LANDFORMS AND ENVIRONMENTAL PLANNING: POTENTIALITIES AND FRAGILITIES

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Abstract: *The relief analysis focused on the geomorphologic application in environmental projects has been developed for some years with the prospect of having a better knowledge of natural environment characteristics in face to the environmental territory planning projects. The theoretic and methodological approach used in these geomorphology-applied projects is based on General System Theory with emphasis on Tricart (1977, 1992), when concepts and theorizes about the ecodynamics processes and ecogeographic assumptions. In the core of this systemic approach, the methodology also includes Ab'Saber (1969), Mecerjakov e Gerasimov (1968) and Ross (1992, 1994, 2006). Considering these authors as theoretic and methodological, it was developed a geomorphologic map and the potentiality and fragility environmental maps. The second product, consists of the environmental potentialities and fragilities, In this context, it reaches a set of environmental units or landscapes, due to the combination of variables from natural environment. In each one of these sets are established several levels or degrees of environmental fragilities according to the theory and methodology used. From which is also evaluated the potential of natural environments. The environmental fragilities identified in the mapping process are classified into a hierarchy, since too weak fragilities, therefore, high potentialities for various uses, to very strong fragilities and low potential for productive uses, but very high environmental and ecological interests. So is these geomorphologic mapping joined with their derivatives, fragility and potentiality environmental are extremely interesting for application to territory environmental planning projects from different scales.*

Key-words: *geomorphologic mapping, fragility, potentiality, environmental planning.*

Resumo: *A análise do relevo voltada para a aplicação geomorfológica vem sendo desenvolvida a alguns anos com a perspectiva de se ter um melhor conhecimento das características do meio natural face aos projetos de planejamento ambiental territorial. A concepção teórica-metodológica empregada nesses projetos de geomorfologia aplicada é baseada na teoria geral dos sistemas com ênfase em Tricart (1977,1992), quando conceitua e teoriza sobre os processos ecodinâmicos e pressupostos ecogeográficos. No bojo desta abordagem sistêmica a metodologia ainda recorre a Ab´Saber (1969), Gerasimov e Mecerjakov (1968) e Ross (1992, 1994, 2006). Tomando-se esses autores como suporte teórico, metodológico e técnico desenvolveu-se uma estruturação de trabalho de pesquisa onde o principal produto técnico são os mapas temáticos de apoio à geração do mapa geomorfológico de síntese e o mapa de fragilidades e potencialidades ambientais. Como primeiro produto da pesquisa, procurou-se aplicar a taxonomia do relevo, desenvolvida por Ross (1990 e 1992). O segundo produto, constitui-se no mapa de potencialidades e fragilidades ambientais. As fragilidades ambientais identificadas no processo de mapeamento são classificadas em hierarquia das de fragilidades muito baixas e portanto com elevado potencial de usos diversos à as fragilidades muito altas e com baixos potenciais de usos produtivos, mas de elevado interesse ambiental/ecológico. Conclui-se que, esses mapeamentos geomorfológicos acompanhados de seus derivados, os mapas de fragilidades*

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e potencialidades ambientais, são de extremo interesse para a aplicação aos projetos de planejamento territorial ambiental de diferentes escalas e direcionados, sobretudo para os zoneamentos ambientais e estabelecimentos de unidades de conservação ambiental e de preservação ecológica.

Palavras-chave: *mapeamento geomorfológico, fragilidades, potencialidades, planejamento ambiental*

The relief analysis focused on the geomorphologic application in environmental projects has been developed for some years with the prospect of having a better knowledge of natural environment characteristics in face to the environmental territory planning projects.

In this context the geomorphologic researches with the purpose of developing relief shapes maps are dependent on cartographic scales applied in the study. Depending on the scale of mapping that is being used, it is necessary to define what sizes of landforms will be represented, as well as, what techniques should be applied to obtain the best results for identifying the environment potentialities and fragilities for the different interests to be used or not by society.

The theoretic and methodological approach used in these geomorphology-applied projects is based on General System Theory with emphasis on Tricart (1977, 1992), when concepts and theorizes about the ecodynamics processes and ecogeographic assumptions. In the core of this systemic approach, the methodology also includes Ab'Saber (1969), Mecerjakov e Gerasimov (1968) and Ross (1992, 1994, 2006).

Considering these authors as theoretic, methodological and technical support, it was developed a structured work research where the main technical product is the thematic map that is used to help in generating synthesis geomorphologic map and the potentiality and fragility environmental maps.As the first product of this research, it was tried to apply the taxonomy of relief, developed by Ross (1990 and 1992) as a starting point for geomorphologic analysis and generation of geomorphologic map with integrated legend, where the relief shapes are pointed with their morphologic and morphometric characteristics associated with materials that support them as relating to lithological structure as the pedologic coverage. So, there is a map with legend from the morphostructural units representing the major forms and increasing according to the scale to other taxons, or better, morphosculptures, types of relief, landforms, types of slopes and recent shapes of current anthropic induction.

The second product, derived from the first, consists of the environmental potentialities and fragilities, which have been applied to the methodology and technical-operational procedures developed on several works attempting to combine the morphologic, morphometric and ecodynamics information with the characteristics of covering materials such as soils and deposits of superficial materials and support materials as the diversity of lithologies and their structural arrangements, as well, the rainfall dynamics during the year. In this context, it reaches a set of environmental units or landscapes, due to the combination of variables from natural environment. In each one of these sets are established several levels or degrees of environmental fragilities according to the theory and methodology used. From which is also evaluated the potential of natural environments, due to diversity of potential uses of the territory which is object of analysis. The environmental fragilities identified in the mapping process are classified into a hierarchy, since too weak fragilities, therefore, high potentialities for various uses, to very strong fragilities and low potential for productive uses, but very high environmental and ecological interests.

So is these geomorphologic mapping joined with their derivatives, fragility and potentiality environmental are extremely interesting for application to territory environmental planning projects from different scales and are directed mainly to the environmental zoning and for establishing the conservation of environmental units and ecological preservation.

INTRODUCTION

The understanding about relief and its dynamics passes through the understanding of the functioning and interrelationship among the other natural ingredients (water, soil, sub-soil, climate and vegetation cover). This way of understanding the relief forms is a significant interest for the physical and territorial planning. This planning with environmental-territorial bias should take into account the resource potentialities and the fragilities of the natural environment, combining with the technological and socio-cultural conditions.

In geomorphology researches a fact that must always be on alert is that the relief forms of different sizes have genetic explanation and are interrelated and interdependent of other nature components. The land surface, which is made up of landforms from different sizes or taxon from different ages and different genetic processes. It is also dynamic, even though human eyes can’t capture it. The dynamics of land forms represent different speeds, being sometimes more stable and sometimes unstable. This behavior depends on natural factors and also the interference of human being.

In this paper, the basic concern is to put into evidence that the execution of technical studies of geomorphologic character engaged into social-economic and environmental issues planning with the use of remote sensors images and the systematic field control which presents social utility. For this reason, the main aim is the generation of geomorphologic maps with integrated subtitles, that allows direct reading, and which product subsidizes environmental planning in physical land spaces of different sizes.

Theoretical and Methodological Basis

The theoretical and methodological approaches which apply to work the geomorphologic research have their roots in the design by Walter Penck (1953) that defined clearly the driving forces of terrestrial landforms, or better, the driving forces from the antagonism of endogenous and exogenous processes. The endogenous forces that fall through the active processes, driven by the Earth's crust and the oceanic dynamics and by lithology erode resistance and its structural arrangement that provides the action of exogenous or climatic processes. In this case a passive action is constant, however unequal, in the face of greater or lesser degree of lithology resistance.

The exogenous action is also constant, as well as differential, both in space and time, in view of local, regional and zonal climatic characteristics and climate changes by over the time. The process of weathering, erosion and transport is made by both mechanical action of water, wind, thermal variation and the chemical action of water, which changes primary minerals into secondary minerals and simultaneously carves the forms of relief.

Based on theoretical principle of the endogenous and exogenous processes as generators of large, medium and small terrestrial relief, Gerasimov (1946) and Mecerjakov (1968), developed the concepts of morphstructure and morphsculpture. The morphsculptural units are products of recent climate action, and also of past climates. They also reflect the influence of diversity resistance the lithology, and its respective structural arrangement, on which was carved. Thus, in a given morphstructural unit, which reflects the lithological diversity, climate types that happened in the past and those that happens nowadays, they can carve some varieties of morphsculptures. For example: a morphstructural large sedimentary basin, where one can find several morphsculpture units. Based on the genetic interpretation, there are two levels of understanding: the first taxon that is characterized by morphstructural of the sedimentary basin, which structural characteristics define a particular pattern of large relief forms, the second taxon is related to the morphsculpture units generated by the climate action over geological time, in the center of this morphstructure. In this morphstructural unit is possible to find peripheral depressions, inclined depressions, plateaus and flat surfaces, summit residue plateau among others. The third taxon (of a smaller size) refers to the Standard Units of Relief Forms, or Relief Types or just Forms, that is where recent morphclimatic processes can be more easily noticed. These Standards of the Similar Forms of Relief are collections of lesser forms of relief, which presenting the distinct appearance among themselves according to the topographic roughness or dissection index of relief, as well as, the shape of the tops, slopes and valleys of each existing standard. It’s possible to have several Units of Relief types or modalities of Standards of Relief Forms to each unit Morphsculptural. The landforms in each individual unit Types of Relief correspond to the fourth taxon in descending order. The landforms in this category are either such as the degradation of the river plains, river or marine terraces, marine plains, lake plains among others; or those resulting from weathering erosion, such as hills, mountains, ridges, cliffs, erosion levels, among others. Thus a unit of Standards of Relief Forms is composed by a large number of relief forms from the fourth taxon.

The fifth taxon in descending order is the slopes or sectors of slopes belonging to each of the individual forms of relief. The slopes of each type of shape are genetically distinct and each one of these slopes sectors is also different. These sectors may have various inclinations that also help to define their characteristics.

The sixth taxon, correspond to the smaller forms produced by current erosion process or current deposits. Those examples are collapse caused by hollow waters, ravines, land-slides marks, recent banks sedimentation, silting, cattle trampling terrace, products of current morph genetic processes and often induced by humans. It may also be mentioned anthropogenic forms such as cuts, embankments, land-slides of hill among others.

The geomorphologic maps should follow the rules of the International Geographical Union, that is: the maps should represent the geomorphic landforms in morphology (morphography), morphometric, morphogenetic and morphochronological. A fact of great complexity is to distinguish the representation levels of geomorphic events depending on the size and scale of their chosen representation.

Fragility and Potentiality of Land Forms

Integrated studies of a given area require an understanding about the dynamic function of the natural environment with or without the human intervention. Because of all the environmental problems of predatory economic practices that have marked the humanity history, it becomes the Physical Planning Territorial even more necessary, not only under economic and social prospect but also environmental. This way, the concern of planners, politicians and society as a whole, exceeds the limits from economic and technological development benefits, but also must be concerned with the development that takes into account the resource potentialities and especially the environment fragilities. In that prospect of economic planning and environmental territory planning, being in the municipal district, state, national, watershed, or any other unit, it is absolutely necessary that human interventions are planned with clear aims for territory arranging.

The functionality of natural environments, as well as, those changed by human actions is driven by solar energy through the atmosphere, hydrosphere and the earth energies that discloses itself in the lithosphere (reliefs - soil - rocks). The frequent exchanges of energy and matter that is processed inside in these great masses, combined with the presence of water in its three physical states, allows the existence of plant and animal life on the planet.

Grigoriev (1968) defines these interactions as the "Geographic Stratum of the Earth" that is, a narrow strip between the top lithosphere and the lower atmosphere which corresponding to the environment that allows the existence of human being as a biological and social entity, as well as other biotic nature elements.

The different natural environments found on the earth surface, which resulting from different exchange of energy and matter between the components are known in the theory of systems such as ecosystems in the biological concept and as geosystem as a geographical concept. In these approaches, where the energy exchange relations are absolutely interdependent, it is not possible to understand the dynamics and genesis of soils without knowing the climate, the relief, the lithology and their structural arrangements, or even, the analysis of fauna without associating it with the flora that gives its support, for its turn can't be understood without knowing about climate, the water dynamics, the soil types and so on. In geographic perspective, human societies can't be treated as strange nature elements and therefore to environmental systems or geosystems where they live. On the contrary, they must be seen as a key part of this dynamic, represented by the energy flows that make the whole system works. However, the progressive changes inserted by human societies in different natural components, increasingly affect the functionality of the system and often lead to serious degenerative processes to natural environment. In this context is essential that the human inserts are compatible, by one side with the potential of resources, and other side with environment weaknesses.

The knowledge about potentialities of natural resources has been a constant practice on researches in the field of earth science. These practices include field surveys, laboratory analysis and thematic mapping of: soils, topography, rocks and minerals, water, climate, flora and fauna, and finally all the components of the geographic stratum that support wildlife and human life. To analyze the weakness, however, two principles are essential. First, that sectored knowledge must be understood in an integrated way, always based on the principle that nature has intrinsic feature of its physical and biotic components. Secondly that each identified environment (geosystem, environmental system, landscape unit), besides their potentialities, they also presents weaknesses. These weaknesses under human interventions destabilize the functionality of the system environment.

The fragilities of natural environments can be applied based on the concept of Ecodynamics Units recommended by Tricart (1977), who defends that ecologic environment is analyzed under the feature of Systems Theory that assumes the exchanges of energy and matter in nature occurs by a dynamic balance relation. This balance is often changed by human intervention in various parts of nature, creating a temporary or even permanent state of imbalances. Thus Tricart (op cit) defined that the environments where they are in dynamic equilibrium are stable, when imbalances are unstable. These concepts were used by Ross (1990), in an opportunity to set new criteria to define Stable Ecodynamics Units and Unstable Ecodynamics Units. Unstable Ecodynamics Units were defined as those whose human intervention changed the natural environment intensely through deforestation and practices of various economic activities, while Stable Ecodynamics are the units that are in dynamic balance and were spared from human action, therefore are in its natural state, such as a forest of natural vegetation. For these concepts could be used as a subsidy to the Environmental Planning, Ross (op cit), expanded the use of the concept, establishing Unstable Ecodynamics Units or Emergent Instability in various degrees: since a Very Weak Instability to a Very Strong. He applied the same for Stable Ecodynamics Units, which despite of being in a dynamic balance, they present Potential Instability quite foreseeable in face their natural characteristics and always possible anthropogenic inclusion. Thus Stable Ecodynamics Units, present themselves as Potential Instability Ecodynamics Units in different degrees, or better from Very Weak to Very Strong.

Basis for Environmental Analysis of Fragilities

The empirical analysis of fragility requires basic studies of relief, rock, soil, land use and climate. Studies must be done from field surveys, with the staff services, from which are generate thematic cartographic products of geomorphology, geology, pedology, climatology, water and use of land vegetation and fauna. These thematic products are accompanied by synthetic technical reports. Thus the study of soils is proper, by one hand, for estimation of agricultural potentialities (agricultural suitability or usability), by other hand, it subsidizes the environment fragility analysis in face to human activities linked to agriculture and stock farming. The geological surveys are basic to understanding the relation of relief/soil/rock, with weather information, especially rainfall (intensity, volume, duration). They are also proper to evaluate the potentialities and fragilities of natural environments, like as roughness of the topographic relief (rates of dissection) and declivity of the slopes, as well as, surveys of land use types, soil handling for agriculture, treated in an integrated, enables to reach a diagnosis of the different hierarchical categories of the fragility of natural environments.

Phases and Intermediary Products

The Geomorphologic map accompanied by a genetic analysis of intermediate products to construct the fragility map. Its execution is done under the procedures defined by Ross (1990 and 1992), who establishes the theoretic technical concepts for constructing the geomorphologic map and genetic analysis from different forms of relief. For the analysis of medium and small scales like 1:50,000, 1:100,000, 1:250,000, it is used as the basis for information of Standards Forms with indicators of topographic roughness or dissection. When the analysis is more detailed, such as scales of 1:25,000, 1:10,000, 1:5,000 and 1:2,000, it uses forms of aspects and slope classes. In these cases one must use the classes ranges already established in studies of capabilities of Usability and Agricultural Fitness associated with those known values as critical limits of geotechnical, indicators of erosion force, the risk of landslides, mudslides and floods.

For the relief variable, taking the declivity of the slopes, the fragilities are defined as follows:

Fragilities classes by the variable declivities of the slopes	
1-Very weak	zero to 2% - plans and high reliefs, or 1º (degree)
2-Weak	3% to 15% or 8º
3-Medium	16% to 30% or 17º
4-Strong	31% to 50% or 25º
5-Very strong	50% or above 25º
5-Very strong	2% or lesser 1º - relief from the flood plains.

Weaknesses classes for the forms of slopes

For the shapes of slopes, mappable in large scales 1:5,000, 1:10,000, 1:20,000 and middle scales1:50,000, the classes of fragilities were ranked on:

1-Very weak	Tp-flat tops of hills, terraces and residual hills
2-Weak	Tc-convex tops of hills and mountains
3-Medium	Vc-convex slopes of hills and mountains
4-Strong	Vr-rectilinear slopes of hills and mountains
5Very Strong	Vc-concave slopes in headwater drainage

Fragilities of the Standards of Relief Dissection (roughness)

For studies of medium and small scales, it is used as a morphometric reference the Dissection Indicators Matrix developed by Ross (1992), based on the ratio of drainage density/dimension inter fluvial average for dissection in the horizontal plane and in degrees of notching the drainage channels for dissection in the vertical plane:

This matrix provides the categories of influences from very weak and very strong, as shown in the figure below:

Matrix for Dissection of Relief Index

Drainage density or dimension Inter fluvial (Medium Class) / **Deeping Drainage**	**Very Weak** (1) 3750m	**Weak (2)** 1750 to 3750m	**Medium (3)** 750 to 1750m	**High (4)** 250 to 750m	**Very High (5)** 250m
Very weak (1) (from 20m)	11	12	13	14	15
Weak (2) (20 to 40)	21	22	23	24	25
Medium (3) (40 to 80)	31	32	33	34	35
Strong (4) (80 to 160)	41	42	43	44	45
Very Strong (5) (160)	51	52	53	54	55

The morphometric categories are classified into fragility classes:

1-Very weak	from matrix 11
2-Weak	from matrix 21,22,12
3-Medium	from matrix 31,32,33,13,23
4-Strong	from matrix 41,42,43,44,14,24,34
5Very Strong	from matrix 51,52,53,54,55,15,25,35,45

The fragilities to the variable Soils:

The criteria used for the variable soil passes through the characteristics of texture, structure, plasticity, level of cohesion of the particles and depth / thickness of surface and subsurface horizons. These characteristics are directly related to relief, lithology and climate, the driving forces of pedogenesis, and determinant factors of physical and chemical soil characteristics. These criteria use as support the research results from Instituto Agronômico de Campinas

(IAC) Estado de São Paulo, from Instituto Agronômico do Paraná (IAPAR), and Projeto Radambrasil do MME, among others.

1-Very Weak	Deep-lands, well-drained, sandy-clayey Oxisols and Clay porous
2-Weak	Deep-soils, well-drained soils, medium textured sandy Oxisoils
3-Medium	Soils moderately depth, medium textured, loamy Ultisoils, Nitosoils
4-Strong	Shallow soil with very thick B horizon, sharp-transition Cambisoils
5-Very Strong	Shallow soils and rocky or sandy-Sandysoils and Entisoils,
5-Very Strong	Organic Soil, with high-hydromorphism Gleysoils, and Spodosoils, Tiomórficos

However, It should be noted that field observations in different regions of Brazil, which show evidences that it's necessary to distinguish clearly the differences between the fragility/erodibility of the soil when the flow is diffuse or when it is concentrated. It's a known fact that the concentrated flow along paths and roads, or even on land prepared for cultivation. It is much more aggressive in the sandy loam Oxisoils / sandy soils than in clay and even shallower as Cambisoils, and Ultisoils Nitosoils. However, the transport of fine debris and colloidal material are more abundant from the surface horizon of soils even by diffuse flow in the second group of soils.

Fragility Classes for Vegetation Covering and Land Use

The analysis of soil protection by vegetable covering involves the construction of the map of Land Use and Vegetable Covering. This work is centered initially on the interpretation from satellite images, in the case of medium and small scales (1:50,000 to 1:500,000) and from air photography, in the case of large scale (1:2,000 to 1:25,000). About interpretation of air photos and satellite images, it was identified the polygons from different types of uses, such as: natural forests, barns, forestry, long cycle crops (coffee, oranges, bananas, grapes, figs, cocoa, rubber, pepper and so on), short cycle crops (cotton, rice, soybeans, corn, wheat, oats, etc..) natural grasslands, pastures, cultivated among others. In the case of urban areas it is necessary to distinguish the patterns of urbanization as much as fencing the green areas, the infrastructure, such as channeling of rain water, paving, curbs, buildings and other patterns.

1-Very weak	Very high protection of soils, primary and secondary forests with a high stage of regeneration
2-Weak	High protection of soils, dense Savannah Forests, forestry with herbaceous cover
3-Medium	Medium soil protection of long cycle crops with curves and terracing to forage among coffee- streets, citrus, papaya, forestry, pasture of low cattle trampling
4-Strong	Weak protection of long-cycle crops soils without forage between streets and short cycle with terracing and in curves
5-Very Strong	Very weak soil protection, deforested land with burning down practices, exposed soils for cultivation and earthworks, short-cycle crops without conservation practices.

Classes of fragilities by rainfall variable**: **Hierarchical levels of rainfall variations

Hierarchical levels	**Rainfall Characteristics**
1- Very Weak	Situation with regular distribution of rainfall throughout the year, with annual volumes, not much above 1000 mm/year.
2- Weak	Situation with regular distribution of rainfall throughout the year, with annual volumes not much more than 2000 mm/year.
3- Medium	Situation with annual rainfall distributed unevenly, with dry periods between 2 and 3 months in winter; in summer with higher intensities from December to March, with volumes from 1300 to 1600 mm/year.
4- Strong	Situation with annual rainfall distribution unevenly, with dry period, between 3 and 6 months, and heavy concentration of rainfall in summer between November and April when there is 70% to 80% of total rainfall, with volumes from 1600 to 1800 mm/years.
5- Very strong	Situation with regular distribution of rainfall, or not, all over the year, with heavy annual volumes exceeding 2500 mm/year, or even irregular rainfall behaviors throughout the year, with episodes of high rainfall intensity and weak annual volumes generally below 900 mm/year (semi-arid).

Source: Based on Ross (1994).

CONCLUSION

From the list of relief variables (morphology and morphometry), rocks, soils, climate (rainfall), land use, vegetation covering is established the classification of the fragility and potential and emerging from the association of Arabic digits where each of the numbers of the numbers set represents a certain value that according to the foregoing classification tables ranges from 1 to 5, or better, from the weakest to the strongest or from the most protected to least protected in the case of Land Use/ Vegetation.

Thus way, the numerical association represents a digit for the relief (1 to 5) other for the soils (from 1 to 5), the less resilient to the more resilient, another digit for the degree of soil protection by vegetation (natural or cultivated), that also ranging from the most to the least protective (1 to 5), another one for the weather/rainfalls (1 to 5).

So, there are Arabic sets of four digits, which combine with each other, numbers from 1 to 5, that can have areas with values of type 1111, 1215, among others and reaching the highest value 5555, where all the variables are absolutely unfavorable.

In order to follow the proposed Ecodynamics Units, it must begin from the following number sequence combination: the first digit refers to the relief, the second is concerning the classes of soils, the third digit for land cover / Land Use, and the fourth digit for classes for rainfall. Thus, the set number 1111 - corresponds to a stable Ecodynamics Unit, or very weak potential instability. Overall number 5555 – The Ecodynamics Unit is Very Strong Emerging Instability, where land use is constituted by the deforested area with exposed soil, very strongly dissected topography and soils much fragile to erosion, soft rocks and very rain weather. The Potential Ecodynamics Units may have different degrees of potential environmental fragilities, but are stable due to little or no human intervention. While Ecodynamics Emerging Units have fragilities, from different environmental gradation and are marked by unstable environments due to human interventions. For example a relief unit that is classified as Very High Fragility, when covered by primary forests is under condition of a Potential Very High Fragility. If the same relief unit is occupied with long cycle crops without adequate management is classified as Emerging Very High Fragility.

The combination of these variables and their respective gradations make possible to generate a synthesis product of presentable by polygons on map to highlight and distributed object of research within the different fragilities of environments (potentials or emerging). With these differences of fragilities, it’s possible to establish an environmental zoning map or ecological-economic zoning, or better an indicative of territorial spaces with a range of productive-economic potentialities or conservation/preservation areas. For each one of these areas or environmental units there are uses/production potentialities or conservation potentialities and the environmental fragilities with limitations for using to human activities.

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