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Short communication

Energy structure perspective as an innovative approach to basic study of different analysis of complex robotic systems

Abstract

In this paper, the idea of using the energy structure perspective for application in the study of complex robotic systems is presented and expanded. The perspective of energy structure can provide a powerful solution for analyzing robotic systems. In fact, among the special capabilities of this approach, it can apply the energy conservation principle simultaneously by considering the effects of related energy wastes during system operation, the possibility of considering movement restrictions in the equation of the energy structure and applying it in the equation explained the movement of the system simultaneously with the first and second laws of thermodynamics, the calculation of the dynamic energy of the system using its movement restrictions, as well as how to apply energy directly, etc. Based on this, the perspective of energy structure can be helpful in studies related to robotic systems, especially systems with specific complexities and different behavioral and movement aspects. This paper develops the fundamental aspects of this issue.

Keywords: robotic systems, energy structure, energy components, dynamic energy, energy wasted, energy stored

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Introduction

The energy structure theory is proposed as a thermodynamic coupled theory.[1–7] The relevant equations are expanded based on the energy components of the system and in an innovative space called energy space. Various functional capabilities from the perspective of energy structure have been presented and expanded in various references. These applications include different fields of classical mechanics to advanced mechanics as well as classical physics to modern physics. The special highlights of this approach can make it a valuable and practical solution in the study of robotic systems from various aspects. Systems with different behavioral aspects, systems with advanced movement restrictions, as well as a high number of members and movement restrictions between them, systems with couples mechanical and thermodynamic behaviors, etc. are in this category. In this paper, while reviewing the basis of energy structure theory, expandable applications of the energy structure perspective for the study of robotic systems as a general, practical and advanced solution are discussed.

Energy structure perspective

Scientific laws are sometimes expressed in new ways or generalized different viewpoints as science advances. At this stage, the importance and application of certain concepts have advanced, and some of them may have a limited scope of application. Meanwhile, considering the importance of the energy conservation principle and its universality, the energy structure theory has sought a new expression for the energy conservation principle. In this new expression, more features of the system, environment, and energy exchange between them can be respected. Therefore, a new concept is proposed to express energy in physical systems, which could be utilized to state the desired equations. In fact, in this approach, energy in physical systems could be stated from a new perspective.[8–15]

The theory of energy structure is related to the expression of the structure of non-dynamic energies and to their precise definition. The corresponding structure and equations are created depending on the energy exchange between the system and the environment. Additionally, the required conditions for the investigation and feasibility of a physical process are obtained. Also, the energy structure of the desired process and its energy exchange with the environment are achieved. This condition is used to check the feasibility of a hypothetical process and in fact, it brings valuable results.[12–15]

According to the definition of the non-dynamic energies of the system, the conservation of energy in the system is defined. From the point of view of the energy structure, dynamic energy is defined by applying the conservation of energy in the system. Dynamic energy depends on the internal structure of the system as well as the way of energy exchange between the system and the environment. The relevant process extracts the system compatibility equations based on the relationship between the dynamic energy and the independent components of the energy. These equations express the process performed on the corresponding system in the energy space.

Based on the principles of Energy structure theory,[15] it is assumed that the total energy can be shown by equation (1):

$$U_T = U_{ND} + U_D \tag{1}$$

That U_T is the total energy, U_D is the dynamic energy and U_{ND} is the sum of all other types of energy. Figures 1 and 2 take two scheme of the energy space approach.

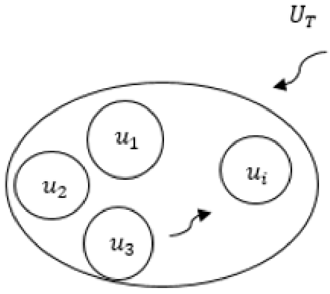

Figure 1 Scheme of a physical system with energy distribution.[1]

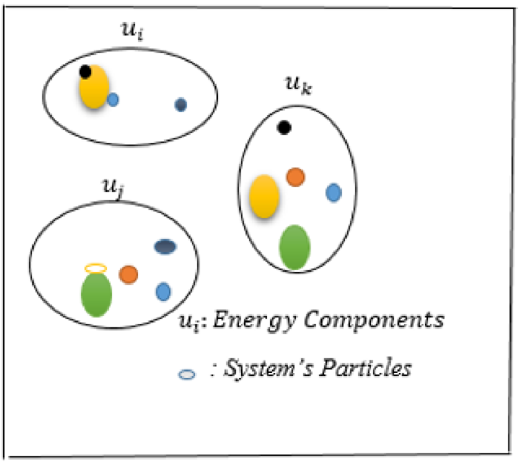

Figure 2 Energy component's approach.[2]

Where u_i is the system's energy component, and U_T is energy exchange between system and its surrounding. Also, non-dynamic energy equation is derived as follows[15]:

$$U_{ND} = (u_1 + u_2 + \ldots + u_m) + [g_1 + \ldots + g_k] + [h_1 + \ldots + h_n] + U_{T_0} \quad (2)$$

Where:

$$g_j = g_j(u_1, u_2, \ldots, u_m) \quad (3)$$

$$h_p = h_p(\dot{u}_1, \ldots, \dot{u}_m) \quad (4)$$

That u_i , $1 \le i \le m$ are independent activated energy components. Finally, it is concluded that according to the fundamentals of the energy structure perspective, this perspective can be a valuable solution for studying the mechanical and thermodynamic aspects of robotic systems.

Finally, the following variations will occur in the independent:

$$\delta u_1 = \alpha_1 \delta U_T$$

$$\vdots$$

$$\delta u_m = \alpha_m \delta U_T \quad (5)$$

That α_i is known as loading coefficients. More details can be seen in reference.[15] So, by assuming that:

$$\alpha = \left[\sum_{i=1}^{m} \alpha_i \left(1 + \sum_{j=1}^{k} \frac{\partial g_j}{\partial u_i}\right)\right] + \left[\sum_{i=1}^{m} \dot{\alpha}_i \left(\sum_{p=1}^{n} \frac{\partial h_p}{\partial \dot{u}_i}\right)\right] \quad (6)$$

$$\beta = \sum_{i=1}^{m} \alpha_i \left(\sum_{p=1}^{n} \left(\frac{\partial h_p}{\partial \dot{u}_i}\right)\right) \quad (7)$$

So, equation (2) can be rewritten as follows:

$$\delta U_{ND} = \alpha \delta U_T + \beta \delta \dot{U}_T \quad (8)$$

Also, equation (8) can also be expressed as:

$$\dot{U}_{ND} = \alpha \dot{U}_T + \beta \ddot{U}_T \quad (9)$$

More details have been provided in reference.[15] Considering equation (1), dynamic energy is calculated as follows:

$$\delta U_D = \delta U_T - \delta U_{ND} \quad (10)$$

By placing the equation (8) in (10):

$$\delta U_D = (1 - \alpha)\, \delta U_T - \beta \delta \dot{U}_T \quad (11)$$

Equation (11) takes the basic dependence of the variation of the dynamic energy to the amount and rate of energy applied to the system as well as α and β .

Equation (11) can rewritten as follows:

$$\dot{U}_D = (1 - \alpha)\dot{U}_T - \beta \ddot{U}_T \quad (12)$$

That takes the rate of dynamic energy.

The main challenges of complex robotic systems analysis

Complete and accurate analysis of robotic systems has particular importance in the field of dynamic fundamentals. Furthermore, the practical aspects of the subject are highly substantial. Therefore, various methods have been presented to analyze the performance of a robotic system. Currently, robotic systems have complex applications and require elevated flexibility. Therefore, there is a need to develop practicable and accurate methods to identify the main and effective aspects of system performance.[16]

Among the most important challenges related to advanced robotic systems, which are either not considered in the classical equations or create a very high computational complexity, it is possible to consider the flexibility of the system components, the analysis of the system with the high number components include the mutual effects of the system components on each other from the viewpoints of stored and wasted energy, the effects of the dynamics of the components on each other, which can significantly reduce the required calculations, dynamic energy, etc. The mentioned challenges can provide a wider scope of concern with the shrinking of the size of the components and in applications with high precision required.[17]

Advanced robotic systems deal with the many challenges that are not considered in classical equations or create very high computational complexity, such as the flexibility of system components and the analysis of systems with a large number of components. Challenges such as mutual effects of system components on each other in terms of stored and wasted energy, and dynamic effects of components on each other, will significantly reduce the required calculations, dynamic energy, etc. The mentioned challenges could provide a broad scope of concern with the shrinking of the size of the components and applications with the high precision required. Therefore, we need a more comprehensive view than what is proposed in classical mechanics. In this case, the effects of different parameters can be taken into account and a comprehensive study can be carried out on the desired system. The perspective of the energy structure will be a suitable solution for this challenge, considering its basis and also the basis of the energy space of the system.

According to the mentioned materials, the energy structure equations obtain the necessary capabilities for the advanced study of robotic systems. In fact, each member of the system is placed with a component in the energy space and the equation of the energy structure of the system is formed. It is in this situation that the dynamic and non-dynamic energies of the system can be calculated and the governing equations in the energy space of the system are extracted. More information can be found in reference.[15]

Conclusion

The perspective of energy structure, the effects of the second law of thermodynamics on the principle of energy conservation

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and the development of energy space are considered. In this view, the collection of governing equations and the necessary conditions for transferring from the Cartesian coordinate system to the energy space are provided. In this system, it is possible to consider the mutual effects of energy between components and the energy behavior of each component of the system. In fact, the energy space and considering each of the energy components for each of the system components makes this possible. In fact, according to the energy applied to the system, the changes in each energy component can be directly calculated based on the behavioral coefficients of the system. By applying the mutual effects of the components on each other, the independent components are determined and calculations are made for the independent number of energy components.

In addition to the mentioned cases, it is possible to consider the size effects in the same primary equations, which is a very important feature as the independence of the governing equations from the side effects. In fact, this issue takes one of the new and important aspects of using the energy structure perspective in the study of advanced robotic systems.

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Conflicts of interest

The authors declare that they there are no conflicts of interest.

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