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The Development of an Intelligent Helicopter Performance Instrument System Incorporating Human Factors and Skilled Based Expertise

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THE DEVELOPMENT OF AN INTELLIGENT HELICOPTER PERFORMANCE INSTRUMENT SYSTEM INCORPORATING HUMAN FACTORS AND SKILLED BASED EXPERTISE

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Studies by Iseler and De Maio (2001) suggest that the helicopter accident rate in the USA is 10 times that of airline accidents, with 20% attributed to pilot error. US Army/NASA studies (Hart 1998) have developed a number of strategies with the goal of reducing the helicopter accident rate including real-time prediction, measurement and pilot cueing. Hardy and Thatcher (2004) described early development work in designing an intelligent helicopter performance instrument system that conducts performance predictions in real time that is being pursued with the aim of providing pilot cueing indicating sufficient performance is or is not available for takeoff, landing and maneuvering flight phases. This paper further describes the research work completed to date including the developmental instrument system that has been assembled from commercial-off the shelf hardware and software that will allow rapid prototyping from results of in-flight performance and human factors testing. The helicopter performance instrument system could significantly reduce pilot workload and enhance safety. It has the potential to assist in reducing the accident rate associated with collisions with the ground during takeoff and landing attributed to the pilot being unaware of insufficient performance of the helicopter.

Introduction

Analyses of US civil rotorcraft accident records over the last two decades by Iseler and De Maio (2001) suggest that the helicopter accident rate to be some 10 times that of corresponding airline accidents, with 20% of the accidents attributed to pilot error, with the primary factor associated with the skill level of the pilot. The highest accident rates in helicopters has been shown to occur with lower cost helicopters and is likely related to the lower skill level of the pilot. Lower skill pilots are more often involved in accidents that their own error is a primary or major factor. As a result of their studies, the US Army/NASA Rotorcraft Division reported through Hart (1998) that they have developed a number of strategies to attain a goal of reducing “the rotorcraft accident rate attributable to human factors and drive train malfunctions by a factor of five by the year 2007”. Amongst these strategies are through the use of human-centered cockpit technology that includes ”real-time aiding to eliminate inadvertent envelope exceedance with real time prediction, measurement, cueing and limiting for critical parameters and components”.

Although several modern helicopters already provide some means of performance prediction through embedded Flight Management Systems (FMS), generally these are limited in their capability to predict hover capability and provide a power assurance check, as described by Eurocopter EC130B4 Flight Manual (n.d.) and the Boeing AH-64D Operator’s Manual (n.d.). These are also aircraft specific and not adaptable to other helicopter types.

This paper presents the development work completed to date in developing an intelligent helicopter performance instrument system that conducts performance predictions in real time and provides pilot cueing for takeoff, landing and maneuvering flight phases. The system uses consumer Pocket PC devices running applications developed using National Instruments LabVIEW software that allow rapid prototyping to address results from performance and human factors testing.

Engine Power Available Versus Power Required

In order to conduct a safe takeoff, landing or maneuvering flight, sufficient engine power must be available to meet or exceed the helicopter power required to conduct the maneuver. Engine power available is dependent upon pressure altitude, ambient temperature and engine condition. Helicopter power required for a task is also dependent upon pressure altitude and ambient temperature, as well as variables such as airspeed, gross weight, center of gravity, vertical acceleration forces, height above the ground, attitudes, size and frequency of control inputs, and aircraft configuration. The difference between power available and power required is termed power margin. Provided the power margin is equal or greater than zero, the pilot has some assurance the sufficient power is available to conduct the maneuver.

The engine power available may be power turbine temperature, gas generator speed or torque limited. Exceeding any of these limitations may result in engine or transmission damage, or the engine may have insufficient power to maintain rotor speed once past these limits, with subsequent loss of thrust and anti-torque effectiveness. The limit which is reached first will be dependent upon the ambient conditions. For example in cold, low altitude conditions, the gas turbine engine typically will be able to produce more power to the transmission than the transmission rating and so will reach a torque limit first. In high temperature, high altitude conditions, the engine may reach a power turbine temperature limit prior to the torque limit; or perhaps the gas generator speed limit prior to the turbine temperature or torque limit.

The power required to conduct a specific task, whether it be a takeoff, landing or maneuvering flight, is dependent upon how much thrust is required from the main rotor and tail rotor, plus power required to run accessories (hydraulics and electrics), as well as mechanical losses. Predicting the power required for a maneuver is not a trivial task. This can only be easily achieved for steady state conditions such as hover or level flight. The Federal Aviation Administration Regulations, 14 CFR Part 27 (2003) and Part 29 (2003) require manufacturers to provide data in the Rotorcraft Flight Manual (RFM) which the pilot can use to predict whether sufficient power is available at varying conditions to conduct certain tasks such as a hover; or data to predict takeoff distances for transport category helicopters.

However the high workload presented to a helicopter pilot, particularly for helicopters without stability augmentation or single-piloted, often leads to the pilot not referring to RFM performance data as a flight progresses. Not doing so means the pilot either resorts to guesswork; previously calculated predictions with large safety margins; or really has no idea if sufficient power is available to safely complete a maneuver. Guesswork as an alternative to performance planning has been a contributing factor in many helicopter accidents, often classified as insufficient planning or poor pilot judgment. Typically the helicopter either has insufficient power to complete a take off, colliding with the ground or obstacles; or, insufficient power to arrest the rate of descent during landing or maneuvering. This is particularly an issue when the takeoff or landing site is at a considerable altitude or temperature difference to where the flight originated, or when significant gross weight changes have occurred (extra fuel, cargo or passengers). Applying excessively large safety margins are also undesirable as they can result in reduced productivity of the helicopter with the pilot electing to carry a lighter payload than actually achievable.

Existing Helicopter Performance Predicting Human-Centered Cockpit Technology

Several modern helicopters already provide some means of performance prediction, engine power assurance checks and display through embedded Flight Management Systems that relieve the pilot from the workload associated with referring to the RFM during flight. These include Eurocopter's Vehicle and Engine Management Display system used in the EC Series of helicopters such as the EC130 (Eurocopter EC130B4 Flight Manual, n.d.) and the performance planning system integrated in the Boeing AH-64D Apache Longbow (Boeing AH-64D Operator's Manual, n.d.). However these are limited in their ability to predicting maximum hover weight and base their computations on a minimum engine power specification. Should the engine be producing more or less power than the minimum specification, the performance predictions in these systems will be inaccurate. These systems are also aircraft-type specific and not adaptable to other helicopters.

Developmental Instrument System

In order to address the limitations of existing performance prediction instrumentation systems and provide real-time performance prediction and cueing for hover, takeoff, landing and maneuvering, a developmental instrument system for integration into a test helicopter and in-flight evaluation has been developed. It consists of commercial off-the-shelf hardware and software in the form of two IPAQ h5150 Pocket PC devices running application code written using National Instruments LabVIEW and LabVIEW PDA Module software. One of the Pocket PC's holds a National Instruments DAQCard 6062E

PCMCIA data acquisition card in an expansion pack. This Pocket PC is designed to acquire atmospheric, helicopter engine and aircraft performance data in real time and transmit the parameters via a Bluetooth link to the second Pocket PC on the pilot's kneeboard for computation and display. The Bluetooth connectivity leaves the pilot and PDA unencumbered by wires and simplifies aircraft integration. While the graphics capable of being displayed for pilot cueing by LabVIEW PDA Module software are somewhat limited, this approach will allow rapid prototyping in response to performance and human factors tests that will be undertaken to evaluate workload, display formats, moding and automation. The system has been bench tested (Figure 1) and is currently being integrated into an ex-US Army Bell OH-58C helicopter, operated by the National Test Pilot School, Mojave, California (Figure 2).

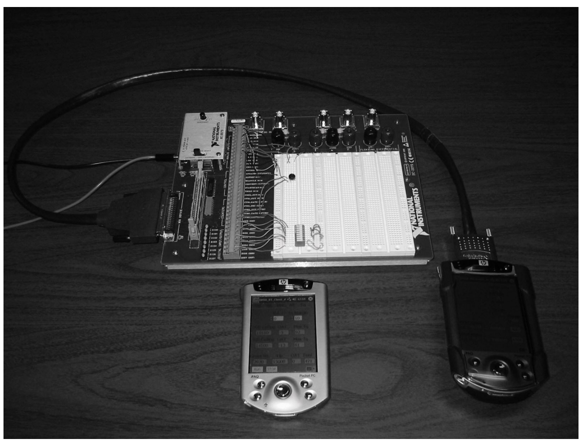

Figure 1. *IPAQ/LabVIEW Based Intelligent Helicopter Performance Instrument System under Bench Test*

Model and Display Development

The first step taken has involved developing detailed performance models for the test helicopter based on the performance data from the OH-58C Operator's Manual (US Army, 1989), US Army flight test reports (Benson, Buckhanin, Mittag and Jenks, 1975, and Spring, Buckhanin, Burch and Niemann, 1979), and takeoff performance predicting methods developed by Burke, Schmitz and Vause (1977).

Figure 2. *OH-58C Test Helicopter*

Code has been developed from these models to predict and display on the Pilot's Pocket PC engine power assurance data, maximum engine power available, power required to hover, hover ceiling, takeoff distances to clear obstacles and available power margins. In particular, power margins between engine power available and predicted power required to hover in ground effect and out of ground effect are displayed and updated in real time based on pressure altitude, outside air temperature and helicopter gross weight inputs. Further to this, knowledge-based techniques are currently being investigated, with the aim of developing a prediction agent based on radial base function neural networks outlined by Thatcher, Jain and Fyfe (2004) and Haykin (1999); or a multilayered perceptron neural (Alonso-Betanzos, Fontenla-Romero, Guijarro-Berdinas, Hernandez-Pereira, Canda, Jimenez, Legido, Muniz, Paz-Andrade and Paz-Andrade, 2002) that would yield a satisfactory prediction of successful optimization of take off, landing and maneuvering events. These techniques will consider actual power being produced by the helicopter engine, rather than just the minimum engine specification. One must also consider that experts (pilots in this case) bring a vast amount of experience or knowledge to the process and the use of expert knowledge as input to the knowledge-based agent/s is also being considered, as suggested by Van Aartrijk, Tagliola and Adriaans (2002).

Conclusions

This paper summarizes the development work completed to date for an intelligent helicopter performance instrument system that conducts performance predictions in real time and provides pilot cueing for takeoff, landing and maneuvering flight phases. The system uses commercial off-the-shelf Pocket PC devices running applications developed using National Instruments LabVIEW software that will allow rapid prototyping to results from human factors testing. The system has the potential to significantly reduce pilot workload and enhance safety. In particular it has the potential to assist in reducing the accident rate associated with collisions with the ground during takeoff and landing attributed to the pilot being unaware of insufficient performance of the helicopter.

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