(Plenary Paper)

3D and Wearable Laser Displays

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Abstract: Display is the most important part of the human computer interface. Mobile smart devices use flat panel displays and have small screen size and limited brightness. Large screens are desired for many tasks and improve the productivity but they limit the mobility. Wearable displays and micro-projection displays enable large screen or wide field-of-view experience while keeping the display engine small. This paper review the various laser based wearable displays and head-mounted projection displays developed in our laboratory. By exploiting the polarization and coherence properties of lasers, we developed novel stereoscopic, super-stereoscopic, and auto-stereoscopic 3D display architectures.

Display technologies play a crucial role in human-computer interaction. Research has shown that people work more efficiently when they work with large screens. However, recent developments in mobile technologies have encouraged people to use and work with small-screen devices such as smartphones and tablets. We can say that the mobility offered by the miniaturized devices has won over the productivity offered by the desktop computers and monitors.

Figure 1 shows the familiar evolution cartoon with two additions by us to illustrate the current state of where things are in terms of displays and human-computer interface. In the future, we hope to have technologies that will help us stand-up again while interacting with the digital world.

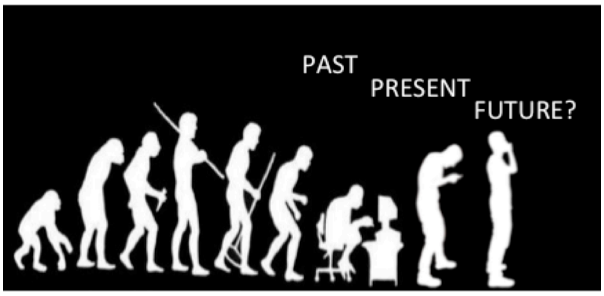

Fig. 1: Evolution theory of displays and human-computer interface. Expectation from the future is to stand-up again.

Despite various outstanding developments in recent years, mobile device displays suffer from two problems: limited miniaturization and light inefficiency. While all the electronic components are increasingly getting smaller and more powerful, smart phones cannot be miniaturized further due to the concerns related to the screen size (and keyboard size). Although the display consumes more than half of the energy of a mobile device, less than %0,1 of the light emitted by the screen enters into the eye pupil and forms an image on the retina. The remaining light is lost and illuminates the surroundings. While only a couple of hundred microwatts of light power would be adequate to see a bright image, the amount of power consumed by the display backlight unit is about 2-4 Watt. As the size and the field-of-view of the display increase, battery power consumption also increases, which makes the light efficiency problem even more serious.

Wearable devices are a good way to increase the light efficiency and decrease the battery power consumption. When the display panel is close to the eye, it naturally becomes more light efficient. Besides, use of passive or active micro-optical components to direct the light towards the eye pupil can dramatically increase the light efficiency.

Ensuring a larger field-of-view in a wearable display requires complicated optical design and lenses. New optical designs using freeform surfaces and waveguide relays helped with miniaturization of optics, but HWD design requires significant compromise in field-of-view, exit pupil size, form-factor, and resolution: they either have small form-factor but limited FOV (Google Glass, etc.) or have large FOV but they are heavy and large (military HMDs) [1].

Various types of wearable displays, head-mounted projection displays with 3D features have been developed in our group. Compact RGB laser diodes are used as a light source [2]. Polarization and coherence properties of lasers are exploited for 3D and focus-free operation. For 3D applications, we developed stereoscopic, auto-stereoscopic, and super-stereoscopic displays using laser scanning based pico-projectors. We also developed novel holographic projection displays.

Fig. 2 illustrates the major display and screen technologies developed with major contributions from our laboratory. Top row shows the wearable display product NOMAD (launched in 2004) and pico-projector product ShowWX (launched in 2009), which are some of the earliest laser based displays commercialized by Microvision Inc. The eyewear display is a recent project in our laboratory using novel light modulators and optical techniques.

Second and third rows in Fig. 2 show other demonstrators that use lasers and MEMS scanners. 3D PicoP is a stereoscopic 3D display using one pico-projector and a polarization rotator that changes the polarization of lasers in between frames [3]. Dynamic pupil tracker is an auto-stereoscopic display using a head-tracker and a rotating screen including retro-reflectors and a vertical diffuser to provide high-gain [4]. 3DHMPD is a head-mounted projector using a stripped off version of a pico-projector that is viewed with high-gain using a retroreflective screen. AR bidirectional screen is a semi-transparent screen that has very good visibility and transmission and can be used from both sides simultaneously [5]. The screen consist of microlens array sandwiched in between layers of UV curing epoxy. Multi-viewer 3D uses an array of pico-projectors to provide multi-user and multi-view without requiring glasses [6]. Finally, super stereoscopic glasses are used to provide two perspective images simultaneously to each eye to overcome the conflict between the convergence and accommodation in regular stereoscopic displays, providing more natural 3D [7].

Acknowledgement

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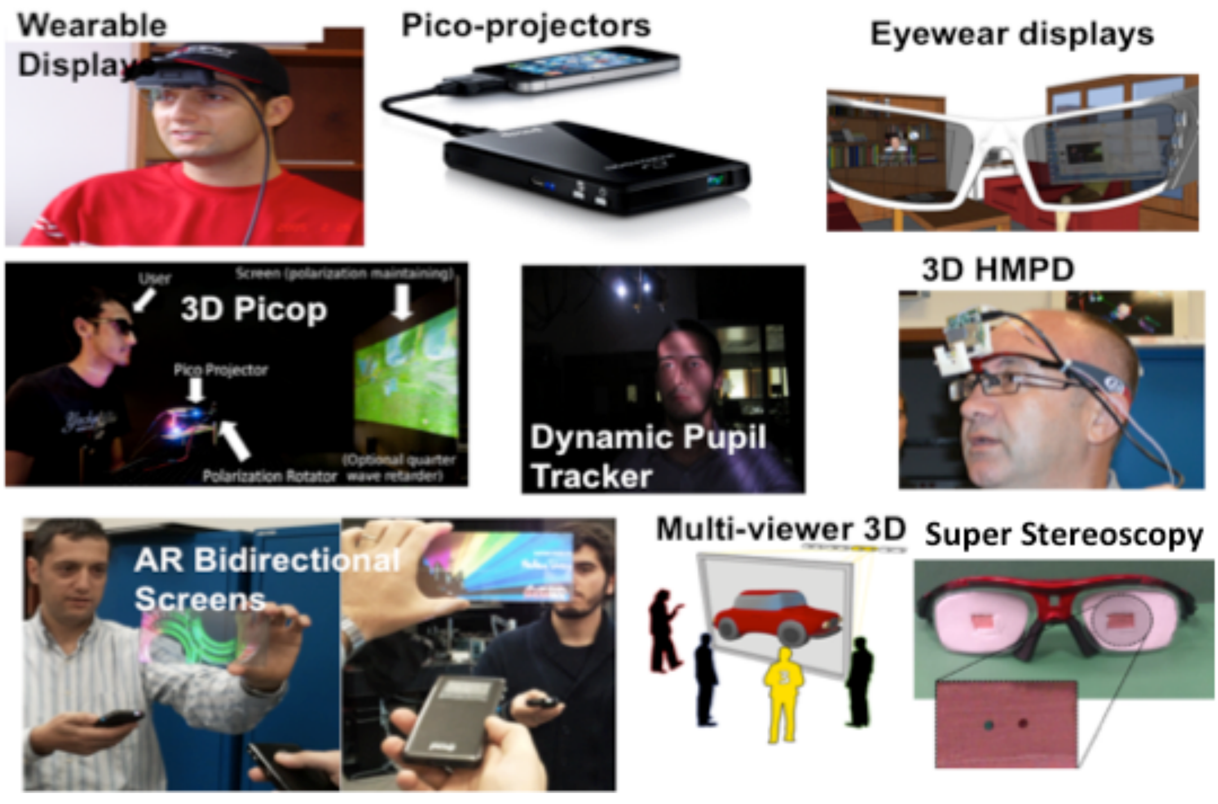

Fig. 2: Various display and screen technologies studied and developed in our laboratory using laser scanners and pico-projectors.