# FORCE MEASUREMENT SYSTEM CORRECTING FOR INERTIAL INTERFERENCE

This application is a division of application Ser. No. 08/589,930, filed Sep. 30, 1997, now U.S. Pat. No. 6,285, 358.

The present invention relates to the use of force measurement techniques, as in touch screen or other touch input computer cathode ray tube (CRT) or related displays to locate the points of touch on the face of the display, and under adverse circumstances where the display apparatus is rather heavy and imperfectly or poorly or insecurely supported or mounted so as to be subject to inertial interference effects, such as vibration or sway, that may cause errors in the force measurement and resulting computed touch location.

While directed, accordingly, to obviating such inertial interference effects and rendering the force measurements immune to the disturbing effects of movement of the mass supported by the force measuring apparatus, as from such unsteady mountings or supports for the force measuring apparatus, the invention even more broadly finds use also with analagous problems arising in other force measuring applications, as well; such as, for example, those of weighing objects on a relatively insecure or moving support, or effecting such weighing in the presence of a relatively large tare mass or counterweight that is excited by rapid operation.

From still a broader viewpoint, the invention relates to enabling the accurate measurement of rapidly changing forces in situations where the associated mass displacements can cause significant inertial interference.

## BACKGROUND OF INVENTION

As above noted, the invention has important application in touch input computer and related displays that employ touch force location measurement techniques. In particular, it provides significant immunity to inertial interference effects in specific systems such as those described in my earlier copending U.S. patent application Ser. No. 857,241, filed Jan. 25, 1992, for METHOD OF AND APPARATUS FOR TOUCH—INPUT COMPUTER AND RELATED DISPLAY EMPLOYING TOUCH FORCE LOCATION EXTERNAL TO THE DISPLAY, now U.S. Pat. No. 5,376, 548.

Before proceeding, however, to address such specific applications, it is believed helpful to consider first the general problems of the vibration, sway or other movement of heavy or poorly or insecurely mounted force measuring systems that may introduce errors into the force measurements and the resulting computations stemming therefrom.

There is always some amount of mass associated with the "measurement side" of a force measuring device to which an unknown force is applied, including all or some portion of the measuring device itself, and the attachment and any related objects between them. If and when the device support changes motion, this supported mass is generally also accelerated. Since the force creating this acceleration passes through the device, the device output can no longer accurately reflect the unknown force.

Additionally, the attachment, the device itself, and the device support, deform in some degree when the unknown force is applied; usually, in an elastic manner. Thus the supported mass must undergo some acceleration as the unknown force changes, at which times the device output responds not to the unknown force alone, but also to the inertial reaction force of the supported mass.



These effects are of practical concern when, for example, a force must be measured in the presence of an unsteady support and an appreciable supported mass, or a rapidly changing force must be measured in the presence of appreciable supported mass and compliance.

An approach to try to avoid such difficulties may reside in attempting to avoid the combinations of conditions listed above. Where such combinations are, however, unavoidable, two prior art techniques for amelioration are noted: viscous damping of the mechanical system itself, and linear filtering of a measurement signal derived therefrom. Damping is primarily applicable to situations such as weighing, where a force, once applied, remains constant until its measurement is completed. During such time as the force remains constant (exclusive of the inertial effects), the intertial error decays exponentially. When the force must be measured as it changes, on the other hand, linear filtering may be particularly applicable. The filter may be of analog electronic, digital electronic, or even mechanical construction, and is typically of low-pass or mixed low-pass and notch design. It passes low frequencies unaltered, but blocks those at and/or near the resonant frequencies, of the suspended mass. A measurement is thus obtained which accurately reflects the low frequency part of the unknown force, but at the expense of abandoning measurement of the high frequency part. Both damping and filtering typically provide faster measurement than can be acheived with no ameliorating technique: but not so fast as could be obtained were there no inertial interference present, or if there were some way to estimate such interference sufficiently accurately so that it could be subtracted from the total signal.

It is to the provision of a novel ameliorating approach that the invention is directed, and will be hereinafter described in terms of the illustrative system of said copending patent application, wherein force measurement is used to locate finger touches on a typical CRT display monitor. Such application necessitates the accurate measurement of as much as 80 pounds, and must contend with flexure in the monitor housing and stand, and the table beneath, as well as in the force measuring platform itself. It has been found that good results (location errors less than 0.1 inch) can routinely be achieved with such a system, provided the table is solid and the monitor housing rests on the platform through small, corner-located feet. The lowest resonant frequencies of such combinations run in the range of 6 to 10 Hz, and a linear filter that strongly blocks frequencies above 5 Hz has been found to provide adequate speed of response.

Such is not, however, the case for less secure monitor supports. Many monitors, indeed, are supplied with a "tilt-swivel" stand. This form of support raises the monitor center of gravity and softens its support, particularly with respect to fore-aft and side-to-side nodding motions. These two changes directly affect the two lowest frequency eigenmodes, dropping them to about 3 Hz for a large monitor on a tilt-swivel stand. A comparable depression of lowest resonant frequencies is seen when a free-standing folding table is used below the platform and monitor. In addition, disturbances such as bumping or leaning upon an insecure table can introduce large low-frequency inertial errors independent of the free resonant frequencies of the system.

While linear filtering with a lower cutoff frequency could, in some instances, be used to eliminate excessive interference from these lower frequencies, this would be only at the cost of a touch response delay which is unacceptable. On the other hand, with only the higher frequency filtering in place, position errors can grow to as much as several inches for