A vibro-haptic interface development for impact detection on UAV wings

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***Abstract*—This paper presents a new sensing paradigm for structural impact detection using vibro-haptic interfaces. The goal of this study is to allow humans to "feel" structural response and eventually determine health conditions of a structure. The target applications for this study are aerospace structures, specifically UAV wings. First, L-shape piezoelectric sensor arrays are deployed to measure structural responses caused by an impact. A unique haptic signal is then generated and wirelessly transmitted to human arms. With the vibro-haptic interface, human pilots could identify impact location, intensity and possibility of subsequent damage initiation. Experimental results demonstrate that human could correctly identify such events, while reducing false indications on structural conditions by the haptic interface. Several important aspects of the haptic capability into structural impact detection are summarized in this paper.**

Keywords: haptic interface, impact detection, structural health monitoring, human capability, structural response

I. INTRODUCTION

In this paper, a novel approach of incorporating haptic interfaces into impact detection and SHM is developed for applications in aerospace structures. Current paradigms of SHM or structural dynamics research efforts have focused on developing techniques that take little use of human intelligence. However, human classification capabilities often exceed those of contemporary classification algorithms [1], and are capable of better adapting to a new situation. Therefore, in this work, we propose the development of a new semi-autonomous SHM paradigm in which novel human-machine interfaces are used to leverage the computational precision and humans' adaptability and classification capabilities. Our focus for this study is impact detection of airplane wings, which may cause important problems during operation [2, 3], especially for composite structures. Composite structures are increasingly used in aerospace applications due to their lightweight characteristics. However, they are vulnerable to impact loads, which is the main source of catastrophic structural failures. Furthermore, due to their anisotropic nature, existing impact detection methods have shown some limitations on impact localization. In order to overcome such limitations, several new methods are also developed [2, 3, 4, 5, 6]. It should be pointed out that all of these methods are carried out autonomously without human intervention.

It is David et. al. [7], who first proposed the new haptic-based sensing network paradigm for SHM. They use a haptic glove to transmit haptic-feedbacks, from the response of a 4 story structure. After 20 minute of training, human could detect structural damage only using haptic signals. The results indicate that the haptic interface system could improve multi-tasking capabilities if optimization of human training strategies and design of haptic signals are made.

We believe that haptic interfaces could provide several advantages to the current SHM practice. For example, if unforeseen circumstance occurs, human intelligence could actively deal with the new situations and find a solution faster and more accurate than SHM detection algorithms [8]. Furthermore, human tends to rely on the sense of touch under unconscious conditions, which make this application ideal for human pilots, whose visual and auditory information is overloaded during the flight. In order to capitalize on these characteristics, we designed and implemented an impact detection system based on haptic interfaces. A wing shape structure was used for the haptic experiment, where the source localization algorithm proposed by Kundu et al [9] was adopted. Haptic signals are then designed and wirelessly transmitted to human arms to provide the necessary information on impact events, locations, and intensity. In order to test the feasibility of this approach, several human subject tests are also performed and the results are summarized in the following sections.