LIQUID LENSES IN MACHINE VISION

Introduction

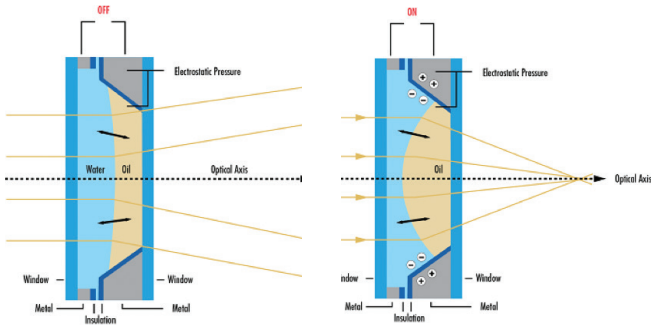
Liquid lenses allow imaging systems to overcome Depth of Field (DOF) limitations by allowing the focus to be electronically adjusted without requiring any mechanical movement. This can be a great solution for applications with varying object heights and working distances. Traditional solutions for these types of applications include motorized zoom lenses or physically repositioning the object to bring it into focus. Another way to increase the DOF in a traditional lens is to increase the f/# by reducing the aperture size of the imaging lens. However, this can also reduce the resolution and amount of light that gets through the imaging system, thereby increasing acquisition rates and reducing image quality. By integrating a liquid lens, an imaging system can change focus electronically without compromising speed or image quality, regardless of the object's distance from the camera. Like traditional optical lenses made from glass, liquid lenses are single optical elements, but are composed of an optical liquid material that can change its shape. The focal length of a glass lens is dependent on the material it is made from and its radius of curvature. The same basic principle applies to liquid lenses, though liquid lenses are unique in that they can change their focal length by altering their radius of curvature. This change in radius is electronically controlled and rapidly changed on the order of milliseconds. Manufacturers use technologies ranging from electrowetting to shape changing polymers to control the radius of curvature and index of refraction of the liquid lens. Both technologies and associated products are presented in the following chapters.

Most imaging lenses are multi-element assemblies because a single optical lens provides insufficient imaging performance. For this same reason, using a liquid lens by itself is ill advised. However, by integrating a liquid lens with an imaging lens in a multi-element design, the speed and flexibility of a liquid lens can be taken advantage of. Having the ability to focus both up close and to optical infinity in milliseconds makes integrating liquid lenses an ideal choice for applications that require focusing at multiple distances where the objects under inspection are different sizes or are at different distances away from the lens such as barcode reading, package sorting, security, and rapid automation. Liquid lenses can be used to maximize imaging system flexibility across a wide variety of applications requiring rapid focusing.

Variable Focus Liquid Lenses – Electrowetting

Variable Focus Liquid Lenses focus using a process called electrowetting, which is the application of electric fields to manipulate the wetting properties, and therefore shape and curvature, of a liquid. The liquid lens cell contains two immiscible liquids: a non-conductive oil and a water solution separated by an interface. Applying a voltage at the interface between the two liquids changes the curvature, and therefore focal length, of the lens within tens of milliseconds. Applying more voltage increases the overall curvature and optical power of the liquid lens. The Variable Focus liquid lenses' capacitive characteristics allows for stable operation in high-temperature environments once a thermal equilibrium is achieved. In addition, the two liquids within the lens have the same density, making the system insensitive to vibration and shock. Variable focus liquid lenses can be difficult to work with, as their small size makes them challenging to use with existing objectives. They are better suited to be fully integrated into optical designs, where their size is less of a limiting factor.

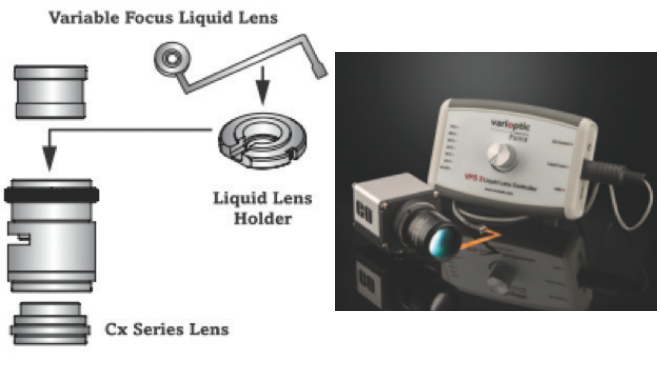
Figure 1



Integrating Variable Focus Liquid Lenses with Fixed Focal Length Imaging Lenses

EO´s TECHSPEC® Cx Lenses are fixed focal length imaging lenses with a unique, modular 3-piece design. The front and rear lens elements are separately housed allowing easy access to the center aperture stop of the lens. This allows users to easily integrate a Variable Focus Liquid Lenses into the center of the Cx Lenses. Available in various focal lengths, TECHSPEC® Cx Lenses provide the electronic autofocus working distance adjustment of a liquid lens with the image quality performance of a multi-element imaging assembly. The step by step diagram bellows explains how a Variable Focus Liquid Lenses can be installed in the Cx Lenses. In addition to controlling the liquid lens directly with a potentiometer, one can also use a camera that has all the necessary hardware already built-in. Both Pixelink and IDS offer such cameras. The liquid lens can then easily be controlled using the respective camera software package.

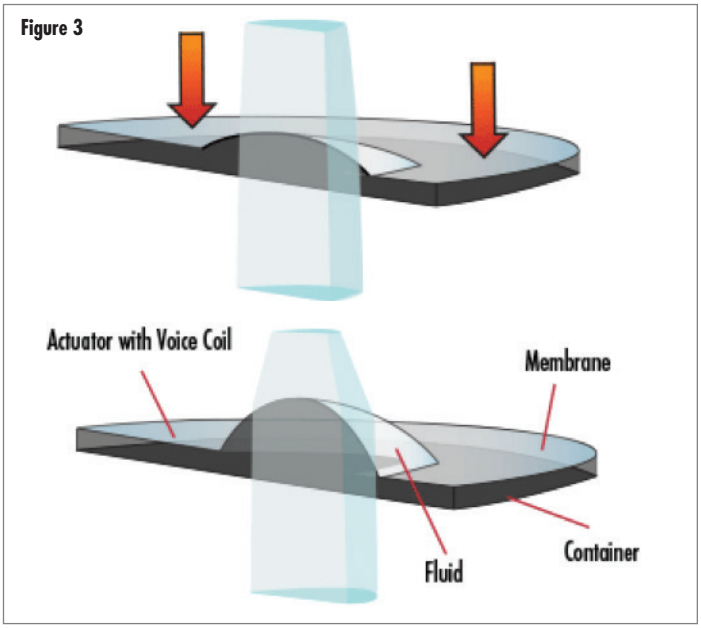
Figure 2



Focus-Tuneable Lenses

Optotune Electrically Focus-Tunable Lenses consist of an optical fluid-filled container sealed with a polymer membrane. A current-driven actuator exerts pressure on the membrane, causing the curvature of the lens (and therefore the optical power) to change. Due to their current dependency, electrically-focused tunable lenses function with low operating voltages and focus within milliseconds. These lenses do not alter polarization, have high laser damage threshold, and introduce minimal aberrations.

Figure 3



Integrating Optotune Focus-Tunable Liquid Lenses with Fixed Focal Length Imaging Lenses

Optotune Focus-Tunable Liquid Lenses are available with C-Mount housing. By using the appropriate thread adapter, the Optotune Focus-Tunable Liquid Lenses can be easily attached to the front of a TECHSPEC® C Series or Ci Series Fixed Focal Length Imaging Lens. Attaching a liquid lens to existing fixed focal length lenses can be useful in applications requiring a large depth of field. The liquid lens allows electronic focus throughout the focus range of the imaging lens. The step by step table below shows the appropriate imaging lens, adapter, and liquid lens combination required for various sensor sizes. Since the liquid lens is placed in front of the fixed focal length lens, it can become the limiting aperture and vignetting should be considered. The following table gives a good overview of the amount of vignetting, using the two differently-sized Optotune liquid lenses within different focal length imaging lenses for several sensor formats

Conclusion

Liquid lenses are innovative optical components that can be used to create powerful and flexible imaging systems. They provide the ideal solution for applications requiring rapid focusing, high throughput and depth of field and working distance accommodation.

By incorporating liquid lenses into designs from the beginning of the process it is possible to produce a whole range of high performance imaging lenses with unparalleled flexibility.

STEP 1: Select a Compatible Lens for Your Application (Recommended Examples Below)

Focal Length	Fixed Focal Length Lenses Applicable Stock Numbers	Camera Sensor Size											
		¼"		⅓"		½,5"		½"		¹⁄₁,₈"		⅔"	
		10 mm CA*	16 mm CA*	10 mm CA*	16 mm CA*	10 mm CA*	16 mm CA*	10 mm CA*	16 mm CA*	10 mm CA*	16 mm CA*	10 mm CA*	16 mm CA*
8,5 mm	#58-000												
12 mm	#58-001, #86-607 - #86-613												
16 mm	#59-870, #85-348 - #85-354, #85-336												
25 mm	#85-355 - #85-361, #85-337												
35 mm	#85-362 - #85-368, #85-338												
50 mm	#86-614 - #86-620												

*Liquid Lens Clear Aperture

Vignetting: Minimal/None | Moderate | Significant | Not Recommended