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Fuzzy Thinking in Sociology

Lars Winter and Thomas Kron

1.1 Introduction

The well-known distinction between soft and hard science cuts a sharp line of demarcation between hard and soft facts of scientific studies. Physics deal with precise hard facts characteristically whereas social sciences are confronted with imprecise soft social facts because social facts are notoriously vague, interpretative facts of meaning. Therefore Fuzzy logic seems to fit perfectly the needs of social scientist that look for mathematical precise models to deal with vague, imprecise data [52]. In this contribution we discuss the usefulness of Fuzzy logic for social sciences in general, and especially sociology. In a first step we summarize some fundamentals of "fuzzy thinking" [10] for social scientist. This will lead to the discussion of the need of fuzzy thinking in action theory, systems theory, modernization theory and empirical research. We discuss the advantage of fuzzy thinking for action theory and social systems theory at length whereas the discussion of fuzzy thinking in modernization theory and empirical research falls short. Modernization theory and empirical research just function as further examples for the need and usefulness of fuzzy thinking.

1.2 "Fuzzy fundamentals" for social scientists

Western scientific community is characterized by a bivalent way of thinking: scientific statements have to be true or false, independent form our ability to find out its logical value. This way of thinking leads to two fundamentals of Aristotelian logic:

(1) The principle of the excluded contradiction: no statement can be true and false simultaneously [$x = \text{not}(A \cap \text{not}A)$]
(2) The principle of the excluded middle (or: principium tertii exclusi): every statements is either true or false [$x = A \cup \text{not}A$].

This worldview is also fundamental for a number of sociological theories [27] but has been an object for reservation; bivalent modelling involves a "problem of mismatching" [24], p. 19: the social realm is grey but science is black and white.

Thus, bivalent thinking is not per se adequate to cope with social phenomena. According to Mario Bunge [8], p. 141 it seems that bivalent thinking is as primitive as the underlying dichotomization is and therefore inconsistent with how the (social) world is organized. Systems possess polar characteristics but also possess some characteristics that are not. Polar characteristics are rather exceptions and not the rule. Therefore we need another way of thinking which is able to cope with world's diversity, including polar as well as non-polar characteristics. One candidate for a (new) way of thinking world's diversity is Fuzzy logic.

Fuzzy-logic is more than just a method. Fuzzy logic implies a new worldview [22], [24], [25], [26] that focuses not just on bivalence but also on polyvalence and therefore challenges the "probabilistic monopoly" of classical Aristotelian logic over the world [23].[1] Polyvalence addresses the fact that systems are fuzzy per se. Fuzzy-logic "refers to the uncertainty of the system. ... A Fuzzy set is a collection of objects without clear boundaries. In a Fuzzy system, there is a transition area where things can belong to either opposite. ... A probabilistic statement concerns the uncertainty among a fixed, unambiguous set of outcomes; a statement of fuzziness concerns uncertainty in the meaning of the outcomes themselves. The uncertainty in a Fuzzy set is to a large extent the uncertainty of the system per se" [64], p. 172. One can imagine easily the progress of fuzzy thinking for how the world is described and explained.

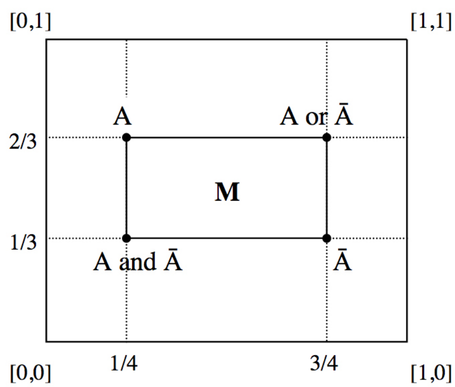

Fig. 1.1. Fuzzy cube

[1] Eastern philosophical thinking challenges classical Aristotelian logics early: "Both Lao-Tze and the Buddah championed the A-And-not-A view of simultaneous opposites. [...] The Buddha built his whole worldview on first breaking out of the black-white shell of words that still binds much of Western culture and the modern science is spawned. This lies at the heart of *satori* enlightenment in Zen Buddhism [...]. [...] In any case I cannot imagine any major Eastern thinker who would claim that $P(A \cap A^C) = 0$ holds for *all events A*. That is the height of logical and cultural extremism. The probability monopoly is over" [23], p. 33). German Idealism also challenges bivalent thinking in science [18], [19], [20].

The progress of fuzzy thinking we have in mind can be demonstrated using the so called "fuzzy-cube" (or "set-cube") (Fig. 1.1). It describes the degree of sets referring to their membership to certain dimensions.[2] Thereby Fuzzy sets are not presented as functions over a basic set but as a single point in a space whose dimensions correspond to the number of elements of the basic set. We can call these elements [x,y] "fuzzy units" (or "fits") that designate the degree of membership within a range of values (0,0 and 1,1) that is calculated by summing up the fits. The set of all of those data pairs is a quadrate with a side length of 1, and a point A within this quadrate is a fuzzy-set A [x,y].

By "mirroring at the central point of the quadrate" one can identify the set notA, i.e. if A [x,y] then notA [1-x,1-y]. With these two sets one can form the set union and the intersection of sets. The latter (A-and-notA) is formed by the minimum of the membership functions:

$$A \cap \bar{A} = (\min(x, x^{'}), \min(y, y^{'})) \tag{1.1}$$

And the set union of two sets is those set-point that describes the most widely rectangular extension of both sets:

$$A \cup \bar{A} = (\max(x, x^{'}), \max(y, y^{'})) \tag{1.2}$$

The set M is the fuzziest set of all sets wherein the known bivalent views loose their validity because the sets A and notA as well as A-and-notA and A-or-notA are identical here! This means that the central theorems of bivalent thinking and are not longer valid.

The subset characteristics of two sets must be "fuzziable" too. The fuzziness of those sets can be understood as entropy, that is, the degree of uncertainty or disorder in a system. A set describes a system of elements. If a set is fuzzy – elements belong to it only partially – this set is vague or indefinite to some degree too. Fuzzy logical entropy measures the ratio between and , that is, the relation of polyvalence to bivalence.[3]

$$E(A) = \frac{A \cap \bar{A}}{A \cup \bar{A}} \tag{1.4}$$

Fuzzy entropy has some major impact on how we understand and model social actors' decision-making.

[2] For further discussions see [24].

[3] Note that the degree of vagueness of a fuzzy set is defined by the similarity of a set and ist complement, therefore fuzzy entropy is identical to the degree of subsethood:

$$Sub(A \cup \bar{A}, A \cap \bar{A}) = \frac{\| (A \cup \bar{A}, A \cap \bar{A}) \|}{\| A \cup \bar{A} \|} = \frac{A \cap \bar{A}}{A \cup \bar{A}} \tag{1.3}$$

1.3 Action Theory

Actor theoretical approaches have to deal with the analytical problem of the so-called "definition of situation" [13], [14], p. 29ff, [63], p. 68, that is, how social actors reflect their selves in a given social situation. To form adequate "bridge hypotheses" [34] social scientist need a method to link an actor's "environment" (institutions, norms, values, communication, symbols etc.) to an actor's "personal setting" like internalised norms and values, identities, emotions etc. Fuzzy logic seems to be an appropriate method to formulate such hypotheses because it enables social scientists to model the link between situational parameters and the actor's personal settings while taking into account that social actors seldom interpret social situations in a perfect unambiguously way.

We discuss subjective expected utility theory (SEU-theory) (cf. amongst others [11], [12] to demonstrate that using Fuzzy logic to model the link between an actor's environment and an actor's personal settings leads to a more realistic model of how social actors define social situations (as real)[4] As a consequence Fuzzy logic enables social scientists to come close to the real process of decision-making in everyday life situations. According to SEU-theory social actors define their situations by considering alternatives of action, consequences of action, evaluations and costs. To model an actor's expectation (p) social scientists combine the parameters mentioned before. An expectation is defined, as estimation about what consequence will be realized if one chooses an action's alternative under empirically given situational conditions. Typically social scientists describe the process of how actors build up their expectations the same way like social actors do, namely by using linguistic terms. Linguistic terms, that is, vague phrases to describe the world, can be understood and modelled as fuzzy sets. Linguistic terms form a system of (social) rules to interpret the world. Thus systems of decision-making consist of if-then-rules that fit for the estimation of a system function. The more uncertain the rules are the wider are the faces that cover the function (see for illustration Fig. 1). In other words: expectations are (more or less) vague if-then-rules. These are e.g. heuristics ("rules of thumb") of decision-making that can be modelled with Fuzzy logic. Fuzzy logic in this case means deciding with imprecise data and imprecise sets [48], [58]. Thus Fuzzy logic allows to model complex contexts in which decision-making takes place easily. The technical expression for this is approximation. We all act in this manner while e.g. driving our car backwards, catching a ball or watching television. The advantage for sociology is: while using fuzzy-logic social scientists can simulate this dynamical "everyday approximation" in decision-making realistically and in an easy way without being forced to fall back on simplifying as-if-assumptions. Take for example the so-called bystander dilemma [9], [33], [31], [32], [51], [60]. The problem we face is why do actors in situations where their help is needed, e.g. a situation where one is attacked, act or just stand on the sidelines or even look the other way. How do actors take a stance on the situation? We take the example of the so-called emotional man [15] [59], p. 107ff as a typical social actor in such a situation. We hypothize, that the feel-

[4] "If men define situations as real, they are real in their consequences" [62], p. 572.

ing of endangerment has an impact on emotional man's decision. We state that there exist four alternative actions: (1) Helping, (2) Signalling his will to help, (3) Ignoring or (4) Leaving the situation. The consequences of action could be "feeling of safety" or "feeling of endangerment". For the sake of the argument we state that there exist two relevant situational parameters that influences the actors decision, namely the number of other actors who will help and the power of the person who attacks. We assume that the feeling of endangerment is reduced when the number of people who help the victim increases. The feeling of safety increases (or sinks) in accordance to the attacker's strength. An emotional man has to decide whether he is going to help, signalling his will to help, ignore or even leave the situation according to his estimation of how many people help and on his estimation about the attacker's strength. It is striking here that such estimations are fuzzy.[5]

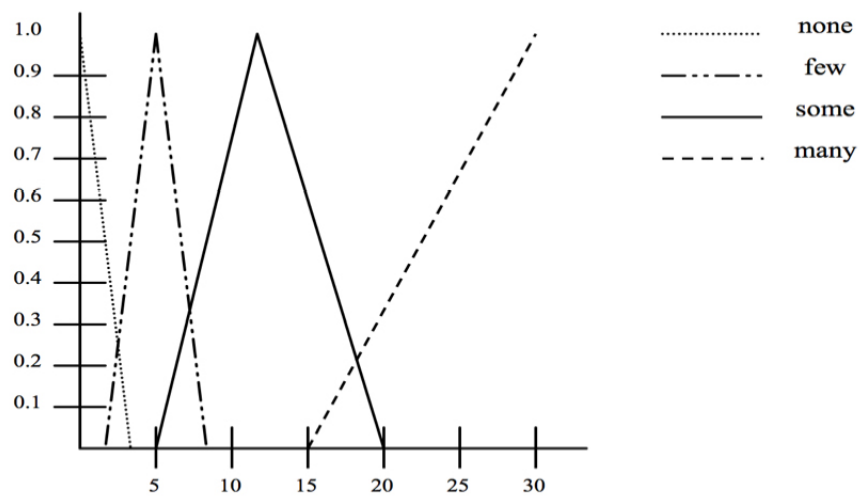

Fig. 1.2. Number of people

In a first step we define the relevant fuzzy sets and their value range to model these estimations (Fig.1.2, 1.3) as input variables of our fuzzy-decision-system. The output-variable "feeling of endangerment" is "fuzzified" as well (Fig.1.4).

[5] Even the estimation about how many people are helping right now or will help could be fuzzy not at least because exceptional circumstances do not allow "rational" precise evaluations of every relevant parameter.

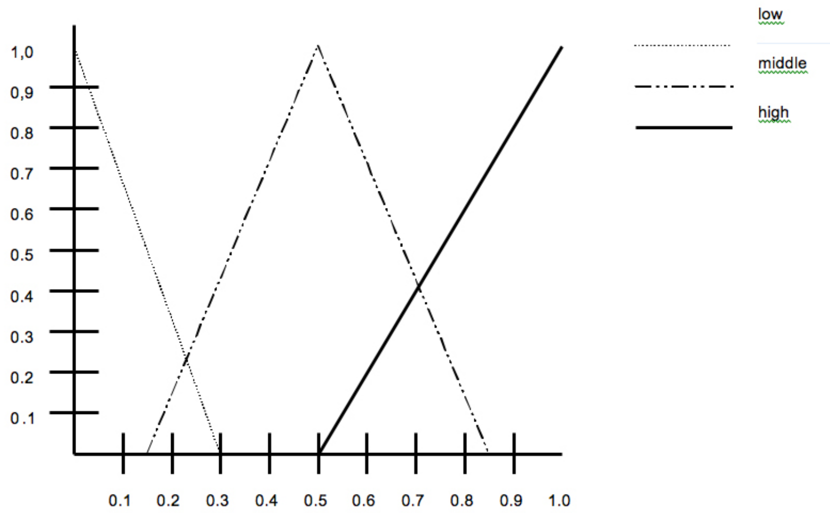

Fig. 1.3. Attacker's strength

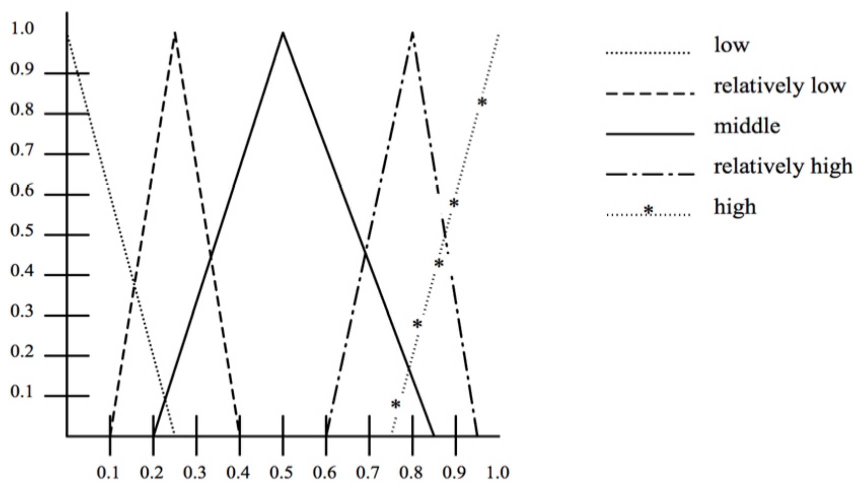

Fig. 1.4. Feeling of endangerment

Now we have to define bridge hypotheses to link the input-variables to the output-variable with the help of simple if-then-rules. In our example we need twelve rules to respect all relevant relations between the variables:

Table 1.1. If-then-rules

	Number of people	Attecker's Strength	Feeling of endangerment
1	none	low	relatively low
2	none	middle	relatively high
3	none	high	high
4	few	low	relatively low
5	few	middle	middle
6	few	high	relatively high
7	some	low	relatively low
8	some	middle	middle
9	some	high	relatively high
10	many	low	low
11	many	middle	relatively low
12	many	high	relatively high

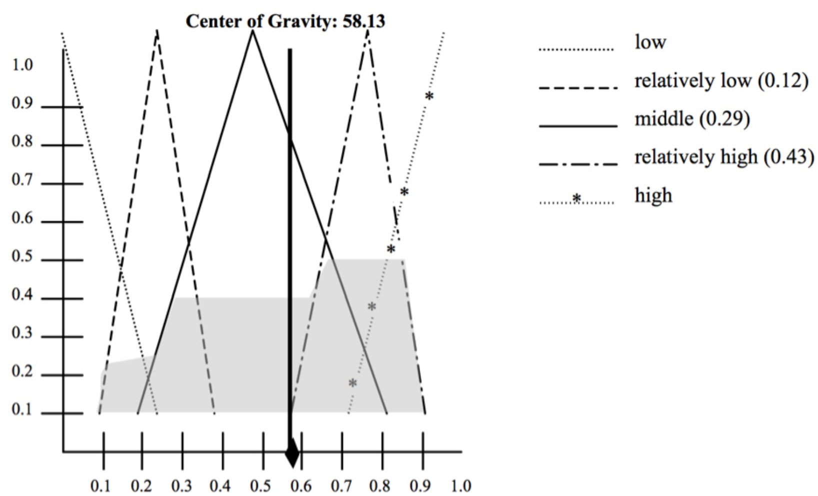

Fig. 1.5. Output "Feeling of endangerment"

For illustration we assume that an actor (emotional man) estimates that 15 other actors will help and that the attacker's strength seems to be quite high. As a result three fuzzy-output-sets (feeling of endangerment) are activated partially (Fig.1.5): relatively low feeling of endangerment is activated to the degree of 0.12, feeling of endangerment middle is activated to the degree of 0.29 and the Fuzzy set relatively high feeling of endangerment is activated to the degree of 0.43). In the end this leads to a feeling of endangerment of 58.31[6], that is, "our" actor expects (p) that he will realize a feeling of endangerment of about 58% if he engages in this situation.

To put it otherwise: all rules exert an effect parallel but only partially. This means that using fuzzy-logic enables social scientists to model overlaps of diverse vague and possible contradictorily expectations too. The result is a fuzzy-weighted average of different expectations. This output value can be displayed in a three-dimensional space (Fig. 1.6).

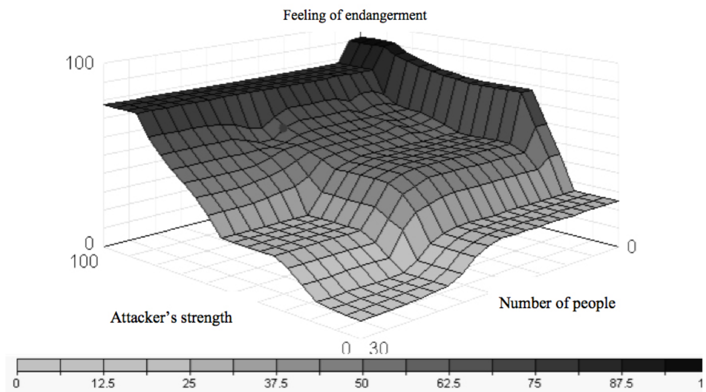

Fig. 1.6. Non-linear relations

It can be seen that such a fuzzy-system allows modelling even non-linear relations easily because every curve can be covered by fuzzy-faces. The broader the faces the less we know about the details of the problem of decision-making. More precision leads to smaller faces but with the consequence that we need more faces (= more information) to cover the curve. In boundary cases the face shrinks towards zero, i.e. we have a natural number and no fuzzy set anymore. But it is difficult to work with small triangles because they do not just loose their fuzziness but also loose their sociological meaning. Precision has its price. It is hard to produce the necessary precision for an explanation but it is eased inasmuch as fuzzy-logic is conformable with different methods of producing bridge hypotheses. And we are able to adjust the faces in such a way that fuzzy systems can model dynamical systems. Moreover Fuzzy logic advantages actor theory by considering an admeasurement of vagueness (ambiguity) in form of fuzzy entropy.[7] The ambiguity of an expectation as a Fuzzy

[6] We use the method of centre of gravity to calculate the output-value.

[7] Note that classical action theory focuses on risky decisions, uncertain decision and safe decisions although it is obvious that actors (most of the time) do not possess non-ambiguous expectations [14], p. 54ff. An actor is absolute uncertain if he is not able to possess any expectation value ($p = 0$). An actor is absolute certain if he possesses $p = 1$. Risky decision takes place if an actor possesses an expectation p between the range of 0 and 1. Ambiguity

set is its entropy, its expectation vagueness [27]. Within the framework of SEU theory we can now formalise the expected-utility-weight (EU) in respect of the actor's ambiguity of expectations: when an expectation p (as a fuzzy set) of an action alternative A has been calculated then it is possible to ascertain its complement as well as the union set and the intersection and therewith calculate the expectation vagueness EV(A). This admeasurement of vagueness can be considered in the calculation rule of expected-utility-weights:

$$EU_i = \sum (p_i - (EV_i \cdot p_i)) \cdot U_i \tag{1.5}$$

If fuzzy entropy is equal 1 (total ambiguity) the actor is totally vague about his or her expectation whatever his/her expectation is based on. The expected-utility-weights are zero. Only if the actor is absolute certain about its expectation (no ambiguity) the common view of SEU theory applies. All values in-between the range of 0 and 1 reduce the expected-utility-weight of the action alternative accordingly. It is possible to derive the expectation vagueness EV from the output-fuzzy-set and to enter it into the formula for utility-expectation-weights of the single alternatives of action. For that purpose we assume that the wider the faces that represent expectations as Fuzzy sets the higher the vagueness of expectation. And: the higher the degree of membership the more this vagueness applies (the more this vagueness is imposed). Thus the expectation vagueness EV can be calculated using the following formula:

$$\text{Expectation Vagueness} EV = face \cdot \sqrt{basiclength} \tag{1.6}$$

In the example given above this would lead to an expectation vagueness of about 22,6%:

$$EU(Helping) = (0.58 \cdot (1 - 0.226)) \cdot U_{Helping} = 0.44892 \cdot U_{Helping} \tag{1.7}$$

In this case expectation vagueness leads to a reduction of the original expectation p about 13% because of the actor's ambiguity in respect of the parameters "attacker's strength" and "number of people who help".

To sum up: Fuzzy logic enables sociologist to formulate bridge hypotheses to model the definition of situation in an easy and realistic way. One major advantage of using Fuzzy logic is that Fuzzy logic refers to differences in kind (i.e. qualitative dimension) as well as to differences in degree of membership (i.e. quantitative dimension) at the same time. The derivation of bridge hypothesis with the help of Fuzzy logic gives social scientists one method at hand to specify the logic of social situations and to describe the parameter for the logic of action-selection in one step. Bridge hypotheses are formulated as if-then-statements. Thus they do not only refer to the estimation of consequences of action but also consider the environmental parameters actors attach importance too. Fuzzy logic is a very useful tool to model

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instead means that an actor is even uncertain about his expectations, that is, he is fuzzy in his expectations.

the relations between situational parameters and actors' orientations because social, symbolized relational patterns are not ascertainable by the interpretation of detailed situational information (crisp set of information), but only few information (fuzzy set of information) are sufficient to recognize and define the social situation. In addition: the fact, that social actors combine situational parameters to a certain pattern that represents the definition of the situation not in every detail but on the basis of more or less vague representations, leads to the idea of "vague pattern matching" that goes beyond detailed reflection of single framing-processes.[8]

1.4 Considering fuzziness in the study of social systems

Although Niklas Luhmann [43], p. 904ff has criticized bivalent thinking in classical Aristotelian logics it is obvious that his conception of social systems idealizes bivalence on the operational level of social systems [27], [30].[9] Surprisingly, only few have yet recognized or even scrutinized the two-valued operational logic of social systems [7], [45], [46], [47]. The two-valued operational logic of social systems is founded in the central distinction between system and environment, which is as Luhmann [38], p. 94 stated inherently problematic because the distinction itself has to be distinguished in a first step. According to George Spencer-Brown [61] observers have to draw a distinction; every observation has to distinguish and designate, that is, distinguishes two sides of the form and designates one side for further observations. The observer functions as the tertium non datur which cannot be observed simultaneously while observation takes place [43], p. 62, 69). Therefore observation has to blind out (have to make invisible) the fundamental paradox that every observation as a form has a different form as a prerequisite, which cannot be distinguished but via a new form of observation. To put it straightforward: if two sides of the form are distinguished one cannot observe the difference without designating one side because otherwise the different values would be observed as equal values [38], p. 80, [39], p. 201. Therefore three modes exist to cope with the paradox of observation [39], p. 201f: factually, if one observes he has to follow the imperative "draw a distinction"; temporarily, if one observes he has to proceed consecutively, that is, observation always affiliates on one side of the distinction but can change the sides in time; socially, one can observe what others observe while reflecting different forms of observation - this is the idea of second order observation. The latter leads over to a critical reflection of Aristotelian bivalent logic. In accordance with Gotthard Günther [18], [19], [20] Luhmann agues that Aristotelian bivalent logic reflects the ontological difference between being and non-being which leads to the idea of the excluded middle: boundaries, caesurae, everything in-between belongs to the non-being, to the realm

[8] Thus frame analysis [16] is a branch of fuzzy pattern thinking for social actors as well as for social scientist.

[9] This is getting obvious in the following citation: "A woman may be pregnant or not: she cannot be a little pregnant. This is true of course for 'system maintenance' as well" [36] , p. 183.

of the ontologically excluded middle [43], p. 905. In a constructivist fashion Luhmann [40], [44] denies the ability to achieve knowledge about how the world really is: we have to abstain form the very idea that we could achieve knowledge of an unobservable and unobserved world, therefore we have to take into account the observer and ask for how does an observer construe identities [43], p. 767. The answer is straightforward: identities come into being while systems operate autopoetically and generate the elements that they need to sustain identity. For that background social systems could be best understood as a recursive network of observations. Or, to put it slightly different: social systems are themselves observers. While observing, that is, affiliating observations to observations, social systems generate eigenvalues that allow specifying which elements belong to the system and allow manifesting the identity of the system in difference to the system's environment [43], p. 60ff. In that sense binary coding functions as a contrast or crispy set [36], p. 91 that assign what belongs to one or the other value [37], p. 76f, [42]. Because binary coding could be easily institutionalized and practically handled, not at least because binary coding reduces complexity rapidly, they enable the system to operate unambiguously in an enormous complex environment [41], p. 177f. To conclude: although Luhmann criticizes classical Aristotelian bivalent logic because it lacks a reference to the tertium non datur of observation, that is: the observer, he does not criticizes bivalence per se. Contrariwise bivalence is the fundamental operational principle of social systems. And this is, as [43], p. 1113 stated, neither a criticism nor a factual statement but just a confession: to observe means to distinguish and to designate otherwise observation could not be possible. But what if the fundamental operations of the social do not follow any bivalent principle? Following Niklas Luhmann [35], [43] the fundamental operations of social systems are communications. Communication is defined as the synthesis of three selections: information, message and understanding [35], p. 92ff. Without going into depth this needs some clarifying remarks. Communication is not understood as an intentional act. Communication therefore has not to be taken as a way of transporting information form on system to another system. Instead, communication has to be analyzed "the other way around", that is, communication has taken place when understanding takes place. Understanding distinguishes information and message as distinct selections. Therefore communication permanently oscillates between information (as information) and message (as information), that is, understanding distinguishes information and message and designates on side of the form for subsequent communications. Imagine for example a bouquet of red roses as a form of communication. Despite what a (fictional) husband has in mind when he is going to present the bouquet of red roses to his wife it is possible that his wife does not understand the gift as a love symbol but as a sign that something (maybe a liaison) gnaws at her husband's conscience. In this case the message becomes informative. One can easily imagine how the communication will proceed in that case. The argument here is that communication is inherently ambivalent because it is in principle possible to take the message as information [1], p. 54ff. But, despite the permanent ambivalent character of communication, what if information and message become liquid in the sense, that the difference is amenable for several interpretations, that is, communication is ambiguous. Colin B. Grant [17] asks in that case for a revision of the communicational components of Luhmann's systems theory. Grant argues that one has always to consider that communication is supplied with contingencies and uncertainties. As Hempel [21], p. 170 states: "the terms of our language in scientific as well as in everyday use, are not completely precise, but exhibit a more or less high degree of vagueness." If communication is inherently vague, this also will be the case of systems that rely on communication. "Thus it follows that systems . . . are porous in their communication" [17], p. 224). Luhmann instead overemphasis the stability of social systems and neglected the vagueness of communication. Although there are reasons to assume that in some cases binary coded schemes to orientate communication really exist, "it can also be said that binary codes . . . and schematisms are in themselves porous" [17], p. 225f. This leads to the conclusion that "if communication is uncertain, this resolution is permanently polysemic" [17], p. 226. Therefore one has to consider fuzziness in the study of social systems; as already mentioned, non-ambiguous communication is possible but could be taken as an exception that proves the rule. Two kinds of vagueness have to be considered in the analysis of fuzzy systems. First, one has to consider the vagueness concerning the binary coding of social systems, that is, not every communicational event can be assigned to one value of the code unambiguously - this kind of vagueness should be termed vagueness of coding. Second, and as a result of the first vagueness, not every communicational event belongs to a system clearly but could cross the system-environment-boundary and therefore could belong to different systems simultaneously – this kind of vagueness is termed: vagueness of affiliation.

1.4.1 Vagueness of coding

Vagueness of coding addresses the fact that communications sometimes cannot be located in a binary coded scheme unambiguously. For example, it seems to be an idealized assumption that the code of the legal system (legal/illegal) [41] always enables an observer to decide what is right or wrong. Using Fuzzy logic as a modelling tool the distinction between legal and illegal can be best understood as crisp sets of the legal system designating two points of a continuous spectrum that "measures" what kind of communication could count as legal or illegal in degree. This continuous spectrum of "legal and illegal communications" consists of several values in between the two crisp sets of legal or illegal communications. This could be called the systemic set-triangular of vague coding.

A communicational event that is located in between the two crisp sets can be called fuzzy unit or fit. Those fuzzy units can be interpreted as the degree a communication belonging to the crisp set values of legal and illegal communication and can be measured easily by summing up the fits. The centre of the continuous straight line connecting the crisp sets of legal and illegal communication can then be interpreted as the most fuzziness form of communication that is legal as well as illegal. To calculate the measure of fuzziness we use the idea of fuzzy entropy (Fig.1.8). If a set is fuzzy, that is, elements do belong to this set partially, the set is fuzzy to some degree. Fuzzy entropy is calculated as the quotient of the distances d between a communicational event A located on s and the crisp sets (1,0 , 0,1) in percentage.

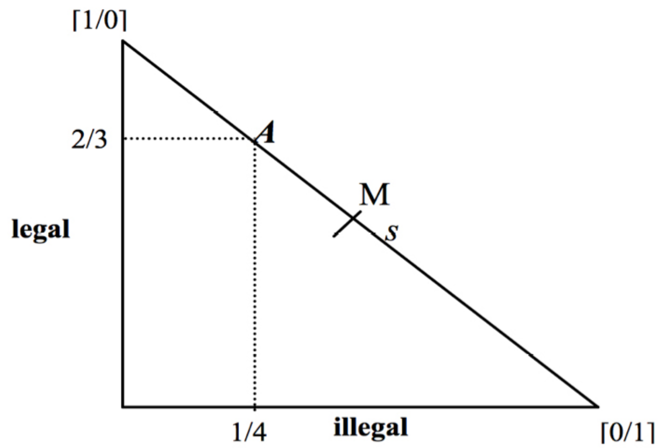

Fig. 1.7. Systemic set-triangular of vague coding

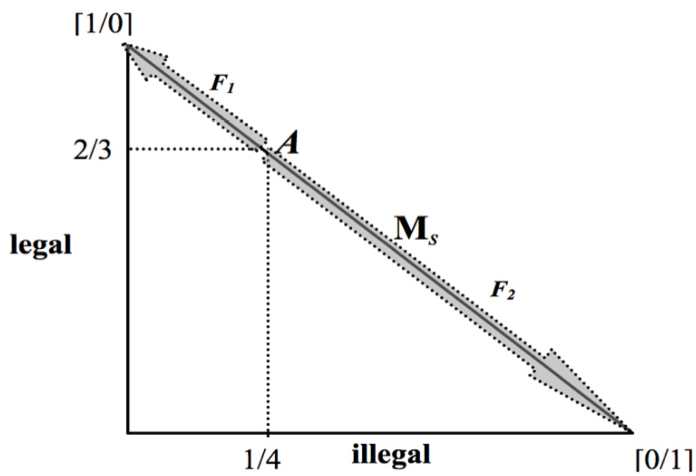

Fig. 1.8. Entropy of Coding

The more a communicational event belongs to one of the crisp sets the less vague it is:

$$\text{Vagueness of coding} : \frac{d_A \to [1,0]}{d_A \to [0,1]} \tag{1.8}$$

The highest degree of vagueness can be measured if a communicational event is located in the centre of *s*: $Entropy_A = \frac{0.5}{0.5} = 1$

One can now imagine easily what would be the case if communication becomes fuzzy: social systems cannot longer place communication unambiguously and thus are not longer able to reproduce the clear distinction between the two values of the code. The code itself becomes vague and at least the distinction between system and environment is becoming porous. But this does not mean necessarily that binary coded schemes will erode completely. Binary coding still functions as a horizon that orientates communication: the systems code is still in place while the idea of bivalent operational logic is dismissed.

1.4.2 Vagueness of affiliation

Taking into account that communications can cross the system-environment-distinction, not at least because the code itself can erode in cases where communication cannot longer be located unambiguously, it is striking here that one has to consider communicational events that could belong to the system as well as to the system's environment. If communication is vague system-environment-distinction will be vague too. A communication that belongs to a system's environment unambiguously is considered to be an element of a blank set. That means a communication that does not belong to a system is defined negatively through exclusion 0/0 .

On the contrary, a communication belonging to a system is defined through the degree of affiliation. Taking into account that a communicational event does not necessarily belong to the values of the code but could vary in the degree of affiliation, it follows that this communication is not a clearly defined element of the system. As pictured in Fig. 1.9 a communicational event A just belongs to the system gradually. This could be interpreted as vagueness of affiliation. The vagueness of affiliation could also be calculated as fuzzy entropy but now measured as the quotient of the distance between A to s and the distance of A to the blank set [0,0].

$$\text{Vagueness of affiliation} : A = \frac{d_A \rightarrow s}{d_A \rightarrow [0,0]} \tag{1.9}$$

It is now getting obvious that the vagueness of affiliation necessarily implies vagueness of coding because every time the degree of affiliation becomes fuzzy it is not clear how the communication can be placed relative to the code values, that is, communication belongs to both value sets of the code to some degree. This leads over to the idea of system's interpenetration. According to [49], p. 14 – and in contrast to [35], p. 286ff – interpenetration addresses the fact that elements could belong to different systems simultaneously. Thus it is untenable to state that elements are either elements of one or another system. Taking vagueness of affiliation seriously it is striking here that communications could belong to one system as well as to another system partially (Fig.1.10).[10]

[10] Surprisingly even Luhmann [43], p. 775 assumes that under the conditions of functional differentiation a multiplicity of communication exists which cannot be located exclusively

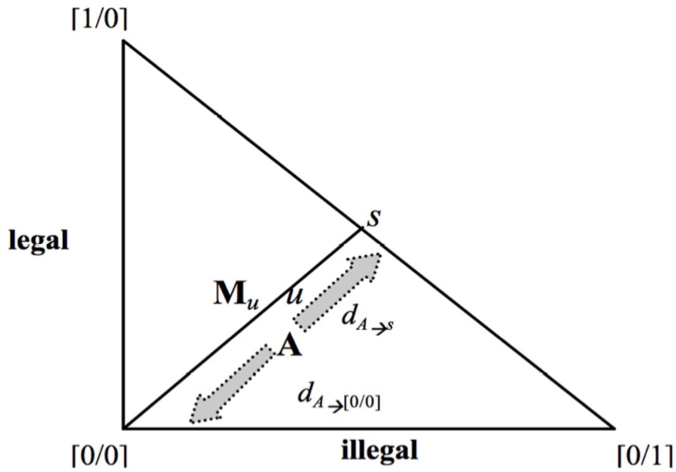

Fig. 1.9. Vagueness of affiliation (System's Entropy)

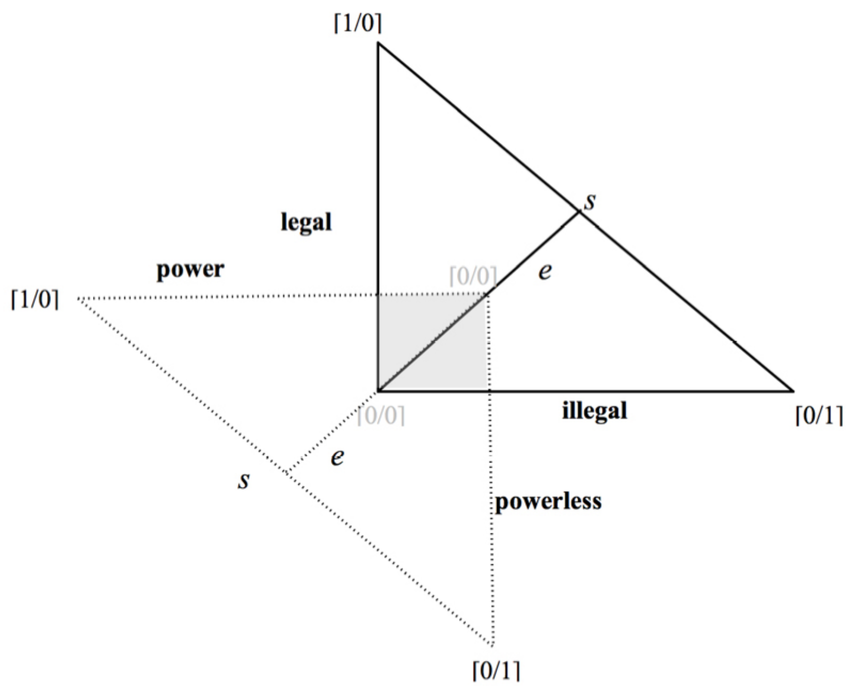

Fig. 1.10. Systems interpenetration

belonging to one system. This is a characteristic of modern society. But instead taking vagueness of affiliation seriously Luhmann argues that vagueness is reduced in time.

Fuzzy logic allows overcoming bivalent thinking in systems theory. Instead of overemphasizing bivalence as a criterion of social systems' stability, fuzzy thinking forces social scientists to have an eye for vague, imprecise communicational processes within social systems and thus sensitize an observer for (social) mechanisms that allow dealing with social fuzziness. Actual Ulrich Beck is one prominent sociologist who emphasizes fuzzy thinking in modernization theory.

1.5 Fuzzy Thinking in Modernization theory

The so-called Theory of Reflexive Modernity by Ulrich Beck [4] emphasizes the need to think in terms of as well as instead of either-or. Straightforwardly speaking, Beck claims - in order to analyze second modernity – for the need of fuzzy thinking in social sciences. The idea of second modernity addresses the fact that institutional settings of first modernity are not longer adequate to deal with the unintended consequences generated by industrial societies and their undamped growth [2]. Second modernity is characterized by social phenomena that do not longer fit in well-defined categories with sharp boundaries. Contrariwise social phenomena of second modernity possess characteristics that correspond to the "new" worldview of Fuzzy logics, namely, that social phenomenon sometimes possess polar characteristics but most of the time do not. Therefore Ulrich Beck [3] claims for a new method of theorizing modern society - methodological cosmopolitism. Methodological nationalism on the contrary perfectly fits in the old institutional setting of first modernity but is nowadays nothing more than anachronistic way of thinking; the logic of methodological nationalism is bivalent in the sense that the categories are well defined and clear-cut, thus methodological nationalism is characterized by dualistic and antagonistic concepts like friend vs. enemy, us vs. them, for us vs. against us. This way of thinking in terms of black and white (good and evil) will fail in the light of second modernity.[11] Thus methodological cosmopolitism takes social fuzziness seriously like in the case of transnational terrorism. The war on terrorism for example fits the needs of traditional institutional settings but is inadequate to deal with new forms of terrorism not at least because there is no country on which war could be declared. Several other dualistic and antagonistic concepts fall short for characterising transnational terrorism as well: e.g., Al-Qaida's ideology is modern and anti-modern, Al-Qaida operates local and global and not at least Al-Qaida is afar and close to its enemies [28]. In short: adequate theorizing of social phenomena needs fuzzy thinking and at least Fuzzy logic as an appropriate tool to model social phenomena.[12] This applies to social research methodologies too.

[11] For example [3] states that *war is peace*.

[12] It is obvious that the idea and model of fuzzy systems is a first step in the right direction. If well-defined and clear-cut social categories do not longer fit the "empirical world" we need a way to think, theorize and model how social systems and social agents proceed in a fuzzy environment.

1.6 Fuzziness in social research

The surplus of Fuzzy logic for the social research was early recognized by Charles Ragin [54], [55], [56], [50]. Charles Ragin advanced traditional Qualitative Comparative Analysis [53], [5], [6] in macro-sociological studies using fuzzy-logical operations to include diversity of kind and diversity of membership degree in configurational analysis of social causal factors. Qualitative Comparative Analysis, generally speaking, aims at identifying necessary and/or sufficient (configurations of) causal factors for a social outcome[13]. Those prime implicants, as Ragin calls them, are common (configurations of) causal factors of a certain group of social cases in regard to a certain social outcome. Prime implicants "explain" how social causes combine to generate a specific social effect. Cases are understood as configurations of variables. Those variables are interpreted as factors that lead to an outcome. The comparison of cases as configuration of factors in regard of an specific outcome (diversity of kind) and their fuzzy membership to those configurational sets of factors (diversity of degree) results in parsimonious explanations that deal with as much complexity as required by sociology but at the same time are simple enough to explain the social effect sufficiently [57]. Because social diversity is complex, comparative analysis often results in different causal paths that generate the same social effect. For classical research strategies (especially quantitative social research) this might seem to be a disadvantage as long as science is looking for causal laws of hard facts. But, as we already stated in the beginning, the realm of the social is not governed by hard facts, therefore there is a need for a method that allows considering diversity and complexity without given up the idea that diverse, complex cases could be explained even if they are fuzzy. To conclude: Formal logic and linguistic formulations converge in Fuzzy logic. The specification of variables and degrees of membership is theoretically and empirically instructed. Thus Fuzzy Set Social Sciences [54] provides an interpretative tool that forces social scientist to bring together theory, empirical evidence and formal logic in one research strategy while considering diversity and complexity of the social realm.

1.7 Conclusion

We gave a brief outline of the usefulness of Fuzzy logic for different branches of sociology. We focused on action theory and social systems theory as two important candidates for fuzzy thinking. The advantages are at hand: Fuzzy logic closes the gab between real-life decision-making in everyday life and traditional models of decision-making (e.g. SEU theory) while taking seriously that a social actor seldom calculates his actions on the basis of precise, sharp, unambiguous expectation. Contrariwise social actors decide on the basis of vague representations of social situations and on basis of vague expectations. Fuzzy thinking in social systems theory considers imprecise and vague communications as well as vague distinctions or

[13] John Stuart Mill speaks of *chemical causation*.

rather imprecise differences. This leads to the idea of fuzzy systems characterized by vague system-environment distinctions, vague code-differences and vague communicational tokens. The social realm is inherently vague, therefore there is a need for fuzzy thinking. Especially modernization theory could benefit from fuzzy thinking in the long run. Nowadays it seems already unimaginable to do macro-sociological comparative research without Fuzzy logic.

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