Measurement Method for Image Stabilizing Systems

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ABSTRACT

Image stabilization in digital imaging continuously gains in importance. This fact is responsible for the increasing interest in the benefits of the stabilizing systems. The existing standards provide neither binding procedures nor recommendations for the evaluation. This paper describes the development and implementation of a test setup and a test procedure for qualitative analysis of image stabilizing systems under reproducible, realistic conditions. The basis for these conditions is provided by the studies of physiological properties of human handshake and the functionality of modern stabilizing systems.

Keywords: Image Stabilizing Systems, Tremor, Handshake, OIS, VR, Anti-Shake, Shake Reduction

1. INTRODUCTION

In the photographic practice, whether digital or analog, the handshake of the photographer often results in a disturbing blur. In medicine, the phenomenon of rhythmic, involuntary muscle contractions, occurring in all healthy individuals, is known as physiological tremor[1].

Recently many camera and lens manufacturers have developed various stabilizing systems to compensate for handshake. The objective of our work was the development of a test method in order to evaluate the quality of image stabilizing systems. The measurement is based on automated, reproducible mechanical simulation of human handshake followed by resolution measurement of captured images.

In order to determine the basic test conditions, Bradley J. Davis' and John O'Conell's[2] method of amplitude measurement of human physiological tremor was adopted with regard to holding photographic cameras. The ascertained values were used for the tests.

The "Siemens SFR" (to determine the spatial resolution of digital cameras) is used for blur estimation in this work. This method was developed in cooperation between Cologne University of Applied Sciences and Image Engineering Dietmar Wueller, in the context of a diploma thesis by Anke Neumann. MTF describes a contrast decreasing extent in an output image compared to the test chart. The two methods to measure MTF described in ISO 12233 have several disadvantages. The visual evaluation method's results can vary depending on the person performing the measurement. The Spatial Frequency Response method (SFR) provides moderate results using consumer digital cameras if they have no access to the raw image data and if the automatic sharpening function can not be disabled[3]. The "Fit Method" uses Siemens stars which are periodically sine modulated in the radial direction. Due to the sine modulation the internal sharpening algorithms of a camera can be avoided. For more information about "Siemens SFR" please refer to a white paper by Christian Loebich[3] and a diploma thesis by Anke Neumann[4].

2. IMAGE STABILIZING SYSTEMS

The development of integrated image stabilizers started in 1980's. Many manufacturers undertook research in this area and invented various concepts for stabilization, like CCD-Shift or Digital Stabilizers. Handshake detection via integrated sensors, rapidly moving mechanical elements and digital signal processing with complex algorithms became state-of-the-art.

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2.1. Survey of the Systems

2.1.1. Control Technology

Two angular velocity sensors (gyros) – one for pitch- and one for yaw-axis are used to gather the information about the shaking of the camera. An additional positioning sensor (e.g. a magnetic hall-effect sensor) detects the current position of a movable correcting element. Out of the processed sensor data a microprocessor calculates the correction amount and direction and sends it to the control system. The control system generates the motion parameters for correction element and runs a voice-coil motor (VCM), piezo-element or another actuator, which is used to move this element.

2.1.2. Optical Image Stabilizer (OIS)

To compensate for handshake, this system, sometimes referred to as opto-electronic image stabilization, uses the optical path. A movable lens group or a prism with movable surfaces shifts the optical path in order to avoid blurring. The correction element's motion is perpendicular to the optical axis in opposite direction to the handshake. The moving force can be either produced by voice-coils or by piezo-elements.

2.1.3. Electromechanical Image Stabilizer (EMIS)

Electromechanical Image Stabilizing System (EMIS), also referred to as opto-mechanical stabilizer, also uses the optical path to compensate for handshake. But in contrast to the OIS, the specific feature of this system is imaging chip's movement to compensate for handshake. This way it is possible to use any lenses with the camera body equipped with EMIS. The movement is achieved either by electromagnetic or by piezoelectric actors.

2.1.4. Electronic Image Stabilizer (EIS)

The electronic image stabilization (EIS) does not use the optical path to eliminate the effect of handshake on image sharpness. Instead of correcting the image on its way to the sensor, this kind of stabilization uses software algorithms to process the pictures after they have been captured. Sometimes Electronic Image Stabilization is also referred to as Digital Image Stabilization.

One way to implement EIS is the Advanced Shake Reduction System (ASR) by Samsung. Two shots of a scene are taken for the stabilization – one blurred picture with the required slower shutter speed to acquire the color and luminance values and a darker one, using shorter exposure time with sharp edges. These two images are then processed by the camera software to reconstruct one blur-free picture out of their data.

Some manufacturers refer to electronic image stabilization in their cameras, which should suppress both motion blur caused by handshake and by moving objects in the scene. The background of these statements is the amplification of the image signal achieved by increasing the ISO speed. The effect is the shortening of the exposure time, which makes the influence of handshake almost imperceptible. A faster shutter speed also "freezes" the moving objects in the scene. Strictly speaking, this method can not be called image stabilization.

2.2. Gyroscopic Sensors

Gyroscopic sensors (gyros), also referred to as angular velocity or angular rate sensors, are inertial sensors. They use the property of bodies to maintain velocity (linear or angular), unless disturbed by forces or torques as described in Newton's law of inertia. The output signal of gyroscopic sensors is proportional to the rate of rotation. It makes them suitable for detection of rotative handshake motions in image stabilizing systems. The vast majority of stabilizing systems uses the benefits of such sensors.

Gyroscopic sensors have their origins in mechanical spinning mass gyroscopes, often used in aerospace applications. An essential part of these gyroscopes is a rotor on an axle which, once spinning, tends to maintain its position in space if the outside gimbals change. Since the invention of Micro Electro-Mechanical Systems (MEMS) and lithographic technologies, it is possible to miniaturize gyros and make them affordable. Another important reason for miniaturizing gyros is the vibrating gyros technology. No bearings are needed to support the mechanics because the rotor is replaced by a vibrating element. In general, a distinction is drawn between optical and mechanical gyros, whereas only mechanical ones can be miniaturized. That makes them interesting for consumer electronic applications such as image stabilizing systems in photographic cameras, camcorders or mobile phones. Various MEMS gyros architectures are available, using quartz, silicon or piezo-electrical ceramic for the vibrating resonator. The advantage of silicon is that it is more suitable for the Integrated Circuit (IC) Technology and the resonators are smaller than quartz ones.

Two separate single-axis gyros are mostly used to detect camera shake. In fact there are gyroscope ICs able to measure rotation of about up to three axes. Admittedly they are too expensive for consumer electronic applications.

The output of a gyro is measured in millivolts per degree per second (mV/deg/s). The sensitivity of MEMS gyros varies according to application range. For example the single-axis sensor used in Nikon Coolpix 8800 detects motion in a range of 0.1° to 1500° per second and outputs 0.66 mV/deg/s[5]. The power consumption of gyroscopes used in consumer electronics is lower than 10mW. They cost less then $10, having worldwide annual quantities of over 1 million pieces. Compound annual growth rate is about 15% (according to Yole Development & Wicht Technologie Consulting/Nexus)[6].

3. PHYSIOLOGICAL TREMOR

All humans, not only those with various diseases but even absolutely healthy individuals tremble more or less under certain circumstances[1]. In medicine this phenomenon is also known as tremor, which is the most common movement disorder. Tremor is a rhythmic, involuntary, oscillatory movement of body parts[7]. It can occur in isolation or as a part of a clinical syndrome. Tremor comes into being when muscles contract and relax repetitively. Involved body parts are usually hands, lower arms and head. There are more than 10 various pathological tremors[8]. Probably the best known tremors are symptoms of Parkinson's disease or multiple sclerosis. Uncontrollable shaking movements mark these illnesses.

Healthy people also exhibit a so-called normal physiological tremor which is not pathological in its nature. Most people are unaware of this phenomenon, because it is usually not visible[7]. This kind of tremor affects both men and women regardless of their age. Physiological tremor can be classified as an action postural tremor which means that it occurs in action, while a limb (e.g. an arm) is maintaining position against gravity (e.g. holding a photographic camera).

Usually physiological tremor is not a problem and can't even be seen by the naked eye. But it can be exacerbated by some factors. First there are some medications (e.g. anti-depressants or anti-psychotics) which can intensify tremble activity. Some stimulants and toxins like caffeine also have similar effects. And finally there are physiological (e.g. narcotic or alcohol withdrawal, hypoglycemia) and emotional (e.g. excitement or fear) states, which have a negative impact on tremble as well.

3.1. Amplitude

Physiological tremor comes into being due to various factors such as mechanical-reflex system and external disturbance[2]. Many attempts have already been undertaken to measure tremor amplitude. There have been studies using accelerometers, digitizing tablets, methods that mimic micro surgical techniques and laser-based systems[2]. Many studies focused on single joints, such as the wrist, or did not study the case of a mechanical load held against gravity like holding a photographic camera. This fact makes a measurement necessary, which has been adapted to a specific tremor characteristic while taking photographs.

Our objective was to measure the amplitude of physiological tremor in the upper limbs exhibited by healthy people holding a camera in their hands. The methods should be as simple and comprehensible as possible. Six healthy people aged 17-35 years were studied. None of the subjects had visible pathologic tremor symptoms. No subjects were taking any medication known to suppress or exaggerate tremor. A laser penlight weighting 35g was used for this experiment. A DIN A3 landscape formatted target, consisting of a grid with 1x1 cm squares was used. In the middle of the target, a cross rule with millimeter-steps was used for further evaluation of the laser light path. The width of the laser light at the target was about 1 cm at the distance used in the study. The circles on the test chart correspond to the 0.2° to 1.0° deflection.

Two digital photographic cameras were used to observe the tremor amplitude under three different conditions. A Nikon D2X with AF-S Nikkor 17-55mm 1:2,8 G ED represented a heavy DSLR with an average size lens. In this case the camera is held with both hands and additionally stabilized by the head of the test person looking through. Nikon Coolpix 8400 was representative of a viewfinder camera and was used in two ways, aiming at the target through the viewfinder and using the LC-Display. In both these cases, the camera was held with one hand only. The difference between them was the additional stabilization by the head while using the viewfinder. Another digital viewfinder camera, HP Photosmart R927, was used to take photographs of the laser light path on the test target. Test subjects stood 10m from the target – far enough to achieve desired accuracy of measurements. They held the cameras either with both hands (DSLR) or with their dominant hand (consumer compact viewfinder camera), aiming at the center of the test target. The path of the laser light was captured with the HP Photosmart R927 fixed on a tripod. For measuring the maximum amplitude, an exposure time of 5s was chosen to integrate the light path deflection over a longer time period. Each person was tested under the three different conditions described above. The three trials were spaced at intervals of 3 minutes.

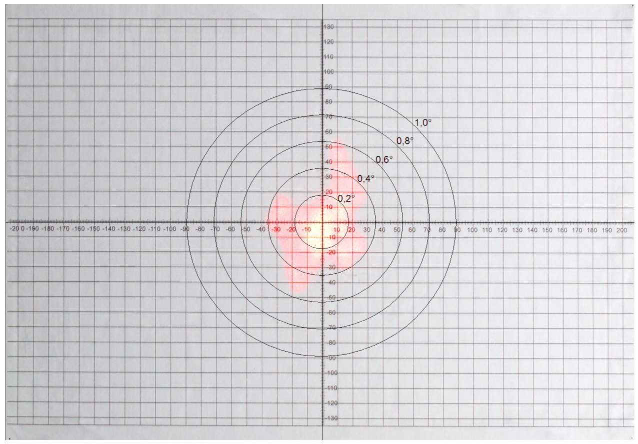

Figure 1. Example of a test image

The images were visually evaluated and the estimated angle values were averaged. After the evaluation, the upper bound for the required angular travel of the vibrating unit was set to 0.6°.

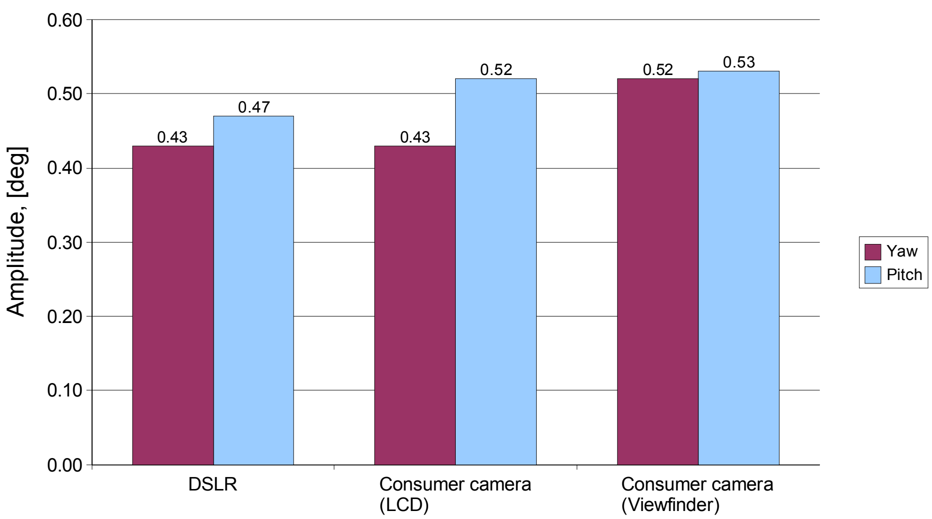

Figure 2. Mean values of the maximum measured amplitudes

The test method described above is generally applicable when measuring the maximum angular deflection holding a camera in the hand. The estimation of the amplitude of a single tremor oscillation is not possible due to the long time exposure of five seconds.

3.2. Frequency

The frequency of a camera shake can be derived from the properties of the physiological tremor. The medical literature[1] claims that the peak of the tremor activity is at about 8-12Hz. The measurements of the engineers by Panasonic[9] showed, that the frequency and amplitude are coherent. The higher the frequency of the handshake, the smaller the amplitude (Figure 3). This means that low and middle frequencies contribute more to the amount of handshake which results in blurred images. The researches by Ricoh[10] leaded to similar results. A diagram in a patent by Ricoh (Figure 4) shows a high-frequency oscillation (about 10Hz) overlaid by a low-frequency component (about 1-2Hz). This low-frequency component has much greater amplitude. This "1/f" characteristic of the handshake frequency has an effect on the choice of proper parameters for a test equipment.

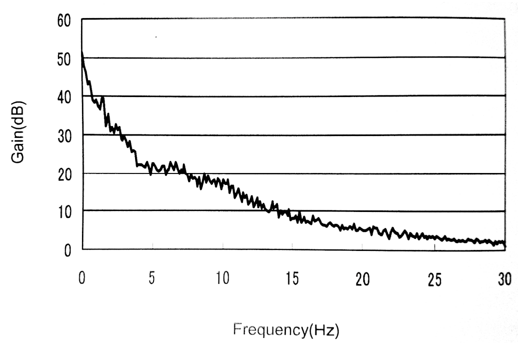

Figure 3. Analysis of image fluctuation frequency[9]

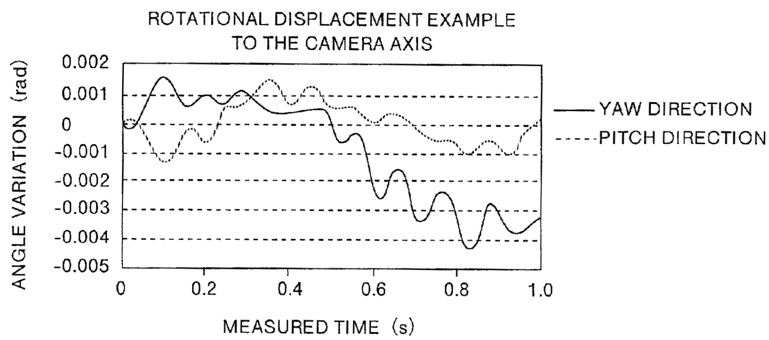

Figure 4. Angular camera displacement due to handshake[10]

4. TEST BENCH

Due to the considerations of the characteristics of the tremor and the functionality of image stabilizing systems a prototype of a test bench was designed. The vibration unit is designed for the reproducible simulation of human handshake. In connection with the measurement of the resolution of captured images, it is used to analyze the quality of stabilizing systems.

4.1. Specifications

The device shakes the camera in two defined directions (pitch and yaw) with user-defined frequency and amplitude. It is possible either to simulate handshake about two axes simultaneously or to use only one single motion direction. The controlling and parameter inputs are effected by the user via computer.

The vibration unit operates within the frequency range of 0...15Hz and is able to achieve angular motion amplitude of more than 1°. It suits both light weighted and heavy DSLR cameras and provides enough space to mount any kind. It is possible to adjust the mounted camera to match its center of gravity in order to achieve reproducible motion.

4.2. Realization

The vibration unit consists in general of two frames nested in each other. This construction allows the simulation of a handshake about the x- and y-axis (pitch and yaw). The frames are actuated independently. Due to this fact a variety of motions can be simulated.

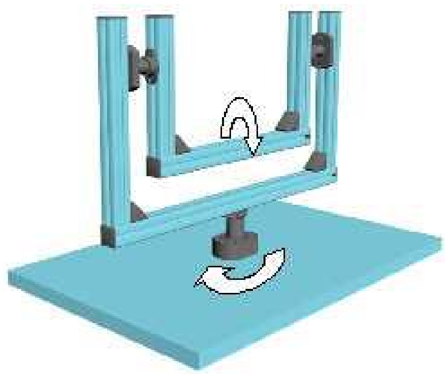

Figure 5. Vibration Unit

A closed loop control allows to actuate the frames very precisely due to high resolution position sensors. The additional advantage of using a closed loop circuit is the stability of the system. The chosen actuators are not limited in their precision. Figure 6 illustrates the stability of the motions. The horizontal offset of the curves is conditional on the characteristics of the feedback position sensors. It is of no importance for our measurements.

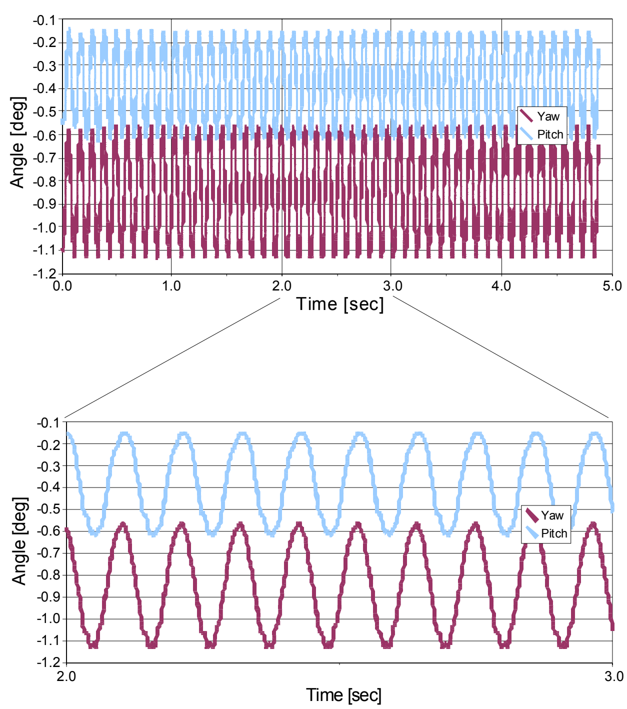

Figure 6. Path-time diagram of both frames at 10Hz and 0.5°.

5. TESTS

There are different approaches to realize a test row to get comprehensible results. Currently an MTF curve of a fixed and unmoved camera is calculated first. This provides a reference for the specific camera and lens combination. A measurement combining both varying amplitudes and frequencies is very time consuming. Therefore two possibilities are available – to vary the amplitude at a fixed frequency or to set a fixed amplitude and go over different frequencies. This is done for the switched off stabilizer as well as for every stabilizing modus since there are mostly more than one. For each image in a test row, independent of which component is being varied, the shutter speed is chosen according to the shake frequency. A complete single oscillation should be captured, this means e.g. testing at 10Hz requires a shutter speed of 1/10s. The ISO speed is set to 100 and the focal lengths of tested cameras should be similar.

The following charts show, how the evaluation is performed. Figure 7 illustrates the contrast behavior when the frequency is varied. The amplitude here was 0.2°. The influence of various amplitudes is shown in Figure 8. The frequency here has been fixed at 10Hz. Figure 9 shows the contrast values at 300 line pairs per image height. This is a more clearly arranged presentation of the values from Figure 7.

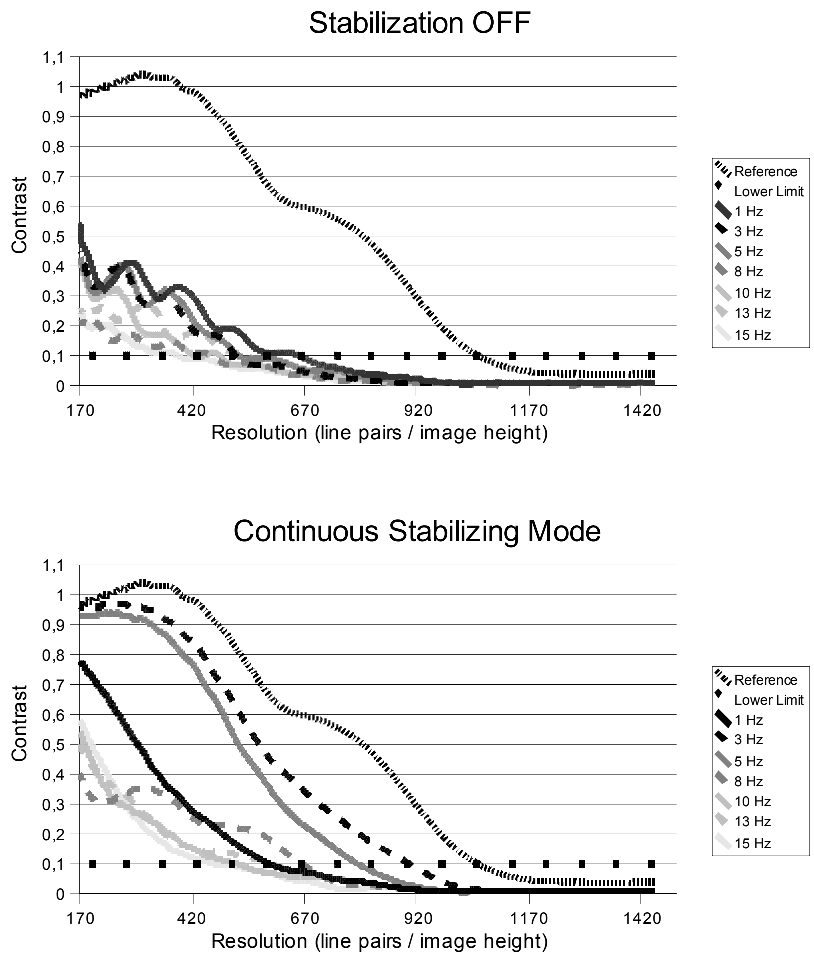

Figure 7. MTF curves (variable frequency).

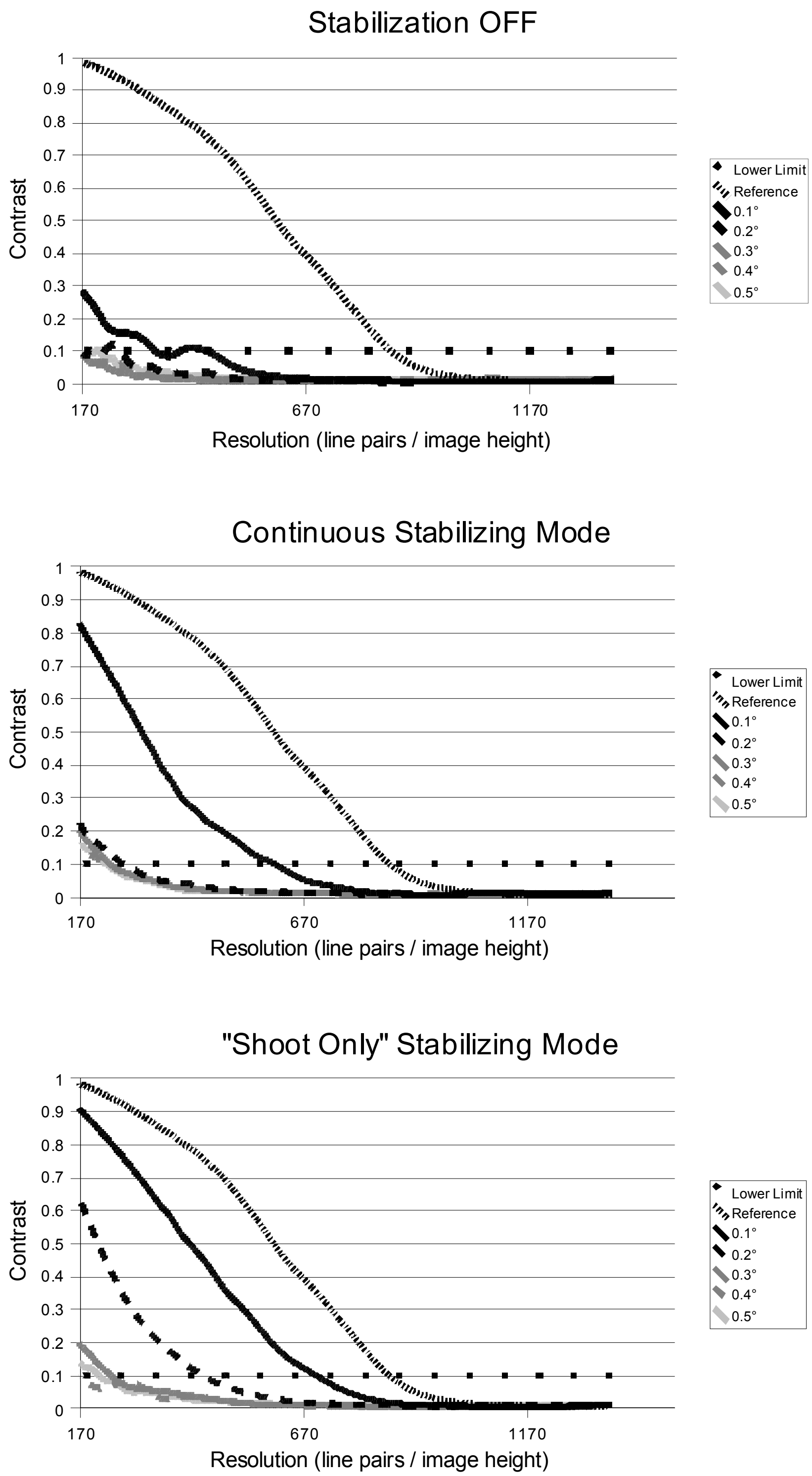

Figure 8. MTF curves (variable amplitude).

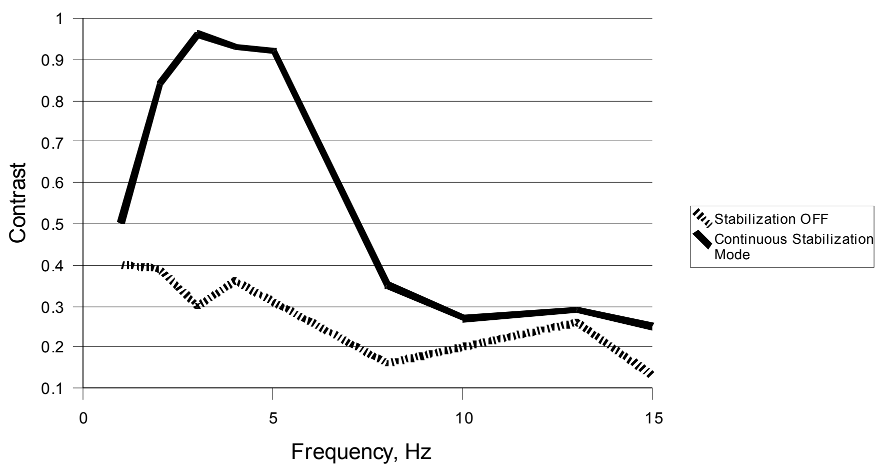

Figure 9. Contrast values at 300 line pairs per image height taken from charts in Figure 7 (variable frequency).

6. CONCLUSION AND DISCUSSION

Our aim was to develop a reliable test method for the measurement of efficiency of image stabilizing systems integrated into digital still cameras or lenses. An analysis of the functioning of recent stabilizing systems was performed. Further studies and measurements of human physiological tremor were carried out in order to define basic conditions for the tests. The gathered findings provided a basis for the design of a mechanical device simulating human hand tremor. A prototype device was constructed.

An improvement of the test method can be achieved when considering the suggestions below. First, more detailed examinations on different subjects with different camera types (DSLR and compact) should be performed to determine statistically firm handshake properties. In order to do this, some additional equipment such as an accelerometer would be necessary. An automatic release of camera's shutter would decrease the testing time, advancing the work flow. If connected to the control unit the shutter release can be actuated in the exact moment when the oscillation parameters (velocity and acceleration) conform to requirements. This would make the test results more comparable. An additional permanent effort of measuring the shutter delay would be caused by this improvement. This delay time must be considered when actuating the shutter release button. A graphical user interface (GUI) can be developed to simplify user parameters input and program updates of the control unit. Full automated tests combining automatic shutter release and controlling program, simulating different oscillation conditions in series, would be possible. A visualization concept for the test results can be developed in order to represent the acquired MTF values in one single chart. For example, a 3D surface chart, representing the dependence of the resolution limit frequency, providing only 10% of the contrast, on oscillation's amplitude and frequency.

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