimensions and leading to multi-layered networks, the article illustrates the multi-dimensionality and multi-layeredness of the human space by considering the production space as a network of interdependencies in which division of labour and the mutual fitting of activities take place along plural dimensions (here identified with tasks and productive functions, capacities, and materials-in-process) and give rise to hierarchical patterns of interdependence along each dimension. The article shows that it is possible to visualize relative positions in different ways depending on the actors' or the analyst's point of view, which may draw attention to a particular dimension of interdependence rather than others. Such open-endedness leads to the relativity of distance. At the same time, the actors' (or the analyst's) point of view, by fixing the focus of attention on specific dimensions and layers, may lead to closure, in the sense that relative distances become associated with the dimension and layer of interdependence that are central to a given context. The article goes on to propose a theoretical framework to study distance and proximity in the human space, and applies it to the problem of how to identify possible definitions of collective interest in a space of interdependent actors.

Keywords Interdependence · Relative positions · Visualization of positions · Plurality of distance · Collective interest

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1 Introduction

Human space is a complex domain. For the relationships between individual and collective actors in that space lead to properties that cannot be reduced to those actors and to the 'laws' of their interaction (Simon 1962). The structure of the human space reflects the architecture of interdependencies within it, which may generate alternative identifications of external boundaries and internal divisions.

Section 2 of the paper discusses human space as a pattern of organized complexity in which human actors and activities are arranged according to *relative positions* belonging to different dimensions and leading to multi-layered networks. This section emphasizes that the plural dimensions and layers characterizing the human space lead to the possibility of identifying a variety of different relative positions depending on which dimensions and layers of interdependence are considered. However, this open-endedness of distance may turn into closure once relative positions become entrenched along a particular dimension and layer of interdependence. Section 3 considers the production space as a network of interdependencies in which division of labour and the mutual fitting of activities take place along plural dimensions (here identified with tasks and productive functions, capacities, and materials-in-process) and give rise to hierarchical patterns of interdependence along each dimension. Section 4 examines the relationship between open-endedness and closure in production networks and highlights that the relative positions of productive activities, and of the individual and collective actors associated with them, depend on which dimension is central to production organization, and on which organizational layer is considered. Open-endedness leads to the relativity of distance. At the same time, the actors' (or the analyst's) point of view, by focusing attention on specific dimensions and layers, may lead to closure, in the sense that relative distances become associated with the dimension and layer of interdependence that are central to a given organization in a given context. Section 5 outlines a theoretical framework for the study of distance and proximity in the human space. This framework is based on a metric structure in terms of common and non-common characteristics and highlights the relationship between measure of distance and judgement of similarity. The section emphasizes that the switch from one dimension of the human space to another and from one layer of interdependence to another may entail switching from one pattern of similarity to another, and therefore to the visualization of different relative positions between actors or groups. This section also addresses the issue of comparison between heterogeneous actors, or groups, and calls attention to the role of categorization in identifying a common standard of comparison in terms of which the relative distance between heterogeneous units can be expressed. Section 6 brings the paper to close by calling attention to the criterion of relative structural invariance as a way of addressing the tension between open-endedness and closure of distances in the human space and as a way of identifying possible definitions of collective interest in a space of interdependent actors.

2 Complexity and Relative Positions in the Human Space

Complexity may be associated with the emergence of organization (Weaver 1948; Simon 1962, 1976; Barabàsi 2005, 2007; Cardinale et al. 2022). In Herbert Simon's words 'complex systems will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not. The resulting complex forms in the former case will be hierarchic' (Simon 1962, p.473). The organization of human activities is a fundamental feature of the complexity of interdependencies in the human space, in the sense that the outcomes of interdependence cannot be immediately derived from the dispositions of individual actors and from the criteria guiding their patterns of interaction. Interdependence and interaction in the human space lead to the emergence of structures, that is, to the emergence of *orderly patterns*. The architecture of the human space is multi-layered in the sense that it reflects orderly patterns that arise from the structuring of human activities across multiple spaces as well as along plural layers of aggregations (such as firms, industries, and production systems), which often take the form of a hierarchy. Activities in the human space tend to be arranged according to their *relative positions*, and subsets of activities tend to cluster into subsystems that may in turn become elements of higher-order subsystems as we move from one level of the hierarchy to another.

Human activities are inherently multi-dimensional. For example, activities in the production domain involve capacities, tasks and functions, and materials (Scazzieri 1993; Cardinale and Scazzieri 2023a, 2024). Distinct patterns of relative positions can be constructed for capacities, tasks and functions, and materials, each of which entails *different spaces*. Therefore, production activities may simultaneously belong to different spaces, and different patterns of interdependence may be identified depending on which set of relative positions is considered. What applies to relative positions in the production domain also applies to human activities in general. This relationship between the multidimensionality of human activities and the manifold relative positions arising from multidimensionality has important consequences for the structuring of the human space. For in this case complexity may arise from the new properties that connectivity and interactions bring into being (Reggiani 2014, 2022). This type of complexity generates features that cannot be immediately derived from the pattern of interdependence prevailing at a given time, since actors may visualize interdependence in a variety of ways and may take a variety of actions therefrom. However, patterns of interdependence can *ex post* be explained by past interdependencies, by the actions taken on that basis, and by their effectiveness in maintaining or transforming those patterns. Complexity arises from the open-endedness of interdependence along the various dimensions of the human space (what we may call *open complexity*).

The above argument entails that two distinct sources of open-endedness may be at work in the human space. As a result, the human space reveals an intrinsic hermeneutic dimension (Scazzieri 2025). First, each dimension of human activity may be associated with a particular configuration of relative positions, which may in turn depend on actors' visualization and context. Second, the switch from one dimension to another may entail the switch from one visualization to another. To sum up, the human space defined as a multi-layered configuration of relative positions and interdependencies is characterized by a rich texture of complexity, in which relative positions arise along plural dimensions of interdependence and may generate different patterns of hierarchy depending on which dimension is most prominent in actors' visualization, and on which visualization takes priority within that dimension. This structure of complexity makes it difficult to derive systemic patterns of interdependence from a simple combination of patterns of interdependence at lower levels of aggregation. At the same time, the multi-layered structure of the human space suggests that open-endedness of relative positions at one level of aggregation may be compatible with *closure* at a different level, that is, to an entrenchment of relative positions that may in turn drive the system towards *new* fields of possibility. The mutual influence of open-endedness and closure in a multi-layered structure of interdependencies makes the human space, as defined in this paper, an important precondition for the interplay of freedom and determination characterizing human activity (von Wright 1980).

3 Patterns of Interdependence and the Architecture of the Production Space

Human activities may be connected to one another along manifold dimensions. For example, in the case of production activities, it has been shown that capacities, productive tasks and functions, and materials are essential dimensions along which activities are related to one another (Scazzieri 1993; Landesmann and Scazzieri 1996; Cardinale and Scazzieri 2023a). We may consider those dimensions as the generators of distinct, and not necessarily coinciding, patterns of relative positions. This means that the organization of connectivity in the production sphere may lead to the emergence of *distinct spaces*, which may or may not be mutually fitting depending on technology, organization, social and institutional context. Matrix $\boldsymbol{C}$ shows a pattern of connectivity in the capacity space: each element c_{ij} of the matrix denotes that capacity i is needed for capacity j to be active:

$$\boldsymbol{C} = \begin{matrix} c_{11} & c_{12} & \cdots & c_{1m} \\ c_{21} & 0 & \cdots & c_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ 0 & c_{n2} & \cdots & c_{nm} \end{matrix}$$

In matrix $\boldsymbol{C}$ the relative positions of capacities are such that certain capacities have a central position because they are indispensable to the working of other capacities (as with capacity c_{11} in matrix $\boldsymbol{C}$). On the other hand, certain capacities may have a central position if they can execute a plurality of tasks. Versatility is common to both cases. However, in the former case we have a type of vertical versatility, in which the capacity under consideration has a central position due to its location at a hierarchically superior layer relative to the capacities involved in performing the subordinate tasks. In the latter case, the versatility of a capacity has a horizontal character, since the generality of that capacity's affordances would be independent of its position in the hierarchy of capacities.

Matrix **T** shows a pattern of connectivity in the space of productive tasks: each element t_{ij} denotes that task *i* is needed to perform task *j*.

$$\boldsymbol{T} = \begin{matrix} t_{11} & 0 & \dots & t_{1m} \\ t_{21} & t_{22} & \dots & t_{2m} \\ \dots & \dots & \dots & \dots \\ 0 & t_{n2} & \dots & t_{nm} \end{matrix}$$

In matrix ***T*** certain tasks are necessary to the performance of other tasks. For example, task *1* is necessary for task *m*, task *2* is necessary for tasks *2* and *m*, etc. However, the centrality of a given task may not coincide with the centrality of the productive function that task executes. In other words, the space of tasks is embedded within a higher-level space of productive functions (Cardinale and Scazzieri 2023a). This means that a central task may presuppose a function of *limited range* (that is, a function that is only required when performing one or few tasks). On the other hand, a peripheral task may presuppose a *central function*, in the sense of a 'general purpose' function needed to perform a large number of tasks. The distinction between centrality of tasks and centrality of functions is important for what concerns the dynamics of technology. For example, relative positions in the space of tasks may 'hide' relative positions of a different type in the space of productive functions. This would be the case if a certain task holds a central position in the space of tasks while its supporting function has limited range (that is, it is needed to perform only few tasks). Technical and organizational dynamics may disrupt the relative positions of existing tasks by relegating certain tasks to a peripheral position in the task space, or even making them redundant. Conversely, a 'general-purpose' productive function could more easily support the switch from one task structure to another along a trajectory of changing production arrangements.

Matrix ***M*** shows a pattern of connectivity in the space of materials: each element m_{ij} denotes that material *i* is needed as an input to process material *j*.

$$\boldsymbol{M} = \begin{matrix} m_{11} & 0 & \dots & m_{1m} \\ m_{21} & m_{22} & \dots & m_{2m} \\ \dots & \dots & \dots & \dots \\ m_{n1} & m_{n2} & \dots & m_{nm} \end{matrix}$$

In matrix ***M*** the relative positions of materials introduce a hierarchy in which certain materials are more central than others for the functioning of the material network. For example, a certain material input may hold a central position in the material space if it is necessary to the production of materials needed in a variety of processes. Or it may hold a central position if it is *directly* needed in many other processes. In both cases, the material holding a central position shows a degree of versatility. However, versatility takes a vertical character in the former case (an example would be uranium needed for energy production, which could in turn be necessary for the functioning of the whole material network in the economy, or of an important subsystem of it). In the latter case, the centrality of a certain material may be associated with a relatively ‘flat’ hierarchy, in the sense that that material is *directly* needed in a variety of processes.

Material spaces have significantly different structures depending on whether ‘deep’ or ‘flat’ hierarchies are dominant. In turn, these structural differences may be associated with different patterns of technological dynamics. A flat hierarchy may undergo significant changes, which may however be circumscribed within certain regions of the material space. Structural changes triggered by compositional changes in the demand for final consumption goods may be a case in point (see, for example, Pasinetti 1981). On the other hand, a deep hierarchy may undergo more radical transformations, especially if one material is substituted for another at the upper layer of the hierarchy. A case in point would be the substitution of one energy source for another, as with the substitution of coal for wood during the First Industrial Revolution, or with ongoing attempts at decarbonization (see, respectively, Wrigley 2016; Coffman and Scazzieri 2024)[1].

The consideration of the capacity, task and function, and material spaces brings to light the *virtuality* inherent to the production space as an all-embracing domain including capacities, tasks and functions, and materials. This is because it is possible to visualize relative positions in different ways depending on the actors’ or the analyst’s point of view, which may draw attention to a particular dimension of interdependence rather than others (Leontief 1991 [1928]; Pasinetti 1973, 1977[1975]; Hicks 1985; Quadrio Curzio 1986, 1996; Landesmann and Scazzieri 1990; Cardinale 2018, 2022; Scazzieri 2021a, 2022; Scazzieri and Quadrio Curzio 2022; Cardinale and Scazzieri 2023a). In addition, the visualization of relative positions, as well as the actions taken on that basis, may change if actors switch attention from actual positions to other positions that may be achieved within each space. For example, a space of productive tasks may be visualized both as a constellation of actual positions and as a constellation of the tasks movements that are feasible considering the higher-level space of productive functions (Cardinale and Scazzieri 2023a). Depending on which visualization is adopted (whether of tasks performed or of ‘hidden’ productive functions), a given task space may be seen either as a constellation of actual positions or as a constellation of possibilities that may or may not be achieved.

Each production network $\boldsymbol{P}$ results from a particular combination of the $\boldsymbol{C}$, $\boldsymbol{T}$, and $\boldsymbol{M}$ matrices:

$$\boldsymbol{P} = \{\boldsymbol{C},\ \boldsymbol{T},\ \boldsymbol{M}\}\,.$$

[1] E.A. Wrigley points out that ‘almost all the energy available in organic economies [such as the economies whose main energy source is wood] was the product of plant photosynthesis derived from the annual *flow* of energy arriving on the earth’s surface from the sun. An industrial revolution was not possible as long as this situation continued since the quantity of energy needed to underwrite the scale of production achieved in the industrial revolution greatly exceeded what was possible in an organic economy. One essential prerequisite for production on this scale was discovery of a different source of energy. This proved possible because fossil fuels could provide access to a massive *stock* of energy […] Indefinite dependence on fossil fuels is impossible because the size of the *stock* available is reduced each time a ton of coal is dug, or an equivalent quantity of oil is pumped, but the use of fossil fuel can provide an interlude during which exponential growth is possible’ (Wrigley 2016, pp. 17–18).

Each state of the network is grounded in a particular form of production organization, and the relative positions of capacities, tasks and functions, and materials reflect the degree of virtuality of relative positions inherent to that arrangement[2]. This virtuality arises from the multidimensionality of each network across the ***C***, ***T***, and ***M*** spaces, which involves a plurality of possible links between those spaces (Cardinale and Scazzieri 2023a, b; see also Scazzieri 1993, Chapter One). The dynamics of each production domain as an all-embracing network results from changes in the prevailing visualization of capacities, tasks and functions, and materials, as well from changes in the visualization of how their relative positions may change, and from the actions taken therefrom.

Changes in visualization take place within the space of virtuality built from the collection of possible relationships between the **C**, **T**, and **M** spaces. This may involve actions taking place and producing effects at different speeds within those spaces. In turn, this process may lead to a complex dynamic in which constraints arising from different speeds of change across the **C**, **T**, and **M** spaces generate transformations within those spaces that lead to a definite 'order of sequence' for the dynamics of the whole production network (Myrdal 1939, p 27). In this way, lack of synchronisation between speeds of change across the **C**, **T**, and **M** spaces gives rise to a complex dynamic that is at the same time open ended and yet constrained within the range of the feasible sequences encoded in the given structure[3].

This feature of production networks calls attention to the role of lack of synchronisation and asymmetries in the more general dynamics of networks in the human space. These networks may be partially independent from one another and yet may influence one another and give rise to a complex over-all dynamic that is inherently uneven due to the different speeds of change across networks. A general criterion of *relative structural invariance* is key in explaining those asymmetries and the unevenness of the processes by which network transformation takes place over time[4].

[2] Each form of production organization results from 'the operation of a complex organizational structure, such that tasks, funds and transformation processes are coordinated with one another both in time and scale. Such a pattern of coordination is often the result of the emergence of a set of interlocking practices, as the ones associated with a workshop or an industrial district, but is not necessarily the outcome of deliberate planning by particular agents' (Landesmann and Scazzieri 1996, p. 211; see also Scazzieri 1993, pp. 87–90).

[3] Nathan Rosenberg emphasizes the role of asymmetries between production elements as key factors in generating bottlenecks that may act as focusing devices in providing the direction of technological change (Rosenberg 1976 [1969]).

[4] Relative invariance is often a feature of near decomposable systems (Simon 1962, 1976; Simon and Ando 1961). An instance are economic networks subject to an impulse or force whenever they are 'allowed to change [their] original state by following an adjustment path that belongs to a limited set of feasible transformations. In fact, the set of feasible transformations is the consequence of both the characteristics of certain elements of [the] economic system that are taken as constant and certain patterns of interrelationships among the different components that are assumed as invariant in the structural specification of the system. In this way, the impulse from which the original state of the economy is modified may be purely exogenous, but the actual process of transformation can be explained in terms of the "dynamic" characteristics of the existing structure (that is in terms of the specific paths of feasible transformations that are compatible with its description)' (Landesmann and Scazzieri 1990, p. 96; see also Scazzieri 2021a, 2022).

4 Dimensions of Interdependence: Open-endedness and Closure

The human space is defined by the relative positions of individual and collective actors. Due to the manifold dimensions of human activity, relative positions may look differently depending on which dimension is considered. Section 3 discussed the different patterns of relative positions that are possible depending on which dimension of productive activity is considered (capacities, productive tasks and functions, or materials). We have also seen that, for any given dimension of production, relative positions may be different depending on whether actors visualize actual pattens of interdependence or virtual positions that could be implemented given the opportunities provided by the higher-order architecture of the production space. In short, visualization plays a leading role, both by drawing attention to particular dimensions of human activity and in making visible virtual positions different from those that are immediately manifest but are no less real as they are *embedded as possibilities* in the production space under consideration. A case in point is that of virtual tasks embedded in the higher-order space of productive functions.

Moving from one production dimension to another introduces a further degree of open-endedness for the visualization of relative positions, while at the same time suggesting alternative routes to closure. The three fundamental dimensions of productive activities are closely intertwined but they acquire different prominence depending on context. For example, under certain conditions capacities or tasks may be of crucial importance in determining the relative positions of productive activities, while in other cases the relative positions of materials may be dominant. This means that the relative positions of productive activities, and of the individual and collective actors associated with them, may change depending on whether capacities, tasks and functions, or materials are the central elements of the production space. This brings to light that also the relative positions of individual or collective actors associated with production activity may change, sometimes radically, when there is a change in the fundamental dimension of productive activity. Open-endedness is an ex-ante feature of production (Scazzieri 1993; Cardinale and Scazzieri 2023a). At the same time, this ex-ante open-endedness may lead to ex-post closure once a particular dimension of production activity becomes the dominant one. We meet here the apparent paradox that the plurality of relative positions associated with the different dimensions of human activity leads to a specific constellation of positions once a particular dimension becomes the central one in determining the relationship between individuals or groups. Depending on which dimension is dominant in the production space, actors may switch from a central to a peripheral position or vice versa. At the same time, dominance reflects actors' visualization of positions at the different layers of interdependence in the production space. For example, if tasks are the dominant dimension, the visualization of relative positions may emphasize the immediate relationship between tasks *or* that between the higher-order productive functions that make task performance possible. To conclude, each arrangement in the production space is embedded in a multi-layered relational structure. This also has significant implications for actors' actions in that space, since actors' visualization may detect the possibility of plural effective actions provided actors' objectives and actions fit the conditions for closure relevant in each context[5].

5 Proximity and Distance: A Theoretical Framework

As we have seen in the previous sections, the complexity of human spaces derives from the plurality of dimensions characterizing human dispositions and actions, and from the plurality of interdependencies arising therefrom. The production space, in which divisions of labour and interdependencies develop across manifold dimensions, and plural layers along each dimension, provides a characteristic instance of that. Human spaces are inherently complex as each individual or collective actors is a cluster of dispositions triggering actions along a variety of dimensions. In turn, this leads to forms of interdependence that develop through time along a variety of routes. For this reason, the properties of human spaces cannot be derived along a single route from the characteristics of actors or of their interaction. For actors have different facets, and patterns of interdependence may develop along different trajectories However, dispositions give rise to interdependencies that in turn make certain modes of interaction possible and others impossible (see Section 3). In other words, human spaces give rise to structures that are *at the same time* open ended and circumscribed. This combination of open-endedness and closure generates multi-layered structures that in turn make interactions effective only within certain ranges of feasibility. This has important consequences for the identification of relative distance in the human space. Individuals or collective actors are more, or less, distant from one another depending on which dimension and layer of interdependence is considered. For example, production processes p_i and p_j may be close to each other in the capacity space but far away from each other in the material space. This may happen because the two processes require the same algorithmic abilities but may also depend on vastly different non-produced resources and materials-in-process. A similar argument would apply when comparing processes, say p_i* and p_j*, conducted at separate locations. The two processes may be considered as close to each other if they require the same materials but far away from each other if they require vastly different capacities. Alternatively, p_i* and p_j* may be considered as far away from each other if they process dissimilar materials but close to each other if they require the same capacities. This argument has consequences also beyond the production space. For example, two regions or countries may be seen as distant or close relative to each other depending on which activity dimensions are considered.

A consequence of this multi-dimensionality of distance is that actors or activities may be differently clustered depending on which dimension is considered. Boundary lines, while not arbitrary, reflect modes of visualization that highlight certain dimensions rather than others. This makes the mode of visualization a central condition for the clustering of actors and activities in each context. However, visualization, while

[5] As Galileo Galilei notes in a passage concerning the making and using of machines, actors' visualizations and aims cannot 'trick nature' (*defraudare la natura*) and trying to do so would inevitably lead to failure and disaster (Galilei 1933 [ms. 17th century], p. 585)

open ended, is also circumscribed. For example, a k-dimensional activity cannot be visualized as an n-dimensional one, with $n > k$. For this reason, distances and boundary lines reflect modes of visualization but the resulting measures of distance are not unconstrained.

The above argument entails that any two actors or activities are more (or less) distant from each other depending on the number of common characteristics considered to be relevant for those activities.

In general terms, we may express the distance between two actors or activities (say, A and B) by distinguishing between the distance between A and B from the point of view of A (d_{AB}) and the distance between A and B from the point of view of B(d_{BA})[6]:

$$\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}} = \begin{array}{ccc} & A & B \\ A & 0 & d_{AB} \\ B & d_{BA} & 0 \end{array}$$

However, if we introduce the assumption of 'distance symmetry' (so that the distance between A and B would be the same independently of the 'point of view' from which the distance is considered) we have $d_{AB} = d_{BA}$. In this case, matrix $\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}}$ gives way to a single scalar value $d_{A,\,B} = 1/\kappa$, where κ is the number of characteristics common to the actors or activities A and B:

$$d_{A,\,B} = 1/\kappa \tag{1}$$

The above definition may be interpreted as associating distance with a single 'order of similarity' (such as weight, height, etc.) (Keynes 1973 [1921, p. 39]; see also Gärdenfors 2000, p. 5). However, the consideration of multi-dimensional actors or activities suggests that *multiple* orders of similarity are possible. This involves switching from matrix $\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}}$ to matrix $[\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}}]_k$, $k = 1,\ldots,m$, in which k denotes the order of similarity under consideration:

$$(\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}})_{\boldsymbol{k}} = \begin{array}{ccc} & A & B \\ A & 0 & (d_{AB})_k \\ B & (d_{BA})_k & 0 \end{array} ,k = 1,\ \ldots,\ m \tag{2}$$

Again, distance symmetry involves that the distance between A and B does not depend on the point of view from which their respective distance is considered. In this case, matrix $(\boldsymbol{D}_{\boldsymbol{A},\,\boldsymbol{B}})_{\boldsymbol{k}}$ gives way, *for each order of similarity*, to a single scalar value $[d_{A,\,B}]_{k\,=}\ (1/\kappa)_k$, $k=1,\ldots,\ m$. This means that, if multiple orders of similarity 1, $2,,\ldots,m$ are involved when considering actors or activities A and B, we may express the distance between A and B by the following m-dimensional vector:

[6] This argument is consistent with Amos Tversky's prospect theory of similarity judgements: '[s]imilarity judgements can be regarded as extensions of similarity statements, that is, statements of the form "a is like b". Such a statement is *directional*; it has a subject, a, and a referent, b, and it is not equivalent in general to the converse similarity statement "b is like a". In fact, the choice of subject and referent depends, at least in part, on the relative salience of the object' (Tversky 1977, p. 328, added emphasis).

$$d_{A,B} = \begin{matrix} (d_{A,B})_1 \\ (d_{A,B})_2 \\ (d_{A,B})_m \end{matrix} \tag{3}$$

Vector $\boldsymbol{d}_{A,B}$ may substitute matrix $(\boldsymbol{D}_{A,B})_k$ only under the distance symmetry assumption. If we drop that assumption, the 'directionality' of comparison becomes a salient feature, so that the assessment of distance when A is 'subject' and B is 'referent' (d_{AB}) would not necessarily be the same as when B is 'subject' and A is 'referent' (d_{BA}). In this case, we fall back to the class of matrices $(\boldsymbol{D}_{A,B})_k$, $k=1, \ldots, m$ as the general representation of distance.

The above discussion suggests that the distance between *multi-dimensional* actors or activities is not always reducible to a weighted measure of the distances relative to the various characteristics in terms of which actors or activities are compared. For example, the switch from one dimension to another (say, from the task dimension to the material dimension in the production space) may be associated with the switch from one *order of similarity* to another[7]. This entails that the characteristics of actors or activities are not always additive magnitudes, and that threshold effects may determine whether a certain increase (or decrease) along a given dimension is relevant or not for the measurement of distance. Peter Gärdenfors notes in this regard that '[t] here is a tight connection between distance in a conceptual space and similarity judgment: the smaller the distance is between the representations of two objects, the more similar they are' (Gärdenfors 2000, p. 5; Scazzieri 2021b). Distance may be independent of the natural units in which characteristics are measured but is not independent of the order of similarity under consideration.

The previous argument brings to light the epistemic character of distance. This is because our conception of distance presupposes both the *visualization* of certain common characteristics between heterogeneous actors or activities along a given order of similarity, as well as the introduction of a *conjecture* about the distance between A_i and A_j. The recognition of common characteristics (and the ensuing introduction of a *distinction* between the holders of those characteristics) is necessary but not sufficient for the identification of distance. Partial similarity can measure social distance only as far as it is associated with the conjecture that the proportion between characteristics that are shared and characteristics that are not shared provides an appropriate measure of distance. We may also note that certain characteristics may be recognised as common and yet not to be relevant for the identification of distance. On the other hand, there could be cases in which few characteristics are a sufficient basis for distance measurement, independently of other characteristics, which could be common

[7] John Maynard Keynes defines the concept of 'order of similarity' as follows in his *Treatise on Probability*: 'When we say of three objects A,B, and C that B is more like A than C, we mean, not that there is any respect in which B is in itself quantitatively greater than C, but that, if the three objects are placed in an order of similarity, B is nearer to A than C is. There are also […] *different* orders of similarity. For instance, a book bound in blue morocco is more like a book bound in red Morocco than if it were bound in blue calf; and a book bound in red calf is more like the book in red morocco than if it were in blue calf. But there may be no comparison between the degree of similarity which exists between books bound in red morocco and blue morocco and that which exists between books bound in red morocco and red calf (Keynes 1973 [1921], p. 39).

or not. In this connection, we may recall John Venn's view that distinctions are only relevant to classification as long as they *do not allow* intermediate cases between 'extreme members': 'however wide may be the differences between one individual and another, and however locally persistent and distinct they may seem, yet if we continue to interpose a succession of individuals between the extreme members they would all alike be considered to belong to one species' (Venn 1907, p. 337)[8].

The above framework provides a distance criterion for a given similarity order. Distance between actors or activities across *different* similarity orders is a more complex matter. For example, social groups A_i and A_j may look close to each other along similarity order σ_p, but far away from each other along similarity order σ_r. Categorization may be a route to identifying distance in case of plural similarity orders provided it is possible to conceive a new similarity prototype (that is, a new standard of comparison) that encompasses the similarity prototypes associated with similarity orders σ_p *and* σ_r. This procedure would lead from the original similarity orders σ_p and σ_r to a new similarity order σ^*, which would be based on circumscribed visualization of the characteristics relevant to σ_p *and* σ_r. We may also conjecture that σ^* would allow previously 'hidden' characteristics to overcome the relevance threshold thereby making those characteristics relevant to judgement of similarity and distance. This framework would allow the identification of distance starting from a situation of different similarity orders for actors or activities. It presupposes: (i) adequate categorization, that is, the identification of a higher-order prototype leading to similarity order σ^*; (ii) the fixing of similarity order σ^* as the new standard of comparison for identification of distance.

If we consider two social groups such as A'_i and A'_j, and we assume that similarity order σ_p assigns to them the following sets of relevant characteristics: $A'_i = \{a_1, a_2, a_m, a_n\}$ and $A'_j = \{a_2, a_m, a_s\}$, the distance criterion provided by definition (1) entails that $\kappa = 2$, so that $d_{ij} = 1/2$. On the other hand, if we switch to similarity order σ_r and we assume that σ_r assigns to A'_i and A'_j the following sets of relevant characteristics: $A'_i = \{a_1, a_3, a_4, a_7\}$ and $A'_j = \{a_2, a_3, a_8, a_{10}\}$, the distance criterion provided by definition (1) entails $\kappa = 1$, so that $d_{ij} = 1$. Groups A'_i and A'_j look more distant from each other along similarity order $\sigma_r (d_{ij} = 1)$ than along similarity order $\sigma_p (d_{ij} = 1/2)$. It is possible to overcome the cleavage between σ_p and σ_r by switching to similarity order σ^*, which entails partially different collections of relevant characteristics for A'_i and A'_j. For example, if we assume $A'_i = \{a_1, a_3, a_{11}, a_{12}, a_{17}\}$ and $A'_j = \{a_1, a_3, a_{12}, a_{17}\}$, we have $\kappa = 4$ and $d_{ij} = 1/4$. In other words, groups A'_i and A'_j look *less distant* from each other under the higher order similarity σ^* $(d_{ij} = 1/4)$ than under either $\sigma_p (d_{ij} = 1/2)$ or $\sigma_r (d_{ij} = 1)$. This argument underlines that bridging *different* similarity orders presupposes switching to a different collection of relevant characteristics, which in turn makes the comparison between similarity orders dependent on visualization of higher order similarity, and on *fixing* that similarity order as the relevant criterion for the identification of distance.

[8]] Recently Ragupathy Venkatachalam called attention to the conventional and heuristic character of classification, and to the relevance of the intermediate cases between 'extreme members' as a privileged area for identifying new forms in the natural and social domains (Venkatachalam 2024).

The visualization of distance between actors or activities presupposes the identification of a standard of comparison *common to them.* Lotfi A. Zadeh's discusses this issue in the context of his theory of *protoforms*. According to Zadeh, a protoform (as prototype) 'may be defined as a sigma-summary, that is, a summary of summaries. With this definition as the point of departure, a prototypical form, or protoform, for short, is defined as an abstracted prototype. As a simple example, the protoform of the proposition "Most Swedes are tall" is "*QA*s are *B*'s," where *Q* is a fuzzy quantifier, and *A* and *B* are labels of fuzzy sets' (Zadeh 2001). Similes provide instances of protoforms. In this connection, it has been noted that comparisons through similes 'played an important part in expressing distances' when 'little progress had probably been made towards an abstract, standardised system of measurement' (Lloyd 1966, p. 186). For example, Homer often expresses distances through expressions such as 'as far as the flight of a spear' (*Iliad* 21 251) or 'as far as the range of a discus' (*Iliad* 23 431 f.) (See Lloyd, *ibidem*). More generally, similes as images may be used both 'as a means of describing the known' *and* as a means '*to apprehend the unknown* by likening it to something known or familiar' (Lloyd 1966, p. 190). In this way, similes (and, more generally, protoforms) point to a way in which *different grades of membership* of a particular set may be compatible with 'decomposition of whole into parts' and with 'integration of parts into whole' (Zadeh 1997, p. 112). In this connection, Zadeh identifies the distance *d* between any given object *u* and its 'idealized protoform' (or *i. protoform*) with the grade of membership $\mu_A(u)$ of object *u* in (fuzzy) set *A*. For example, 'the concept of oval object may be defined by employing an ellipse as an i. protoform', and 'the distance between a given oval object, *A*, and its i. protoform […] could be related to the grade of membership of *A* in the fuzzy set of oval objects. The concept of an oval object may be viewed as an instance of a protoform-centered concept' (Zadeh 2003, p.2). The above conception refers to the degree of *common* membership of actors (or activities) *i* and *j* in a set of characteristics associated with a given idealized prototype[9]. In this way, a relationship is introduced between social distance and the 'deep semantic structure' (Zadeh 2003, p.1) of human space.

This point of view has far-reaching consequences for the identification of interdependence between actors or activities. For interdependence is compatible with manifold visualizations of it by individual and collective actors (Cardinale 2024; Cardinale and Scazzieri 2023a). This makes visualization of interdependence to reflect actors' disposition to identifying a 'most common' prototype, and to interact on its basis despite characteristics that may be highly differentiated across actors or activities. There is therefore a close relationship between the identification of distance in human space and the formation of categories[10]. For instance, any given actor may be associ-

[9] This approach to similarity and difference was anticipated in Plato's view that a central philosophical problem is to see 'clearly *one* Form everywhere extended throughout many, where each one lies apart, and *many* Forms, different from one another, embraced from without by one Form; and again *one* Form connected in a unity through many wholes, and *many* Forms, entirely marked off apart' (Plato, *Sophist*, 253d, as quoted in Lloyd 1966, p. 433).

[10] The relationship between categorization and membership of a set of characteristics is highlighted in the theory of *conceptual* fuzzy sets, in which 'a label of a fuzzy set represents the name of a concept and a fuzzy set represents the meaning of the concept' (Takagi 1994, p. 333). In this case, the 'shape' of the set is determined by the meaning of the label, and the latter reflects the contingent structure of activation of

ated with different degrees of membership in a certain class (say, in a certain social group) depending on the way in which that class is identified as a category.

This argument entails that individual and collective actors may visualize different patterns of interdependence depending on how they visualize their membership in the different, and sometimes mutually exclusive, classes into which a social space is partitioned. Classes (as categories) generally allow different grades of membership: '[m]ost, if not all, categories do not have clear-cut boundaries. To argue that basic object categories follow clusters of perceived attributes is not to say that such attribute clusters are necessarily discontinuous' (Rosch 1978, p. 35). In view of this, 'categories can be viewed in terms of their clear cases if the perceiver places emphasis on the correlational structure of perceived attributes such that the categories are represented by their most structured portions' (Rosch 1978, p. 36). In particular, 'prototypes appear to be just those members of a category that most reflect the redundancy structure of the category as a whole. That is, if categories form to maximize the information-rich cluster of attributes in the environment and, thus, the cue validity or category resemblance of the attributes of categories, prototypes of categories appear to form in such a manner as to maximize such clusters and such cue validity still further within categories' (Rosch 1978, p. 37; see also Neuman 1974; Rosch 1975; Rosch and Mervis 1975; Thagard 1992)[11].

We may conjecture that the ability, or lack of ability, to identify inclusive categories (that is, classes allowing a 'large enough' grade of membership) may increase (or, respectively, diminish) the likelihood of compromise in the interaction between actors in each context. This may the case when inclusive categories lead to a more nuanced understanding of the consequences of conflict or compromise. For example, by making visible consequences that would be hidden to actors constrained within less inclusive categories (such as categories associated with narrower time horizons; see also Pabst and Scazzieri 2023). We may conjecture that different forms of compromise or conflict will be associated with different prototypes, and that these prototypes may be linked with specific purposeful activities: 'form and function, normally investigated as opposing properties, are aspects of the same process, and organisms are highly sensitive to their coordination' (Varela et al. 1991, p.177). It has been noted in this connection that aim-specific prototypes often presuppose a combination of pre-existing polar categories (see Maybury-Lewis and Almagor 1989, who call attention to the blending of polar categories (prototypes) in cultural beliefs and institutions).

The above argument entails that the identification of distance in the human space results from the following stepwise procedure:

(i) A set of common characteristics **C** is identified within a space of heterogeneous individuals or groups.

salient features for the set under consideration. In particular, 'a long-term memory is used for the network representing knowledge and a short-term memory is used for the distribution of activation values representing the meaning of a label of a fuzzy set in interest' (Takagi 1994, pp. 333−34).

[11] The concept of 'cue validity' denotes the likelihood that a given object would fall under a given category or prototype because of a particular characteristic (the 'cue') (see Rosch and Mervis 1975).

(ii) A sub-set of common characteristics **C*** $\subseteq$ C is selected. This is the set of characteristics that are both common and relevant to the identification of distance in the case under consideration.

The above procedure suggests that characteristics may be common and yet irrelevant to identification of distance. It also suggests that the collection of common *and* relevant characteristics **C*** may be smaller than **C**.

Both associative and fixing principles are at work behind the above procedure. Associative principles allow the identification of **C**, while fixing principles allow the selection of **C*** from **C**. The above argument suggests that, for any given pair of actors or activities A_i and A_j, a contraction of the characteristics set **C** is associated with increasing distance d_{ij} if and only if the set **C*** of common and relevant characteristics is also contracted. Similarly, an expansion of the **C** set is associated with diminishing distance d_{ij} if and only if the set **C*** is also expanded. By definition (1), distance is inversely related to the number of common characteristics κ (provided such characteristics are recognised and considered to be significant). Hence, any contraction of **C** affects d_{ij} if and only if the number of active characteristics in **C*** is also diminished. Similarly, any expansion of **C** affects d_{ij} if and only if the number of active characteristics is also increased.

The above conception of distance calls attention to the close analogy between distance, similarity judgement, and the acquisition of knowledge through induction (Scazzieri 2021b). This is due to the combined role of associative and fixing principles. Limited information suggests that theoretical concepts may be essential to allow similarity judgement when assessing the structure of available evidence. This situation is related to induction by analogy. In the identification of distance, the discovery of a sufficient number of common characteristics between any two actors or activities suggests that those actors (activities) are significantly similar. Here, distance is a conjecture associated with induction by analogical reasoning. We assume that active common characteristics (the characteristics included in set **C***) give a cue into the structure of social interdependence, even if we are far from a complete description of actors or activities. This argument entails that framing is central to the measurement of distance and the acquisition of knowledge through induction (Scazzieri 2021b, 2025). The selection of a limited number of common and relevant characteristics (subset **C*)** from the set **C** of common characteristics is a step in common to both the contraction and the expansion case. In both cases, common and indispensable characteristics must be separated from characteristics that are common and dispensable. This operation presupposes partial similarity (among natural objects, or social objects), and makes it possible to generalise from limited information to broad categories. Association and fixing are essential to the comprehension of the human space. Association allows identification of categories encompassing plural characteristics. Fixing makes one or more associations active. As a result of fixing, characteristics are bundled together, and 'natural' associations may be detected between individual actors or groups.

6 Towards a Political Economy of Distance

The above argument suggests that different spheres of human activity may be associated with different patterns of interdependence, and that, for each sphere of activity, the relevant pattern of interdependence may vary depending on the actors' point of view. As we have seen, this approach entails a plural definition of distance between individual or collective actors (see Section 5). A consequence of the plural definition of distance is that actors, or actors' groups, that are far apart by a certain definition of distance may be adjacent by another definition of distance (or vice versa). Measures of proximity based on territorial sovereignty or economic interdependence are a case in point. For example, two territories that are separate from each other by political boundaries may be glued together by the same pattern of economic complementarity. On the other hand, a territory under the same political sovereignty may be divided into sections that could in turn belong to different networks of economic interdependence (Pabst and Scazzieri 2023). This possibility was recognized long ago by the Italian political economist and legal theorist Cesare Beccaria, who wrote that 'the political borders of a state are not always, or almost never, the same as its economic borders […] The land of one nation nourishes the industry of another, the industry of the latter fertilizes the land of the former: those two nations, despite having divided sovereignty and being reciprocally independent of their respective political laws, are in fact a single nation closely held together by the strength of physical laws, and dependent of one another in virtue of their economic relationships' (Beccaria 1971 [ms. circa 1769], p. 391).

Plural identifications of distance between individual or collective actors may lead to alternative viewpoints concerning the identification of collective interest in a space of interdependent actors. For the visualization of collective interest reflects a membership criterion, and that criterion may lead to different, and sometimes opposed, memberships and loyalties depending on which dimension of interdependence is considered, and on how the distances are measured along that dimension (Cardinale 2017, 2024; Cardinale et al. 2017). For example, a 'circular flow' representation of the production system (Leontief 1991 (1928)), such as one in terms of input-output relationships, allows different aggregations and hence potential forms of membership. One is the aggregation into 'classes' defined by the type of income received (wage, profit, rent); another is aggregation into industries defined by the output they produce, which include the labour and capital that are used to produce those outputs; yet another is 'vertically integrated sectors' (Pasinetti 1973), which include labour and capital across industries that enter the production stages of a final good. Depending on the criteria of distance that are more salient for groups of workers and firms, membership to one or another aggregation could prevail, each of which may be associated with different collective objectives (Cardinale 2024).

A plural definition of distance brings to light the relationship between collective interest and membership criteria, and may reveal routes along which economic and political aggregations could be transformed over time. For example, the geographical distribution of interdependent economic activities could shift over time, as a result of the deepening of division of labour or of changes in patterns of international trade. The extent to which such changes give rise to changes in the relative salience of different membership criteria is likely to reflect the persistence or change of the social understandings of similarity and distance in each context.

7 Conclusion

The human space as a complex system is a multi-dimensional and multi-layered architecture of interdependence and connectivity. Its dimensionality reflects both material and immaterial features, whose salience may vary depending on actors' dispositions and context. This makes the organization of complexity of vital importance while also making it subject to changes in actors' dispositions and circumstances. This paper suggests that, at any given time, the dimension that provides the fundamental architecture of the human space is the one that actors are inclined and/or bound to consider as such in the context in which they live. Once that dimension is identified, the criterion of relative structural invariance suggests what can be the hierarchy of motions between components of the human space. The structural approach to complexity followed in this paper calls attention to the architecture of the human space while also emphasizing the partially contingent characteristics of that architecture. This suggests new lines of inquiry into the topological features of human interdependence from the theoretical, empirical, and policymaking points of view.

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