**////Title: Improving 3D Orientation Tracking in Gyroscope Sensors**

**////Standfirst:**

Gyroscopes are widely used to measure the orientations and rotation speeds of moving objects – but according to one pair of researchers, the techniques we currently use to measure them are introducing significant and easily avoidable errors. Through their research, Dr Sara Stančin and Dr Sašo Tomažič, both at the University of Ljubljana in Slovenia, introduce a mathematical framework which accounts for how all three rotations measured by a gyroscope happen simultaneously, rather than in a sequence.

**////Main text:**

Gyroscopes are important tools used for measuring the orientation and rotation speed of rigid, moving objects. Traditionally, they are made up of a spinning disc, mounted onto a circular support – which is free to rotate about the disc’s axis. The latest advances in technology have improved significantly on this initial design. Today, many gyroscopes are based on microscopic, vibrating mechanical elements, which are integrated with electrical components. Others are composed of optical fibres, and operate based on the rotation-varying interference of light.

When combined with accelerometers, gyroscopes have numerous applications across many different fields. Because they can measure changes in orientation and speed, they are essential components of many navigation systems, including those used on board ships, aircraft, space telescopes and planetary rovers. Gyroscopes based on microscopic electro-mechanical systems – or ‘MEMS’ – are used as motion sensors in smartphones, tablets, wearable fitness trackers and other smart devices. These MEMS-based devices can also be found in virtual-reality headsets, robotic vacuum cleaners and modern cameras.

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Despite the crucial roles that gyroscopes play in our modern world, Dr Stančin and Dr Tomažič argue that current techniques for interpreting their measurements are still far from perfect. The problem, they argue, stems from the ‘sequential’ interpretation of the measurements of the three gyroscope rotations – which are used to simplify the calculations involved.

Essentially, this approach breaks the apparent rotation of the gyroscope into three rotations around orthogonal axes, and assumes that these occur in a sequence: one after the other. In reality, the apparent rotation takes place about all three orthogonal axes simultaneously. So far, researchers have often assumed that breaking rotations into three-part sequences will give the same results as calculations of more realistic, simultaneous rotations – but this isn’t really the case.

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Through their detailed mathematical analysis, the duo showed that the sequential approach is likely introducing unnecessary errors to the measured orientation . These errors are fairly insignificant for small rotation angles, but can build up over time to have a significant impact on the accuracy of the end result. Researchers are already aware that errors exist in modern gyroscope measurements, but currently, they are mostly attributed to imperfections in rotation sensors, as well as random and unavoidable measurement noise.

Based on their theories, Dr Stančin and Dr Tomažič argue that in addition to these errors, the sequential rotation interpretation can be just as influential. Recreating their findings in real experiments, the pair proved that the simplified assumption of sequential rotations is a source of error in itself.

This error arises since rotations are generally not commutative, which means that changing the order of the successive rotations also changes the final orientation of the rotating body. Since there are six possible sequences of successive rotations about three axes, there are also six possible final orientations. However, none of these final orientations is correct if the rotations are simultaneous. As a result, the researchers explain that significant improvements in accuracy can be achieved by correctly assuming that rotations take place about all three axes simultaneously.

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Leading on from these discoveries, Dr Stančin and Dr Tomažič next aimed to establish a reliable basis for incorporating simultaneous rotations into the methods currently used to track the orientation of rigid bodies.

They showed that a gyroscope directly measures the three components of the rotation vector that is aligned with the rotation axis, and whose magnitude is equal to the rotation velocity. If the rotation axis does not change during the measurement, the final orientation of the object can be calculated in a single step by multiplying the rotation vector by the time interval of rotation. The vector determined in this way is called the simultaneous orthogonal rotation angle – or ‘SORA’ for short.

On top of this, SORA didn’t include any mathematical principles that greatly differed from existing, well-established orientation tracking techniques.

Ultimately, these results present a promising outcome – that the errors introduced by sequential measurements are easily avoidable. Dr Stančin and Dr Tomažič believe that SORA is well-suited to calculating the orientations of rigid, moving bodies in real time – a capability that could have far-reaching consequences for modern orientation-tracking systems.

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Today, gyroscopes are widely used in vehicles as diverse as aircraft, submarines, and cars; as well as in motion tracking in humans, and even robots. When used in combination with accelerometers, the instruments are often crucial for measuring the positions, velocities, and altitudes of moving objects over time – making it particularly important for their users to accurately quantify any errors in their measurements.

The researchers show that the errors in existing techniques can largely arise not from flaws in our sensors, but from the mathematical assumptions we make when interpreting their measurements. With this in mind, the accuracies in orientation measurements could be considerably improved.

Using SORA, this could be done with very little effort, and won’t require any major changes to the techniques currently used to calculate gyroscope rotation speeds. The duo now hopes that their discoveries could soon pave the way for new capabilities in the most cutting-edge of gyroscope technologies.

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This SciPod is a summary of the paper ‘Angle Estimation of Simultaneous Orthogonal Rotations from 3D Gyroscope Measurements’, from Sensors. doi:10.3390/s110908536

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