Disseminating Sustainability Concept for Engineering Education via Typical Control Oriented Engineering Applications

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Abstract

In product design and manufacture process, especially for all large-scale systems, sustainability acts as a great challenge. Sustainability requires that the needs of present should be met without compromising the capability for future generations to satisfy the coincident needs. Essentially, the sustainability symbolizes the particular relationship between various things and different people. Engineering education regarding this sustainability issue is critical to preserve the natural environment and natural resource for future generations as well as to enhance the living standards for human beings. As a result, it is necessary to endow the concept of sustainability to course instruction and research project development. The sustainability is a multi-disciplinary and multi-objective issue, which will be investigated from perspectives of all engineering disciplines in terms of economic, environmental and societal benefits. In this article, the role of sustainability on operating mechanisms of mechanical, electrical, environmental and biomedical systems are investigated while the feasibility of instructing these knowledge are discussed. In addition, some typical control oriented engineering applications of this concept will be evaluated. Several potential real world applications corresponding to sustainability issues are proposed afterwards, such as optimal usage of energy resource, automotive fuel economy and emission control, robotic integration of smart sensors study, and so on. These applications can be closely related to course instruction and research project development in areas of electrical engineering, mechanical engineering and civil engineering.

Introduction

Engineering education system complements theoretical derivation and practical implementation. In most cases, it is a systematic procedure including lectures and experiments as well as some intensive research requirements on modeling, analysis, design and application for solid problems of electrical, mechanical, civil, automotive engineering, etc. For every discipline of engineering, sustainability is an important concept for the effective usage of the diminishing world resources, which is fundamental for product design, process development and manufacturing. In general, any consumptive usage of natural resources, global crisis, natural disaster, global warming, desertification, ozone depletion and pollution belong to unsustainable development; while non-

consumptive use of natural resources, human resource and biodiversity conservation belong to sustainable development. There are a wide variety of applications associated with sustainability, namely, product sustainability, development sustainability, environment sustainability, economic sustainability, manufacture sustainability and process sustainability. As a matter of fact, most engineering products have to be designed, manufactured, assembled, disassembled, recycled, remanufactured to maintain sustainability. To implement sustainability principles on product design and to apply novel theory on sustainability of large scale manufacturing systems, some modeling and optimization approaches will be needed for educating, training and disseminating sustainability on science and engineering [1]. For engineering education, modeling in terms of intrinsic physical mechanisms out of different mechanical, electrical, civil and environmental systems, should be conducted respectively. As an example, material selection method has been presented using a set of life cycle energy terms in order to evaluate material options for automotive components. The energy consumption spent during multiple phases of product lifecycle should be distinguished, from which intelligent manufacturing is to be applied on manufacturing and processing technologies for the sustainability of energy resource, renewable raw materials, recyclable resources, environmental impact, energy usage reduction, quality maintaining, production line improvement [2]. Sustainable products are products that are fully compatible with nature throughout the entire life-cycle. The performance to cost ratio is an actual index reflecting the effectiveness of design and manufacture. Some concepts and techniques in the area of optimization and intelligent control can be discovered and developed for the concern of sustainability issue on class instruction and laboratory exercises. This goal is to preserve the environment and respond to demands for increasingly customized products at competitive prices by virtue of sustainability consideration. As a result, both coordination and optimization can be conducted for multi-disciplinary large-scale system design and manufacture, where objective functions can be investigated to describe tradeoff between ecological and economic goals. At last sustainability criteria and optimization correlate to deliver high quality design and product[1-11].

Impact of Sustainability on Engineering Education

Sustainability issue covers every aspect of economy, environment, society and everyday life. Development and application of scientific principles of sustainability for engineering education and potential industrial implementations involves all features out of society development. At the same time, sustainable product development depends on education, training and dissemination of new knowledge on sustainability science and engineering. Sustainability is generally listed as two distinctive categories: strong sustainability and weak sustainability. To make a comparison, green house effect leads to the depletion of ozone layer, which is harmful to environment and can not be substituted; economic crisis may result in unemployment and starvation. Both cases belong to strong sustainability. For a system with weak sustainability, monetary compensation could be used for actual loss in terms of pollution after-treatment and habitat conservation, etc. Considering scope of impact, there are economic sustainability, environmental sustainability and societal sustainability. To enclose the concept of sustainability on engineering education, several factors must be considered: environmental consciousness (e.g., emissions, ecobalance, toxicity, lifecycle), societal impact, economics, resource utilization (energy efficiency and consumption, material utilization, waste minimization), manufacturability and product design. Sustainability is reached from all perspectives of engineering and scientific disciplines with an objective of

promoting societal, economic and environmental benefits of green engineering. A measurement can be established among economic, environmental and societal sustainability in economic terms. As a result, natural resource, fresh air and clean water can be assigned with an economic value. Sustainable manufacturing is concerned with energy, environment, economic, safety, health and waste disposal aspects of process sustainability. For potential industrial applications, it is important to broaden the scope for class instruction content since manufacturing sustainable product is one of primary challenges to industry which involves interdisciplinary approaches. As an example, for purposes of environment protection and cost minimization, a monitoring strategy for contamination should be taken in an efficient manner with real-time and remote capabilities based on control technology. Sustainability index for manufacturing process modeling and technology transfer could be empirical based, analytical based, numerical based, intelligent control based. Model objective function and constraints are used for validation optimization. Manufacturing recyclable products are environmentally responsible, which depends on continuous enhancement for sustainability. Measurement and quantification of product sustainability is demonstrated by environmental impact, societal impact, resource utilization and economic recyclability. The sustainable development enables national industry to create global contribution by exploiting emerging technologies and enhancing economic, ecological and social sustainability. Economic growth should be achieved without compromising the sustainability of any other part of economy, environment and society. It is a straightforward way to disseminate the important concept of sustainability by engineering education.

Sustainability Applications on Robotic Control

It is a fact that manufacturing plays a vital role in a sustainable economy, fully taking into account of the technical, environmental and social dimensions. Some emerging technologies for design and manufacture exist in sustainable economic and product development. Research and innovation on robotic control and automation provide a milestone for economic development and produce intelligent production capability which makes it more competitive. Sustainable design and manufacture concept should accompany each stage to robotic control application. In a low-level robotic control, some basic sustainable sensory devices are needed to perform a number of basic actions such as vision, touch and grasp. In a high-level robotic control, sustainable integration of electrical, mechanical, haptical, optical and biological functions recognize the object pattern and determine the presence and orientation of that object. The computerized robot is needed throughout pattern recognition process. To compute the location and orientation of a robotic end-effector, it is necessary to obtain precise information of the linear movements involved among various components of the robotic arm control systems. Sustainability investigation procedure is actually the integration of various product and process development requirements. To achieve a satisfactory computer enhanced robotic control, some precise dynamic mathematical models of robot arm systems are required. The engineering focus is to make sure that relevant processes and resulting processes fit together in a seamless manner. People, nature and accomplishment should fit together synergistically at the sustainable design of robotic control systems. Several sustainable development principles have to be followed for sustainability applications on robotic control, which include effective usage of natural resource, human resource, technology resource, financial resource and institutional resource as well as knowledge background development.

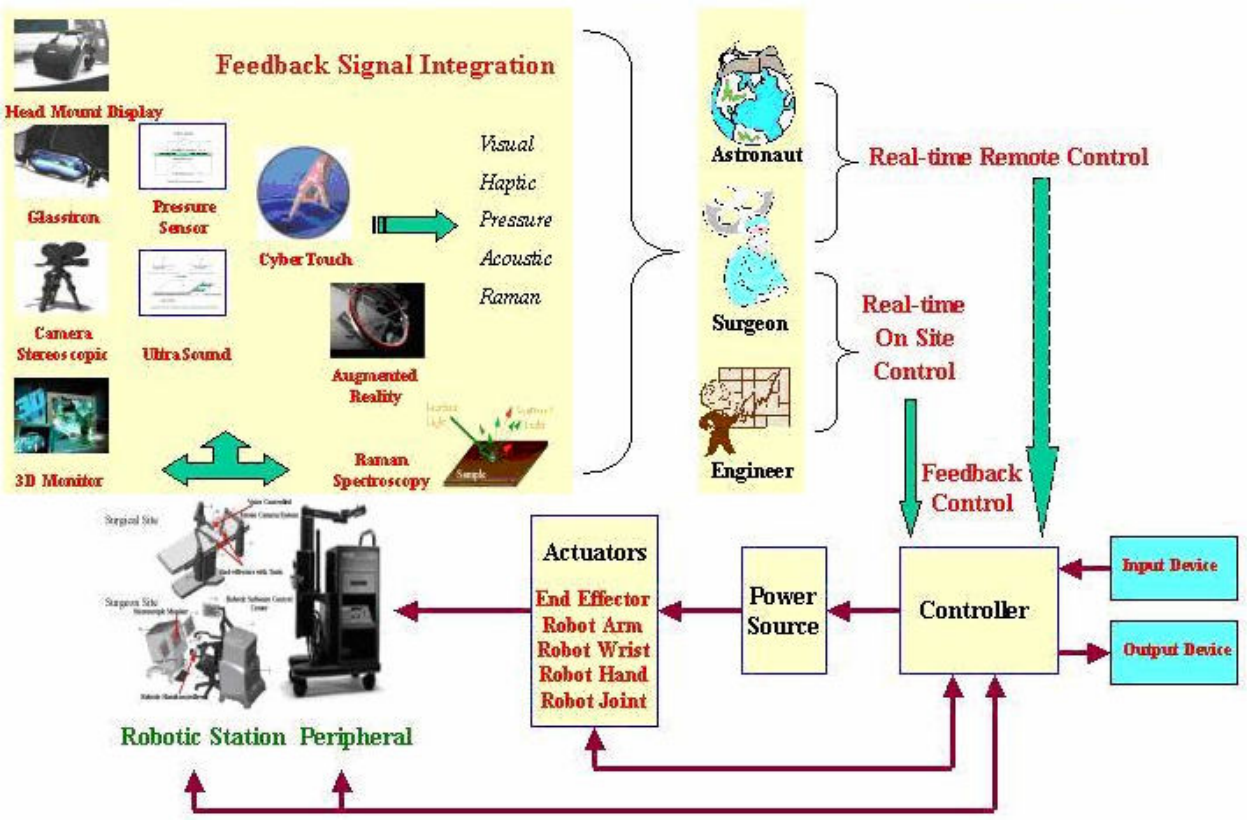

Fig. 1 Sketch of Medical Tele-Robot Control Application

Sustainable Applications on Energy Resources

Energy is the first necessity for all manufacture and product design process. Sustainable energy usage thus takes a leading role where the concept of green energy can be used to represent manufacture sustainability. To reduce dependence on gasoline, diesel, coal, natural gas, nuclear and other fossil fuels so as to limit carbon dioxide and greenhouse gases, preserve or restore natural habitat, alternative energy resource needs to be discovered step by step. Creativity and originality should be ignited during class instruction. First of all, solar energy is natural and tightly related to our everyday life. Its insufficiency lies in that its power density is very low. When technology and performance breakthrough can be provided to the thin film solar cell devices, obviously then it can be simply used as renewable energy. Secondly, hydrogen is the third most abundant element on the earth surface. Hydrogen can be an abundant and clean alternative fuel due to renewable, efficient and zero emissions. In the mean while, if the safety issue can be solved for the hydrogen fuel cell, it could become a primary energy carrier in future. Thirdly, as for another natural energy resource, geothermal energy has the potential to make a significant, clean and economical contribution to the energy supply. In addition, wind energy is by far the cleanest form of energy around, which is non-polluting and minimally disruptive to the natural environment, without emissions, excessive noise or waste by-products. Moreover, a few sustainable resources in remote areas can also be taken into full consideration due to plentiful, renewable and sufficient, such as natural gas, ocean currents, hydroelectric source, and so on.

Green engineering for both classroom education and practical implementation requires that sustainable products are recycling, renewable, non-toxic, non-hazardous and energy-efficient. It gives rise to the sustainable technology including renewable energy, natural energy and solar energy. Manufacture systems should operate in partnership with conservation of global natural resources and prevent this contamination from spreading. It is challenging to provide fuels, lubricants, adhesives, solvents, paints and other materials to the advanced society without depleting nonrenewable resources. Potential consciousness of sustainability is most likely to be achieved throughout intensive procedures of classroom instructions and experimental exercises.

Sustainable Applications on Automotive Control

Gasoline, diesel, coal, natural gas and nuclear energy are still most dominating energy resources despite of the fact that some alternative resources have the advantage of none disposal or none toxic gases, while most of the time these energy resources can be renewable in a closed-loop, low-emission and small power level environment. One technology of automotive control is to use exhaust gas recirculation (EGR) strategy, where pollutants of HC, CO, NOx and unburned gases will be re-circulated into engine combustion chamber for complete dynamic reactions. Another approach is to use some addictives into the fuel and lubricating oil in order to reduce the levels of harmful and toxic emissions. For instance, diesel fuel is used to power heavy load trucks and engineering vehicles at almost every corners of world with toxic emissions, such as HC, CO, NOx and soots. Small amount of power from addictive clean sources can bypass the need to endanger the environment. The aim is to use some extra substances or use closed-loop design for engineering restoration which can lead to enhanced environmental and energy efficiency. The schemes of sustainable automotive usage include: new engines, hybrid vehicles, alternate fuels, exhaust gas aftertreatment, fuel efficiency, light weight materials and lead reduction, etc. For the economic sustainability concern, multi-objective optimization is needed to obtain tradeoffs among different requirements of automotive control, such as fuel economy, emission levels, idle speed quality, driveability, and so on. This should be applied to not only the operating stage, but also the manufacturing stage. For example, multiple level optimization can be applied to combustion chamber design of automotive engine, with uncertainty of cylinder bore and stroke, valve diameter and environment conditions using multiple-level deterministic formulations. Optimization and artificial intelligence are effective in achieving robust designs under an expense of increased computational expense. The endowment process of those modern engineering subjects depends heavily on the thorough engineering education.

Conclusions

Engineering education is one of most dominating areas for developing scientific principles of sustainability for training, applying and dissemination of sustainability science and engineering. The development of science and engineering is classified into unsustainable development and sustainable development based on economy, environment and social effects. Course instructions and laboratory experiments are both important approaches to widely distribute the concept of sustainability. Being general engineering discipline to implement on diversified electrical, mechanical, civil, biomedical and chemical systems, control engineering education is also

closely related to the sustainability issue by a variety of theoretical instructions and experimental exercises. This investigation indicates the signification of potential sustainability applications which are best for accomplishment, people and nature. Some control oriented applications related to engineering sustainability issues are presented and discussed. It is also pointed out that in order to solve this type of complex multi-disciplinary engineering problem, implementation of multi-objective optimization will be the best solution to achieve maximum potential benefits from sustainability related projects.

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