Exploring the Links between Thermodynamics and Social Sciences: The Contribution of our Understanding of Space and Time Relationships

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Bernard Guy

Mines Saint-Etienne, Institut Mines Telecom, France

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EXPLORING THE LINKS BETWEEN THERMODYNAMICS AND SOCIAL SCIENCES: THE CONTRIBUTION OF OUR UNDERSTANDING OF SPACE AND TIME RELATIONSHIPS

Bernard Guy

Mines Saint-Etienne, Institut Mines Telecom, France

ABSTRACT

I present the links I see between thermodynamics and social sciences. I am particularly interested in understanding different levels of social reality, whereas thermodynamics links different levels of physical reality. I begin with some general considerations about models in science. We build them to understand or even predict the future. I insist on certain characteristics of the links between disciplines: the recursivity expresses the influences in both directions, e.g. from the macro to the micro, and not only from the micro to the macro. In order it works properly, any system needs an exterior to itself, where certain choices are made, for example that of the standards used for measurements. I then look at the construction of the concepts of space and time and the consequences on the understanding of thermodynamics. Space and time are the other name for the comparison between phenomena. They can thus function differently from one level to another of the social / physical reality. They are given a variable meaning depending on the level. A lower level is frozen in its most probable state (intervention of the entropy function). I conclude with a look at the social sciences and, under the inspiration of thermodynamics, look for an entropy and an internal energy to assign to a social group, when this group is defined from a collection of groups at a lower level.

Keywords: models, natural sciences, social sciences, recursivity, entropy, internal energy, space, time, movement

1. INTRODUCTION

I am exploring here the links between natural and social sciences. I am not a specialist on the subject and I will only give some general remarks in relation to my way of apprehending thermodynamics, and in relation to my way of apprehending the concepts of time and space. These are lines of research, a framework for future work. It is necessary to renew our understanding, before we have a new look at the equations.

The subject is huge and there has already been a very large number of contributions to the matter. I am myself interested, among many other topics, by the understanding of different levels of social reality [1], while I think that thermodynamics tries to connect different levels of physical reality, from microscopic to macroscopic [2]. Social reality itself is manifested from the level of small groups of people to the level of countries and continents. With Emile Durkheim [3], I am wondering whether there is an autonomy of social facts with respect to the psychology of individuals, while Auguste Comte and his positivism [4], discusses the hierarchy of sciences, from mathematics, astronomy and physics to what he calls social physics. I am also interested by the works of French mathematician René Thom [5] who stresses the importance of what he calls the qualitative morphology of natural systems.

2. MODELS IN SCIENCE

As physicists, we are interested in producing models to confront reality. To model is to produce an abstract discourse, self-coherent in the manner of mathematics, in correspondence with reality. Depending on the cases, we just want to better understand, or we wish to predict the future.

Another way to speak of the duality between understanding and predicting is to speak of a progression of modeling from qualitative to more quantitative role; we can speak of different degrees of modeling. *Degree zero*: literary description, refers to linguistics and its relationship with formal logic and mathematical logic. *Degree one*: qualitative: the physical / mathematical model allows to order the observations (typology of solutions). *Degree two*: semi-quantitative: the orders of magnitude observed correspond to what is expected (approximate resolution). *Degree three*: quantitative: prediction of the evolution of the parameters in time and space (full resolution, if necessary numerical). Models can play an important qualitative role. Qualitative does not mean the absence of mathematics, but the mathematical developments mostly allow us to put order in our mind.

In our conference we also wish to promote links between natural and social sciences. There are different ways that we

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can have of linking the scientific disciplines: - analogy; - merging: one discipline as a subdiscipline of a larger one; - hierarchical structure: ontological / methodological reductionism; - autonomy of a discipline with respect to other disciplines; - collaboration of disciplines: parallel / serie.

We may make a stop on what I call the recursivity type links between different disciplines; this means that one discipline needs an input from a second discipline and the second one also needs inputs from the first; this is understood within a relation-based rationality (as composed with more substance-based rationality): in the top-down direction, one discipline can provide a context for another, a motivation, a historical framework, some quantitative data. For instance, mineralogy for materials Science (downward), and in the upward direction, the physics of materials can provide some parameters for minerals. In other instances, if we put the two disciplines within a hierarchical structure, it is not only the way from micro to macro, but from macro to micro, that must be stressed [6].

In order to make the disciplines work properly, we also need an exterior to the disciplines from which our conventions are founded. There are no universal laws as dictated by reality; we always need conventions of social nature, for instance in the choice of standards. These two characters (recursivity, existence of an exterior) are related to my way of understanding the trilogy space / time / movement; we will find them in thermodynamics as well.

When comparing natural and social sciences, let us stress that in the sciences of the mind, according to W. Dilthey [7] (I think we can extend what Dilthey says to the social sciences), we seek to understand, whereas in the natural sciences we seek to explain. *Explain*: we are looking for some ingredients of more elemental nature whose combination will allow to predict what we observe. *Understand*: we seek to be able to talk about social facts in order to accompany them.

One important point concerns reflexivity in the social sciences: in other words, if a prediction is announced, the announcement itself will change the behaviour of social agents. This is why the word prediction has a very different meaning in both fields (perhaps we should not use the same word) [8], [9].

In the social sciences, a number of characteristics should be noted: enormous number of variables, dependence on historical and cultural context, more conventions subject to free will; with them, we should do not limit scientific knowledge to *causal knowledge*, or *laws*, and rather consider them as giving *conditions of possibility*. Performativity is also a peculiar characteristic of these sciences.

3. SPACE, TIME AND MOVEMENT

Let us now present my way of understanding the concepts of time and space [10], [11]. In order to do so imagine a one-dimensional model world in which three material points are shown: two points 1 and 2, supposedly fixed, marking space, and whose distance can serve as a ruler; and one point 3, moving from 1 to 2, marking time, and which can serve as a clock (constant speed). Let go right to the conclusion: it is important to note that one cannot think independently - the constant immobility of points 1 and 2 at the ends of the ruler, and - the constant mobility of clock point 3.

A conceptual circle is inevitable: the boundaries of movement are themselves understood by comparing movements: points 1 and 2 are seen as "fixed" if the movement that can be associated with them is much slower than the one attached to 3. In the endless regression that invites us to rely on other points to judge the mobility or fixity of the points we are studying, we must pragmatically mark a stop by defining a standard movement. This is what we are doing with the second postulate of relativity theory. In doing so, we stop both the bounds of the movement (this is a frame in the sense of physicists) and its "speed", i.e. we govern the relative movement of the bounds and the mobile; or rather (not to mention speed, which only comes second), we establish a unitary link between space and time for the standard. In a regression to infinity we would need another clock to be sure that the first clock runs at a constant pace, etc. The choice of a standard is of social nature, also external to the physical system. By considering a material point, we have frozen the world at a lower scale, but we can envisage a nested hierarchy of systems that corresponds to a hierarchy of space and time scales. There are different ways to decide the border between space and time.

In short, we promote an understanding of the trilogy time-space-movement where movement is "prior" to space and time. Movement engenders - space as the amplitude of movement, - time as the process of movement. We justify the primacy of motion by a prior step of *designation*; another way of doing so is to refer to a provisional fictitious point of view, forgotten once the standard time-space links are understood in a new way (the philosopher H. Vaihinger [12] stresses the indispensable role of fictions in science).

These considerations also reveal the importance of a relational rationality (we only see relations between things), and not only a substantial one. *Relational*: time is not space, space is not time (cf. the recursivity we discussed in first part).

This relational rationality reveals the need for conventions of a social nature, external to the system under study. This is also why one should revise the boundaries between scientific disciplines.

4. THERMODYNAMICS

This vision of the relationship between space and time has many consequences in thermodynamics [13], [14]: *the boundary between space and time is subject to arbitrariness…*

- The boundary between equilibrium and non equilibrium is not imposed to us by reality, it is decided, depending on the time and space scales that interest us or that we are able to grasp.

- Concept of scale: we ignore the movements (« no time ») at lower scale.

- The interior / exterior (and the boundary) of a system follow: we speak of the interior when the system is no longer monolithic.

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- The distinction between heat and work is not intrinsic but a matter of scale and convention.

- One cannot ultimately separate kinetics from transport (diffusion) processes.

- Time arrow is always connected to space arrows (gradients in the system).

We may stress the natural arising of entropy and its probabilistic meaning: when we decide to freeze the system at a lower scale, we freeze its configuration in the most probable state: entropy and its probabilistic meaning naturally arises. The possibility to assign an entropy to an individual particle is acceptable, provided the particle is considered as the collection of putative subparticles at a lower scale, whose most probable configuration has been taken. After entropy, internal energy and heat transfer are the new physical quantities in thermodynamics with respect to mechanics

Without showing all the intermediaries of reasoning, I will say that the foregoing allows me to understand a hierarchical structure of thermodynamics. The hierarchical structure already exists, I insist to say that it contains this understanding of space and time. One ignores or decides to ignore movements on a lower scale, one freezes in space what is time and movement on a lower scale. There is no end in the sense of micro or macro.

We can define laws and coefficients at each scale. For example, Newton's laws at one scale, Fick's of Fourier's laws at another, these laws are different. We can speak alternatively of a hierarchy of thermodynamics. Writing an entropy balance, with or without a source term, seems to be an intermediate step in the equation-making process. If we say that P(S) is different from 0 or if we write an inequality involving S, it is because there are phenomena on a lower scale that we have not yet frozen. S will serve as a measure for this.

We can also stress the importance of the recursivity aspect that plays in thermodynamics; for instance at the micro level we speak of velocities of particles, and at the macro level of temperature. For that example, recursivity expresses that the mean velocity squared $\langle u^2 \rangle$ is actually derived from the temperature measurement (individual velocities are not known), whereas it is more usually thought that temperature is derived from the knowledge of the velocities. Depending on the situations, the link is either top down or bottom up. The conventions of external nature refer to the choice of standards for space, time, energy and so on.

When we become interested in the social sciences and use the understanding of thermodynamics, we can look for - a hierarchy of scales, - laws of passage from one scale to another; - the definition of certain new "functions" such as entropy and internal energy; - micro-macro recursivities; - external inputs.

5. SOCIAL SCIENCES

We now turn to the social sciences. We will focus on two issues and discuss first, at least qualitatively, the search for an entropy in some social sciences, and then discuss, still qualitatively, the questions of internal energy, heat and work for social sciences… Entropy and internal energy are the two physical quantities proper to thermodynamics.

The first step of thermodynamic inspiration is to place ourselves in front of a hierarchy of scales for social groups. In the following, both a hierarchy of social groups and a hierarchy of scientific disciplines more or less related to these levels are proposed. There is no social level, no individual level per se, but relative to each other. *Social groups*: world/ union of countries / country / town / district / neighborhood / group of people / family / individual. *Scientific disciplines*: international relations / politics / social sciences / psycho-social sc. / psychology, psy- sciences / cognitive sciences / psychoanalysis / neurophysiology / biology / physics.

The question is then to understand the passage from one level to another level of these hierarchies. We may want to move from one level to another in order to understand how an individual opinion manifests itself in a collective opinion; or to see how a characteristic of a small social group, for example its wealth or poverty, is measured quantitatively from one level to another; we want to define the wealth of a city in terms of the wealth of a family.

The connection between the levels will be used to define a policy: for instance, how to define a policy in relation to choices of an ecological nature, e.g. use of the bicycle; how to define a policy in relation to the question of wealth and poverty.

But the wealth of the same family can vary over time: what value to take? Opinions can vary, etc. This is where there are possible choices; taking an average, taking the most probable value according to weighting choices that can be discussed: over what range of time, over what range of space? Other policies could be decided, e.g. considering the lowest wealth value....

It is this approach that can give meaning to what we could call social entropy: we can give several expressions according to the different levels, we can define different laws of behaviour according to the different levels.

We did not discuss yet about the micro-macro recursivities? The transfer of understanding may operate in the ascending or descending direction, from the micro to the macro: votes and elections, polls, taxes ... But there are also transfers from the macro to the micro: orders, laws, redistribution of aid ... and it is up to the definition of the individual who needs society, we need the world to construct ourselves. In the details of the construction of laws and the measurement of useful parameters, these influences must be taken into account in both directions (Fig. 1).

And there are also conventions of external origin: one cannot do without principles of a metaphysical nature: for example, we say: “there must be equality among the people”, or: “we must support the weakest”, or: “there must be fraternity”... A convention of human rights may be signed, etc.

I am only giving a very general framework which can help to put some order into a specific and more quantitative research, that can be undertaken.

After the entropy, one can also think about the question of an internal energy for larger social groups, based on a lower

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scale internal energy for smaller groups. In Fig. 2, I have shown the large group as a giant, it represents a collection of individuals at the lower scale. This giant can perform a work in the physical meaning, W_n with a heat loss Q_n; the internal energy variation is ΔU_n.

If one seeks to relate the internal energy U_n to the internal energy at the lower level U_{n-1}, one must add to this internal energy U_{n-1}, the kinetic and potential energies at this level that contribute to the definition of U_n. This potential energy is a way of understanding the relations between people which can increase their motivation, desire and ability to perform such or such work. One can write equations. These are the kinds of considerations one can make when discussing social internal energy

All things being equal, it is possible, depending on the cases, that when people collaborate, the internal energy expanditure of each may be less than the expanditure for same total work but each working for himself. Together we can!

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REFERENCES

[1] Johnson D.P., *Contemporary sociological theory. An integrated multi-level approach*. Springer, 2008.
[2] Guy B., "The architecture of thermodynamics and its future development <hal-00863970>", 2013. [On line].
[3] Durkheim E., *Les règles de la méthode sociologique*, Paris : Librairie Félix Alcan, 1885.
[4] Comte A., *Cours de philosophie positive*, Paris : Gallimard, 1830.
[5] Thom R., *Paraboles et catastrophes, entretiens sur les mathématiques, la science et la philosophie*, Paris : Flammarion, 1980.
[6] Morin E., *Introduction à la pensée complexe*, Paris : Seuil, 2005.
[7] Dilthey W., *Introduction aux sciences de l'esprit*, Paris : Aubier, 1947.
[8] Dupuy J.-P., *Introduction aux sciences sociales. Logique des phénomènes collectifs*, Paris : Ellipses, 1992.
[9] Dupuy J.-P., « Paradoxes quantiques et libre arbitre de l'homme », in: *Théorie quantique et sciences humaines*, M. Bitbol dir., CNRS Editions, pp. 41-55, 2009.
[10] Guy B., "Time and space are of the same stuff <hal-00651429> (English version of a paper appeared in *Philosophia Scientiae*)", 2011. [On line].
[11] Guy B., *SPACE = TIME. Dialog on the system of the world*, Paris: PENTA Editions, 2019.
[12] Vaihinger H., *La philosophie du comme si , 1923, trad. Ch. Bouriau, Philosophia Scientiae*, Nancy: Kimé, 2013.
[13] Guy B., "What can a better coupling between space and time bring to thermodynamics ? <hal-01529570>", 2017. [On line].
[14] Guy B., "Time arrows and space arrows: an understanding of the second law of thermodynamics", *Entropie*, 1, ISTE Open science, 2020.

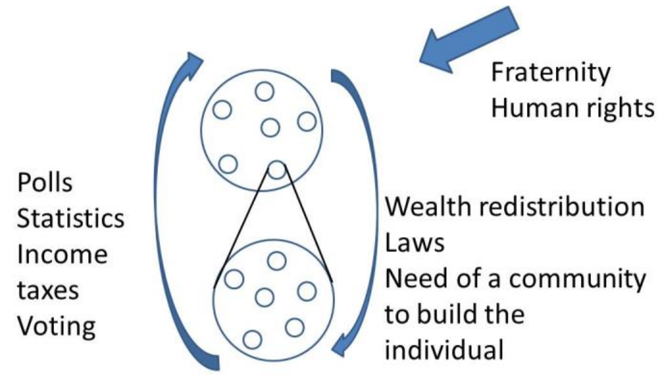

FIGURE 1: RECURSIVITY IN THE SOCIAL SCIENCES

Social groups have been represented at two levels of scale: at the top a larger group that has as its elements the groups at the lower level. Influences are in both directions, from bottom to top and top to bottom. There are also constraints of external origin.

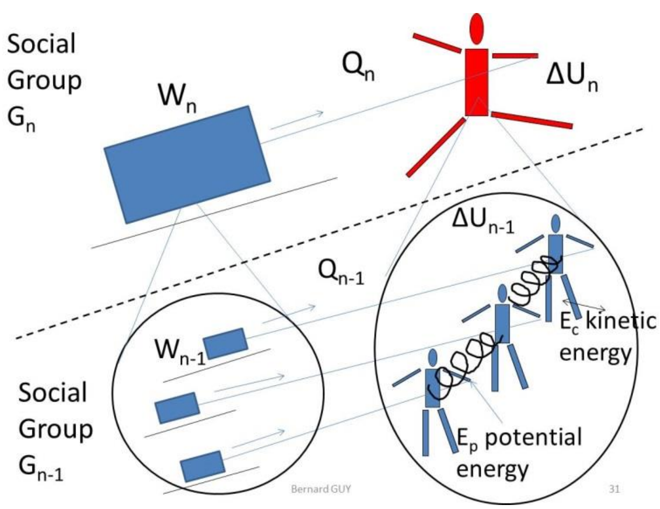

FIGURE 2: INTERNAL ENERGY, WORK AND HEAT IN THE SOCIAL SCIENCES

Two social groups G_n and G_{n-1} at two levels are represented. The internal energy U_n is understood as the sum of a kinetic energy and a potential energy at the n-1 scale. The work W_n can be accomplished by the sum of lower scale works W_{n-1}.

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