MAR12-2011-003828

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Bio-Inspired Adaptive Coloration – Knowledge Gained by Comparison of Nature and Man-Made Technologies

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Adaptive coloration, achieved through the use of pigments and reflective surfaces, is used by biological organisms to resemble natural surfaces and/or vividly communicate information. The key to this approach is that light incident on the organism is manipulated to perform the adaptive coloration (i.e., no light is created in the process). Only recently have man-made display technologies (E-paper) attempted to achieve similar adaptive reflective properties. For biological organisms, as well as display technologies, the following features must be controlled simultaneously while minimizing optical losses: pattern, texture, multiple colors, diffuseness, reflectance, and polarization. Many e-Paper technologies have attempted to duplicate optical effects that are utilized in nature. However, to date, they fail in comparison to the optical performance of biological systems. Thus, engineers working on adaptive reflective surfaces may benefit by examining equivalent biological systems in greater detail than previously achieved. On the other hand, intense research and development into adaptive reflective surfaces has given us a mature understanding of the optics of man-made surfaces, and the advanced measurement standards required for scientific involvement. Although this framework currently exists, it is underutilized for the analysis of biological coloration. To advance the field of adaptive coloration, the gap between biology and engineering must be bridged by developing a consistent framework of scientific metrics important to the performance of all platforms of adaptive reflective surfaces. In this presentation, the optics of adaptive coloration are presented in detail. Biological and technological methods are compared based on the construction, physics, and optical performance of each type of adaptive coloration. These comparisons are discussed at the system (organism), device (organ), and pixel/materials (cellular) levels. The main outcomes of this investigation are: display engineers gain insight from techniques perfected in nature; biologists benefit from an understanding of the types of characterization and metrics that could be extracted from biological organisms; and all scientists gain a clearer picture of the long-term prospects for adaptive reflective technologies.