MM2090

Assignment 4

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2.1 Snell's Law

Snell's law is a formula used to explain the change in angle of movement of light when it passes through a surface bettween two differnt mediums. While the law is named after Willebrord Snellius, it was first accurately described by Ibn Sahl over 600 years before Willebrord Snellius It states that the sines of angles of incidence nd refraction is equivalent to the ratio of velocity in medium or equivalent to reciprocal of the indices of refraction.

2.2 Snell's Law equation

$$\frac{\sin(\theta_2)}{\sin(\theta_1)} = \frac{\nu_2}{\nu_1} = \frac{n_1}{n_2} \tag{1}$$

2.3 Terms in Snell's Law equation.

The terms in the equation are

- θ_1 - The angle of incidence (angle measured from the normal to the incident light)
- θ_2 - The angle of refraction (angle measured from the normal to the refracted ray)
- ν_1 - Velocity of light in the incident medium
- ν_2 - Velocity of light in the refraction medium
- n_1 - Refractive index of incident medium
- n_2 - Refractive index of refraction medium

2.4 Importance of Snell's Law

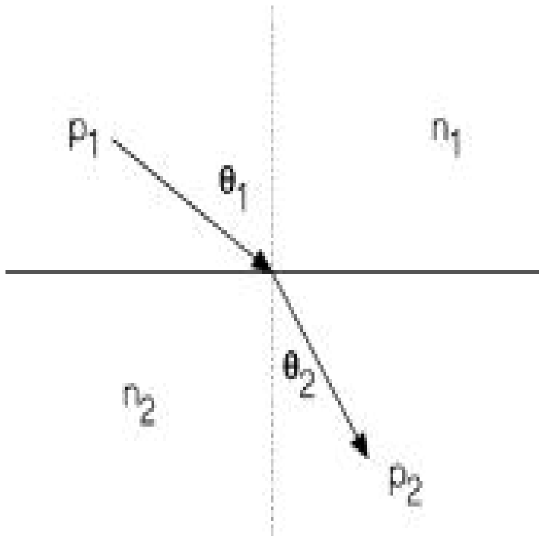

Figure 1: Light changes its direction of propogation as it passes through an interface of two diffrent medium

Snell's Law serves as backbone for Optics and related studies, with every application of refractive optics relying on this formula. It can predict the movement of light thorugh surfaces (refer fig.(1)) and this has led to countless applications. It is used while making lens for spectacles and experimental purposes.

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A Markov decision process [2] can be described as a tuple $\langle S, A, T, R \rangle$, where

- S is a finite set of states of the world;
- A is a finite set of actions;
- $T : S \times A \to \Pi(S)$ is the *state-transition function*, giving for each world state and agent action, a probability distribution over world states (we write $T(s, a, s')$ for the probability of ending in state s', gievn that the agent starts in state s and takes action a);
- $R : S \times A \to \mathbb{R}$ is the reward function, giving the expected immediate reward gained by the agent for taking each action in each state (we write $R(s, a)$ for the expected reward for taking action a in state s);
- A stationary policy, $\pi : S \to A$, is a situation-action mapping that specifies, for each state, an action to be taken.
- $V_\pi(s)$ is the expected discounted sum of future reward for starting in state s and executing policy π.

In this model, as described by figure 2, the next state and the expected reward depend only on the previous state and the action taken; even if we were to condition on additional previous states, the transition probabilities and the expected rewards would remain the same. This is known as the Markov property.

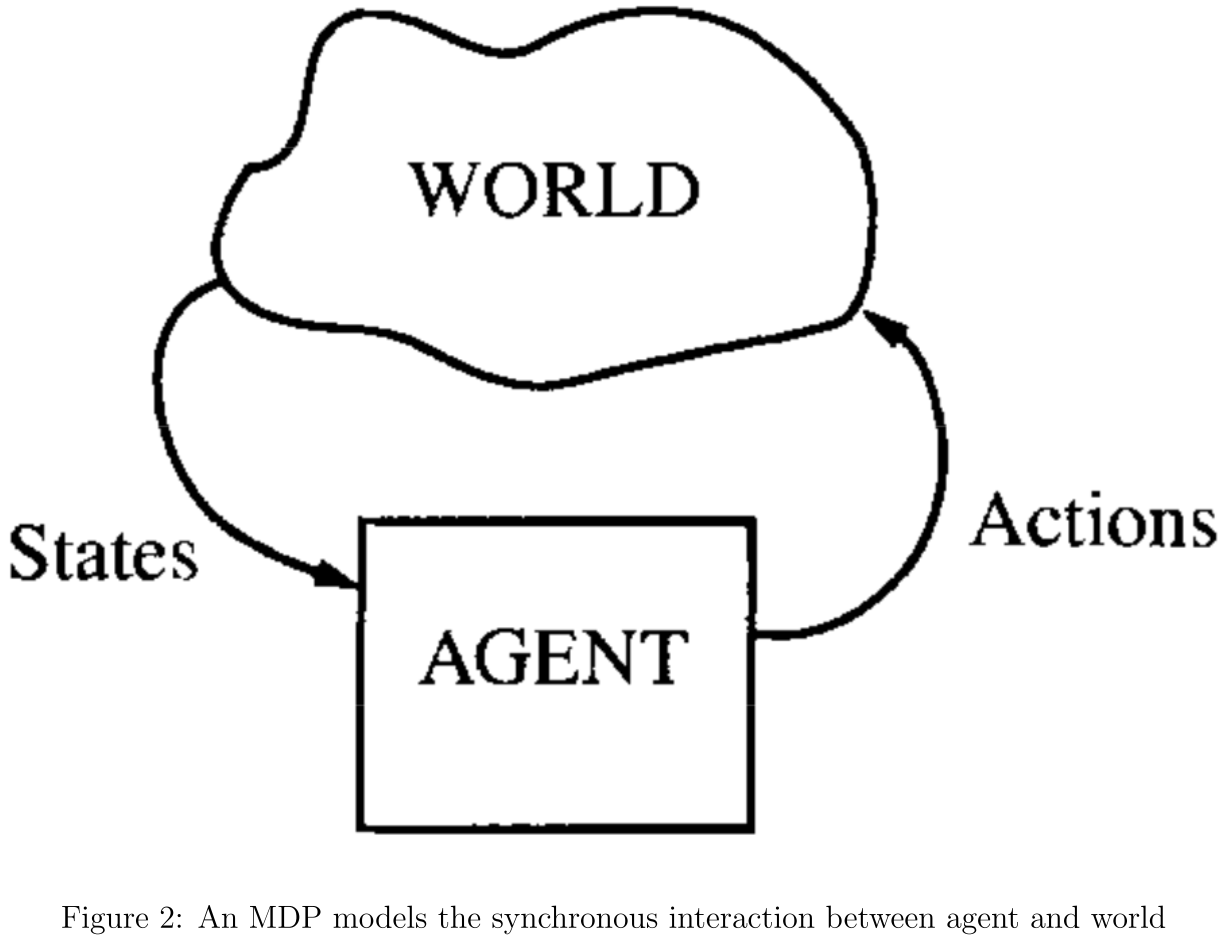

Figure 2: An MDP models the synchronous interaction between agent and world

3.1 The Value Function

$$V_\pi(s) = R(s, \pi(s)) + \gamma \sum_{s' \in S} T(s, \pi(s), s') V_\pi(s') \tag{2}$$

3.2 The Optimal Policy

Given the Value Funcition 2 a greedy policy with respect to that value function, π_V, is defined as

$$\pi_V(s) = \underset{a}{\operatorname{argmax}} \left[R(s, a) + \gamma \sum_{s' \in S} T(s, \pi(s), s') V(s') \right] \tag{3}$$

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$$\nabla \times \vec{B} = \mu_0 \vec{B} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t} \tag{4}$$

Eqn. 4 is commonly known as Maxwell's fourth electromagnetic equation. It is an expansion on Ampère's Circuital Law and is hence also known as the Ampère-Maxwell Law. Currently a more generalized form is used, which takes into account the behaviour and interference of material substances in eletric and magnetic fields [1].

4.1 Terms used in the equation

- $\nabla\times$ - Curl Operator
- $\vec{B}$ - Magnetic Field Vector
- $\vec{J}$ - Current Density Vector
- $\vec{E}$ - Electric Field Vector
- μ_0 (Constant) - Permeability of Free Space
- ϵ_0 (Constant) - Permittivity of Free Space

It is an important equation as it links two phenomena, which were previously thought to be separate, magnetism and electricity. It also finally proved that light is an electromagnetic wave, (as seen in Fig. 3 taken from a paper by J. Gratus, M.W.McCall and P.Kinsler [1]) leading to a whole new area and direction of research.

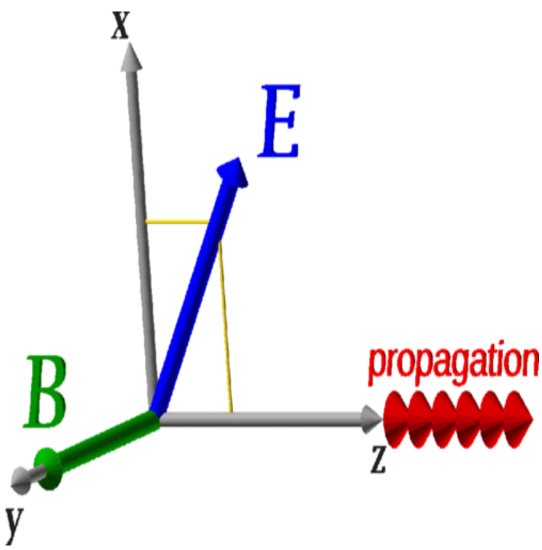

Figure 3: Propogation of Light with respect to magnetic and electric fields

References

[1] J. Gratus, M.W. McCall, and P. Kinsler. Electromagnetism, axions, and topology: A first-order operator approach to constitutive responses provides greater freedom. *Physical Review A*, 101(4), 2020. cited By 2.

[2] L.P. Kaelbling, M.L. Littman, and A.R. Cassandra. Planning and acting in partially observable stochastic domains. *Artificial Intelligence*, 101(1-2):99–134, 1998.