Fat Finger Syndrome Solution Found with Finite Element Analysis

Samsung employs realistic simulation to design mobile device keypads for fewer typos

Anyone who's ever typed on a computer keyboard or mobile device keypad has experienced this: While aiming for one letter, you hit a different one on a nearby key. The result? Poor spelling, mangled messaging, an email you never should have sent. As electronic devices and instrumentation become increasingly compact, the search for a cure for "fat finger syndrome," as it is known in the industry, is becoming ever more urgent.

Flat touch screens operated by pressure sensors may be taking over tablet computers and smart phones, but keypads and keyboards are still widely used in many electronic devices. Desktop computers, laptops, some cell phones, remote controls, and appliances, such as washing machines and dryers, all still rely on the touch of a finger on a spring-loaded key.

At the Global Production Technology Center of Samsung Co., Ltd. in Suwon, Korea, engineers strive to stay ahead of the trends toward tinier keys and denser key layouts with each new model. "We are working to make products both smaller and easier to use," says Soo Hyun Park, Manufacturing Core Technology Team, Global Production Technology Center at Samsung, "so we want to reduce the amount of mistyping that can occur on the more compact keypads."

Samsung engineers decided to delve deeper into the fat finger phenomenon by examining the physics behind keystrokes, finger pressure, and strike angle to determine what can go wrong and how to make it happen less often. "Since keyboards will remain widely in use for the foreseeable future, we will continue to study the physical user interface to better understand the ergonomics of human-device interaction," says Park. Using Abaqus finite element analysis (FEA), they were able to cut mistyping errors from 35% to 7% with an intermediate prototype model of a QWERTY keypad, so named for the sequence of letters that run left to right on a standard type-key layout (see Figure 1).

Realistic simulation of the interaction between human fingertips and device keys enabled Park's team to identify the variables that lead to mistyping. "By systematically modifying the relevant design parameters, we could see which keypad configurations led to the least number of typing errors," he says.

Where the finger meets the keypad

When they first decided to tackle fat-finger physics, the engineers realized that they needed two different finite element models to realistically simulate the problem: one of a human fingertip and the other of a device key.

Nature has, of course, already designed the 'perfect' human finger configuration; Samsung needed to come up with an FEA model that could mirror it. "It was important to define the separate material properties of skin, subcutaneous tissue, bone, and nail in order to model the overall biodynamic response of the finger," says Park. Since most small-device QWERTY keypad users type with both thumbs, the engineers started from the thumb bone structure of a 178 cm (about 5 feet 9 ½ inches) tall male combined with exterior skin surface data from a 3D laser scan.

Basing their finger-parts' definitions on previous studies of human tissues, they queried the available material models in Abaqus for the properties and element types they needed to build their FEA model (see Figure 2, left). The nail and bone were modeled as linearly elastic, while the skin (epidermis and dermis) was assumed to be hyperelastic and linearly viscoelastic. The deeper subcutaneous tissue of the finger was represented by a biphasic

Figure 1. Prototype of an intermediate mobile personal computer (now discontinued) that was used in the Samsung keypad optimization study.

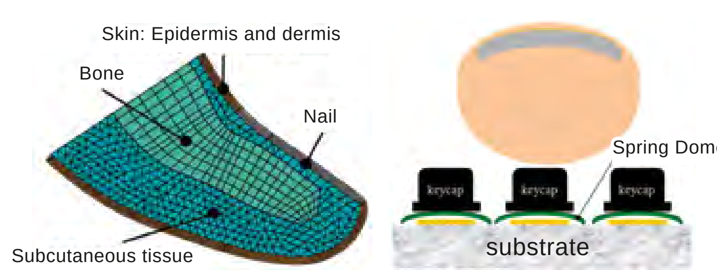

Figure 2. Abaqus FEA model of side view of a human thumb tip (left) and CAD model of finger contacting keys showing spring dome (right).

material composed of a fluid phase and a hyperelastic solid phase (essentially a sponge-like porous material representing muscle, fully saturated with fluid to represent plasma).

Next the team needed to create a virtual keypad where the interaction of fingertip and key could be simulated. When a key is pushed, it compresses a spring dome (see Figure 2, right) that completes an electronic circuit to register whatever symbol (letter, number, or punctuation mark) is on that key. As they meshed their FEA models, the engineers built in a nonlinear spring element beneath the key to simulate this action of the spring dome.

To capture the 'snap ratio', which is the tactile feeling that the user experiences when pushing down on a key, they lab-tested an actual spring dome with a load cell underneath it to record the pressure as the key was pushed with different degrees of force. They could then use this real-world spring stiffness data to characterize the response of the nonlinear spring element in their model.

Striking a balance between a host of variables

Now it was time to put thumb and key models together. By surveying users' real-world gripping and pushing behavior as they typed (they photographed 16 men and five women as they struck the 'K' key with their thumb), the engineers had pinpointed the average angle they wanted to use where the finger model hit the key model. This turned out to be 16.6 degrees from the front of the keypad and 16.4 degrees from the side. When the 'K' key was pressed, the force on the two neighboring keys on either side was calculated; the 'mistyping ratio' could then be defined as the force on the neighboring key buttons divided by the force on the target key.

The contact pressures predicted by the thumb/keyboard FEA model (see Figure 3) were compared with test measurements obtained through the use of an I-SCAN instrument (from Tekscan), which contained an extremely thin (0.1 mm) flexible tactile load cell sensor. There was good agreement between models and tests.

With a working FEA model of fingers striking keys now in hand, the engineers next turned to design optimization of the key layout. What side-by-side configuration of keys would produce the least mistyping? The team identified seven design variables:

- Width of key
- Height of key
- Vertical angle of key
- Pitch of key
- Inclined angle between center points of adjacent keys
- Reference face level of key
- Slope of key.

Each of these seven variables needed to be applied to the three keys being studied. "The Python script in Abaqus was very useful here because it enabled us to automatically carry out multiple, repetitive FEA-model tasks," says Park. The mistyping ratio of each analysis case was determined and then a response surface method was used to identify the optimum key position. The analysis revealed that the first five design variables all had pretty similar effects on mistyping, while the last two (reference face level and slope) showed stronger, yet contradictory, tendencies. Running through 27 sets of analyses, the engineers determined that the pitch of the keys on either side of the center key had to

Figure 3. Analysis of mistyping ratio.

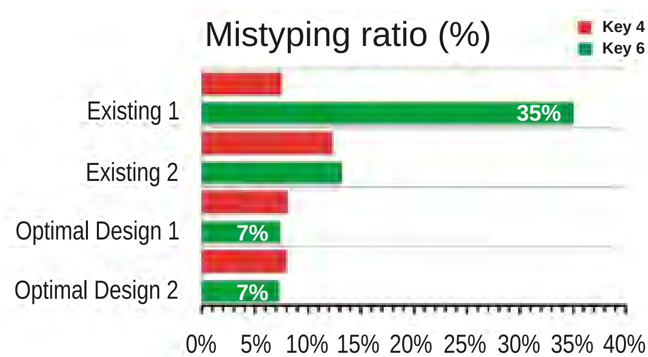

Figure 4. Previous prototype device keypad designs (top two sets of bar graphs) produced too much mistyping (an error rate as high as 35%). Optimal design 2 (bottom bar graph) showed the lowest overall mistyping ratio (7%).

be made greater in order to decrease the mistyping ratio. (Isight could now be used to automate the running and post-processing of these jobs.)

Using the results of their virtual finger/keypad optimization exercise, Park's team was able to systematically alter their key design variables and identify a design for which the mistyping ratio improved from a 35% error rate to 7% (see Figure 4). Again, the FEA results showed good agreement with subsequent experimental tests.

Going forward, Samsung engineers see value in developing hand, arm, and whole body models so that all aspects of the user's motion can be incorporated into device design. Says Park, "As human/device interfaces continue to advance, the use of FEA to model these interactions will contribute to reduced trial and error with the design process and improve the 'emotional' quality of our products."

About Soo Hyun Park

Soo Hyun Park is an engineer of Mechatronics & Manufacturing Technology Center for Samsung Electronics Co., Ltd. Since joining Samsung in 2006, he has developed new structural analysis techniques for the company using Abaqus, and he has managed many projects for electronic products. Park graduated with a M.S. in Mechanical Engineering from Seoul National University in 2006.

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