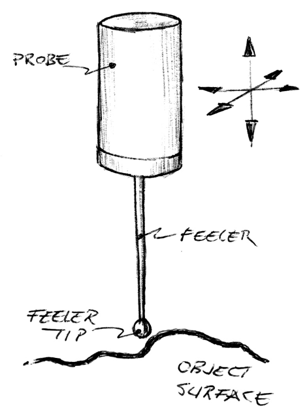
Getting The Feel For It

The design principle for an ultra sensitive touch probe

Probably one of the most basic range mapping techniques is a CMM with a mechanical probe which feels its way over the surface of an object. It registers each step of the way and creates a grid of points which represents the shape of an object. While the accurate positioning of the probe is very important the method that the probe uses to detect or feel its way over a surface is equally important. Ideally, the probe should be super sensitive, responding to even the slightest touch and yet be completely insensitive to acceleration or rapid movement of the CMM. It should also be robust, solid state, not cost a lot and be basic in design. The principle idea for a probe that meets these demands is presented here which can be built using some basic electronic components, common materials and a bit of patience.



Introduction

Seeing is believing. There is a lot to suggest that our ability to see is probably one of our most important senses. That should be no surprise considering the profound impact that vision system technologies have had on science, society and industry. The ability to capture and/or view a scene of something allows wide application. Take for instance the significance of the microscope in microbiology, the telescope in astronomy and the video camera for YouTube. 3D range mapping literally adds a new dimension to vision technologies. And, these days we can scan just about anything from large surfaces of the earth to large molecules.

Contact Range Mappers

Many different range mapping technologies exist. Each has their own merit and limitations. While some may be more flexible than others there is no trick part that does it all. As such, it’s important to choose the right technology for the job.

Probably the best way to categorize the many different range mapping technologies is to divide them between the non-contact and contact types. As this writing pertains on the design of an ultra sensitive touch probe we will focus on the latter.

Contact type range mappers, also known as 3D digitizers, are extremely slow in comparison to their non-contact 3D scanner counterparts. They are blind and must feel there way over a surface. Each point is gathered step by step.

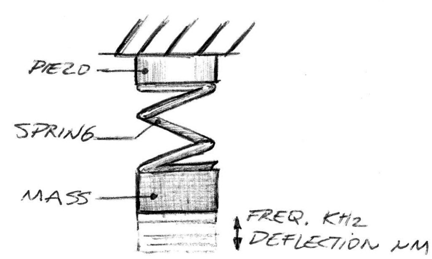
Yet, contact systems are not prone to false positives in comparison to non-contact systems. Moreover, they are extremely accurate. Don't forget that this same tech, at a smaller scale, is used to map large molecules! Its probably one of the more important tools used in Microsystems and nanotech.

However the contemporary probe designs found on CMM's leave much to be desired. These, usually mechanical or electro resistant type systems, are costly, somewhat complex and, more importantly, only reasonably sensitive to touch.

The Mass Spring Based Probe

In the late 90's I was working on part of a system of a very complex piece of machinery. I needed to dynamically measure the mechanical stability of a suspended or sprung mass. Otherwise stated, an object that was supported by a suspension was moving up and down and I needed to know if the amplitude was exceeding its designed range. The range was about 20 nanometers! (25.4nm = 1 millionth of an Inch) Due to certain criteria, mechanical measurement was preferred. But the *"observer influences the measurement"* thing comes to mind; How to mechanically measure the position of an object without actually touching it.

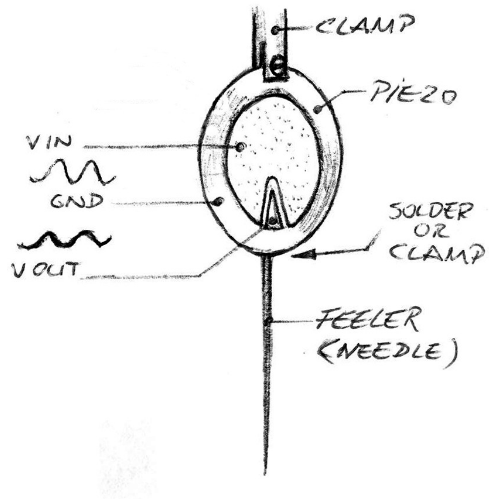
The answer to achieve this was to use a tuning fork. The type used to tune musical instruments. At least the workings of this instrument carried the principle idea. If you tap on one of its ends it makes a certain sound or tone. The ends of the fork resonate at their natural frequency. Making the ends shorter will raise the frequency but lower the deflection or amplitude. But here is the really interesting part; if you touch the excited fork, even slightly, the tone suddenly collapses. The resonating vibration of the touched end is dampened and to a very minimal extent mechanically coupled with the surface skin of your finger. The frequency and amplitude drop. Hey, you have just created a solid state, supersensitive, low cost touch probe which is virtually insensitive to rapid movement. All that it needs now is to be redesigned for use as touch probe.



In a nutshell, what we are doing is creating a mass spring system which operates at its natural quarter wave frequency. Its a quarter wave system since one end is fixed while the other end is open and free to vibrate. This open end is the probing end for our application.

The next question would be to decide what parameter should be monitored that will represent the touching of an object. It would seem apparent to listen to the audio tone. If it collapses then you know it's touching something. You could design a fork to resonate at high frequency, much higher than humans can hear and have a microphone monitor the system. The elevated working frequency would isolate the system from most all ambient sounds except maybe pre infrared type TV remotes. To further improve on the system you would apply some means to excite and maintain the resonating frequency of the system. A solenoid would not be practical but a piezo element would be perfect.

A (natural) piezo element is special crystal or salt material that is electrically capacitive and changes shape in an applied electrical field. Interestingly it also can produce electrical tension when acutely strained. A piezo element would be driven by an alternating electrical signal and integrated between the fixed end and the sprung mass. The alternating electrical tension would be set at a frequency which results in the mass spring system resonating at its natural frequency.



Piezo elements come in many shapes and sizes and their cost range from several cents to many Dollars. Probably the least expensive and most commonly found types are the disc types used for audio applications. This type consists of a thin brass disc onto which a thin layer piezo material has been applied onto one surface side. The piezo material has been radial polarized to contract and expand along this direction under the influence of an alternating electrical voltage. While the deflection of the disc resides in the micrometers the frequency range and response of these simple devices is astounding. One important added feature of these types of piezo's is that the piezo is typically divided into two regions; one large region and a smaller one. The larger region is used to cause the unit to deflect (motor). The smaller region (generator) is used for feedback! Remember that you can cause a piezo to change shape under the influence of an electrical tension but the opposite applies as well. The smaller region contracts and expands due to the deflection of the larger region. What does this all mean? Well, instead of monitoring the audio we simply monitor the alternating voltage wave of the smaller region of the piezo disc. If this voltage collapses then that is an indication that the system has touched something.

By itself the shape of the piezo disc is not really suited to follow the surface of an object. Obviously some type of “feeler” needs to be attached to the disc. The mass of the piezo is small requiring very high frequency alternating drive voltage. This is not practical. The feeler could be a thick needle used to sew thick materials. In any case the feeler will represent the touch element of the probe and the nominal mass of the mass spring system. The mass of the needle will lower the resonating frequency of the system and allow much less difficult frequency tuning. The feeler should not be too thick either. We want the deflection of the vibrating needle to, preferably, reside in the micrometer range.

So, regarding the layout, the disc is fixed/clamped at the edge of one end with a large thick needle attached to the other. There are several ways to attach the feeler. Gluing is not advised as the glue is usually not stiff enough to acoustically couple the materials.

That leaves soldering or clamping. Clamping requires a screw and boss which might add too much mass to the system. Soldering allows for a very good acoustic mechanical coupling but introduces heat to attach the materials. Still, when done correctly it is an effective way to attach the feeler.

To drive the piezo (~Vin) you will need some basic electronics such as a frequency generator which produces a steady and consistent sine wave and a scope to monitor feeback from the piezo. The alternating voltage to drive the piezo will reside at about 30 Volts and the frequency will be in the KHz region and up. The exact frequency of the mass spring systems resonating frequency will need to be found. This is achieved by monitoring the voltage amplitude output of the smaller region of the piezo disc (Vout). A frequency sweep using the function generator and a scope to monitor the voltage amplitude of Vout will need to be performed. You will notice that at a certain frequency the voltage amplitude from Vout will suddenly start to rise. This is the resonating frequency of the mass spring system. With this frequency known you could build a standalone mini frequency generator that allows some degree of frequency adjustment. The feedback (Vout) could be rectified and, with some basic electronics, produce a signal output that is compatible with your machine controller input. One last tip is to use very thin wiring soldered to the piezo so that the wiring does not induce harmonic reflections. The GND connection can be at the clamp.

While this article only provides the principle idea and no PCB's, CAD drawings, parts list etc. I think you get ***the point***.