Wildlife GUARDSS: Using Uncertain Real-Time Information in SignalingGames for Sustainability

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Mobile sensors, e.g., unmanned aerial vehicles (UAVs), are becoming increasingly important in security domains and can be used for tasks such as searching for poachers in conservation areas (Fig. 1). Such mobile sensors augment human patrollers by assisting in surveillance and in signaling potentially deceptive information to adversaries (Fig. 2), and their coordinated deployment could be modeled via the well-known security games framework. Unfortunately, real-world uncertainty in the sensor's detection of adversaries and adversaries' observation of the sensor's signals present major challenges in the sensors' use (Fig. 2). This leads to significant detriments in security performance. We propose a novel game model that incorporates uncertainty with sensors. The defender strategy in this game model will consist of three interdependent stages: an allocation stage, a signaling stage, and a reaction stage (Fig. 3). We represent these using six states (Fig. 4). We design an algorithm, GUARDSS, to solve the game model and provide some experimental results (Fig. 5).

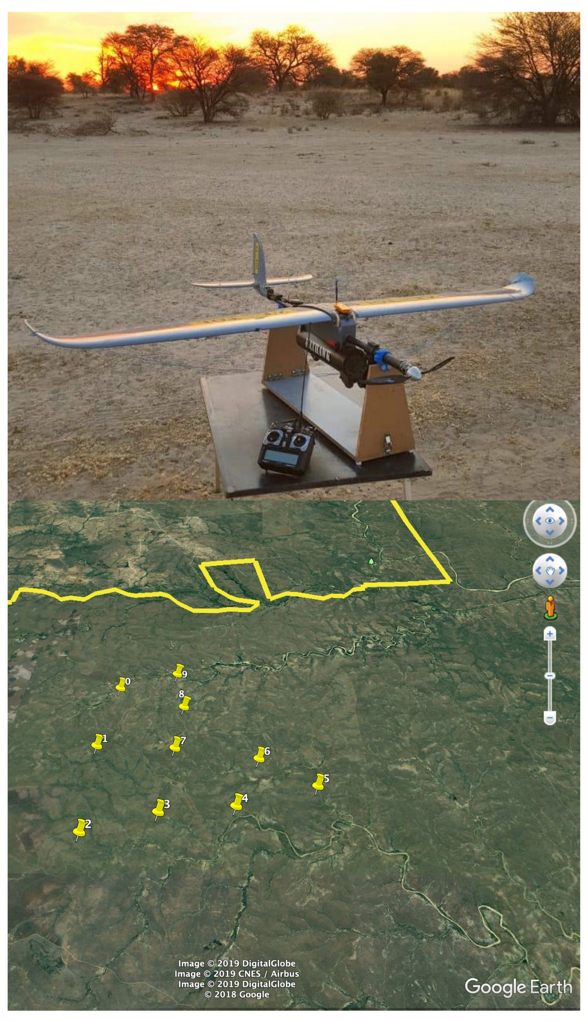

Fig. 1: Conservation drone and protected area in Africa where it is deployed. The points represent potential poaching locations.

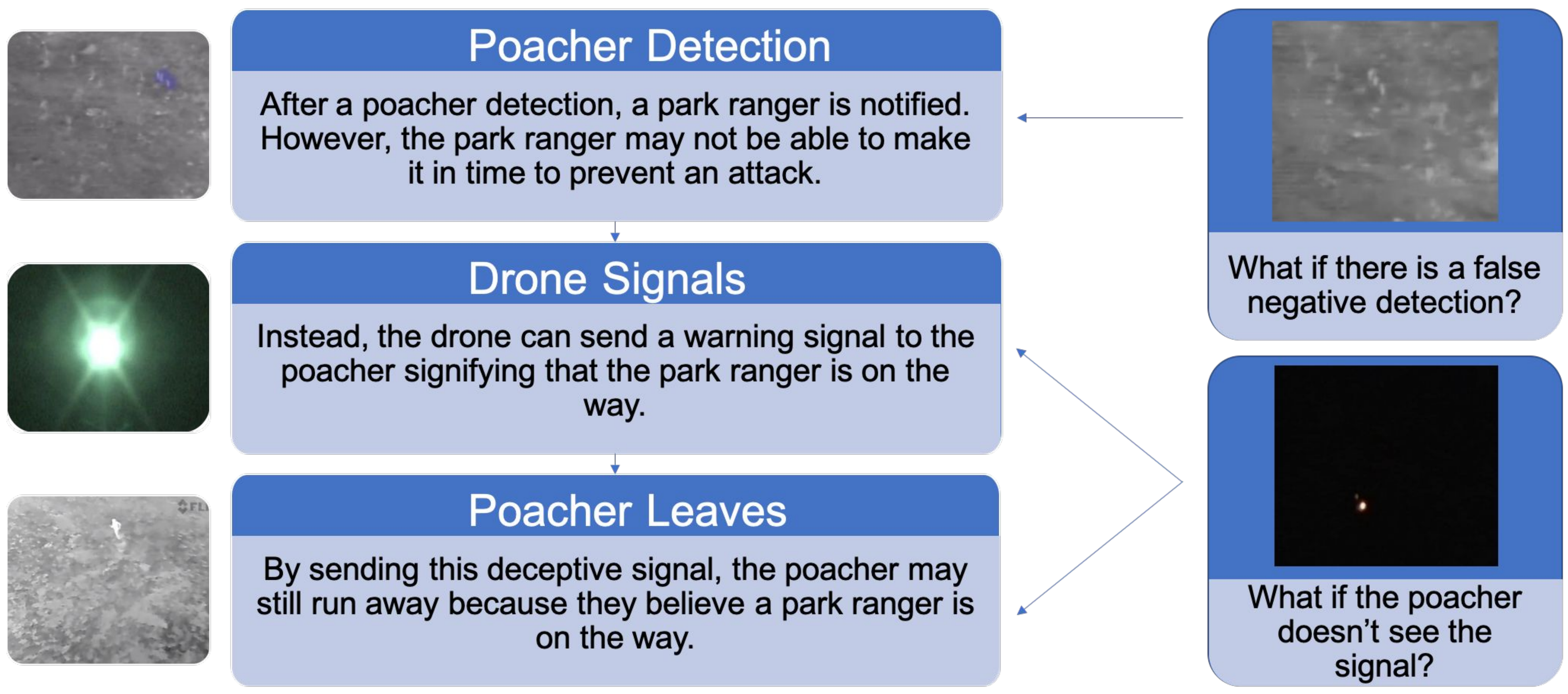

Fig. 2: In strategic signaling for conservation (illustrated step-by-step on the left), there is poacher detection, followed by signaling (emitting light) from the drone, and finally reaction by the poacher. During deceptive signaling, park rangers do not respond, but the poacher may still run away. However, this process may be complicated by uncertainty (right), such as missing a poacher who is actually present (false negative detection), or the poacher failing to see a signal.

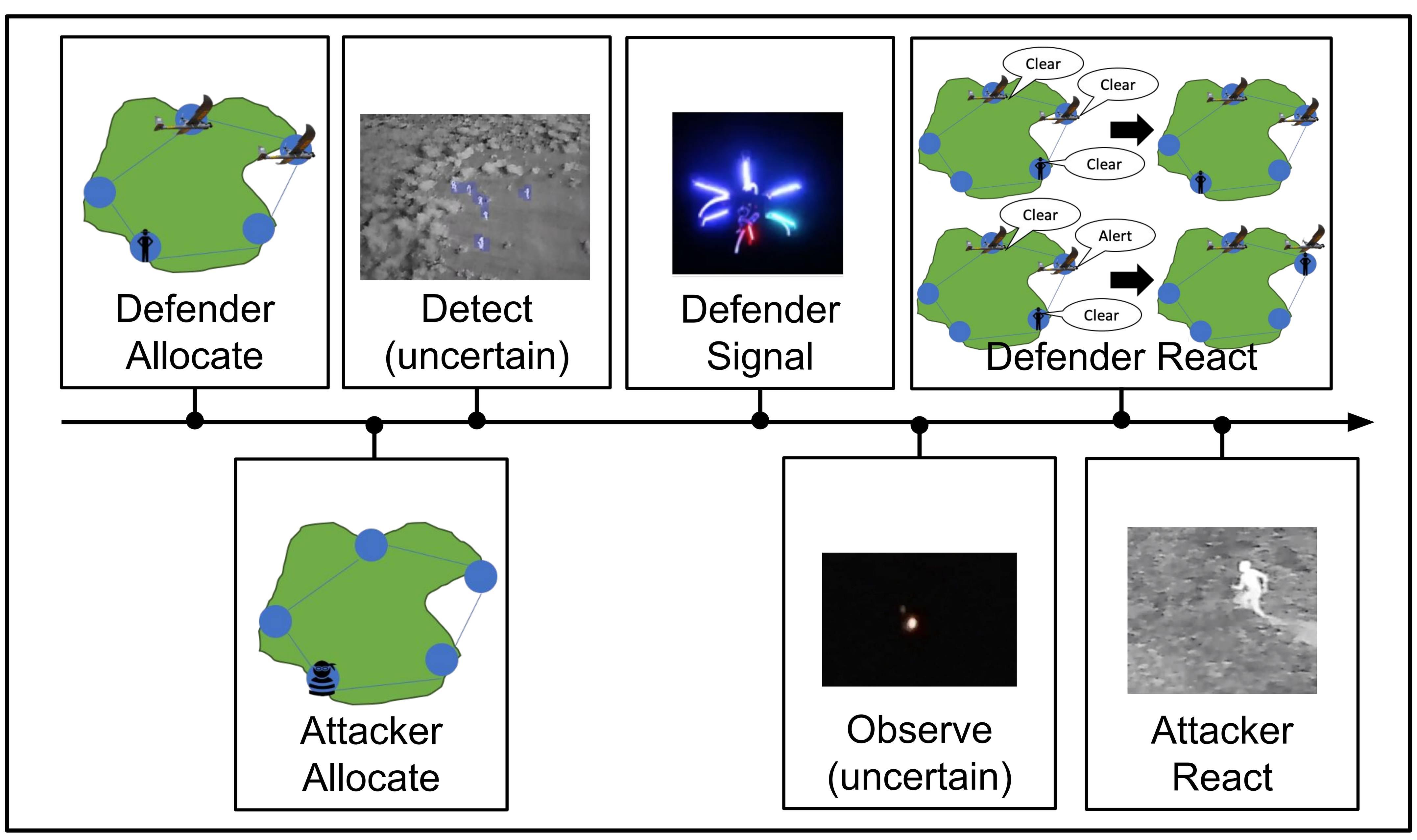

Fig. 3: Timing of the game model. (i) the defender commits to a mixed allocation strategy; (ii) the attacker chooses a target to attack; (iii) sensors detect the attacker with uncertainty; (iv) sensors signal based on the signaling scheme; (v) the attacker observes the signal with uncertainty; (vi) the defender re-allocates patrollers based on sensor detections and matching; (vii) the attacker chooses to either continue the attack or run away. If a sensor detects the attacker, then nearby patroller(s) (if any) always go to that target, and the game ends. If no sensors or patrollers detect the attacker, the patroller moves to another target to check for the attacker.

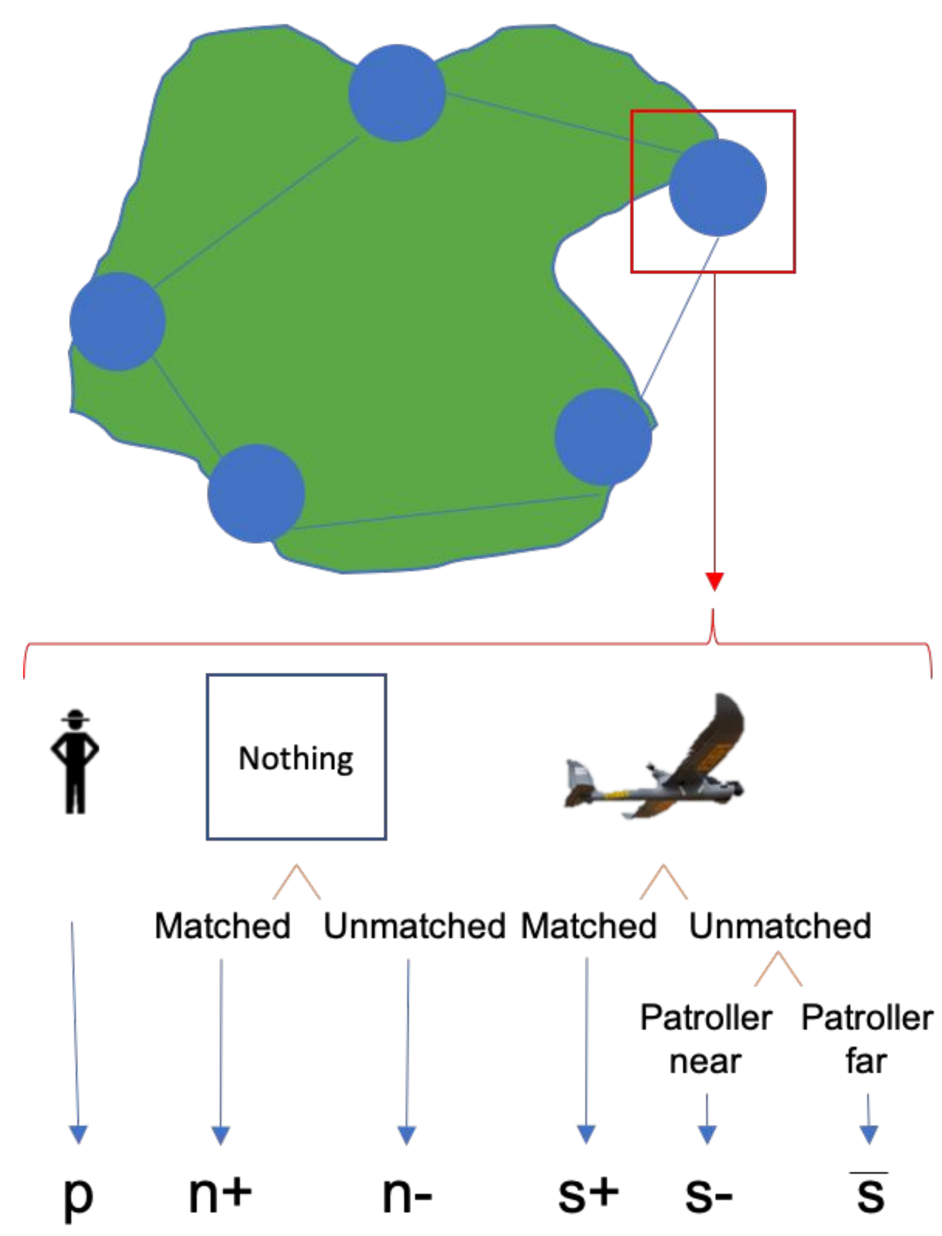

Fig. 4: Six state representation. The target is assigned a patroller (p), nothing (n), or a sensor (s). If no patroller is near a sensor (s), there is no response to a detection. If there is a nearby patroller, the target is either matched (n+, s+) (a patroller moves there in the reaction stage) or not matched (n-, s-). A patroller goes to s- targets on detection only.

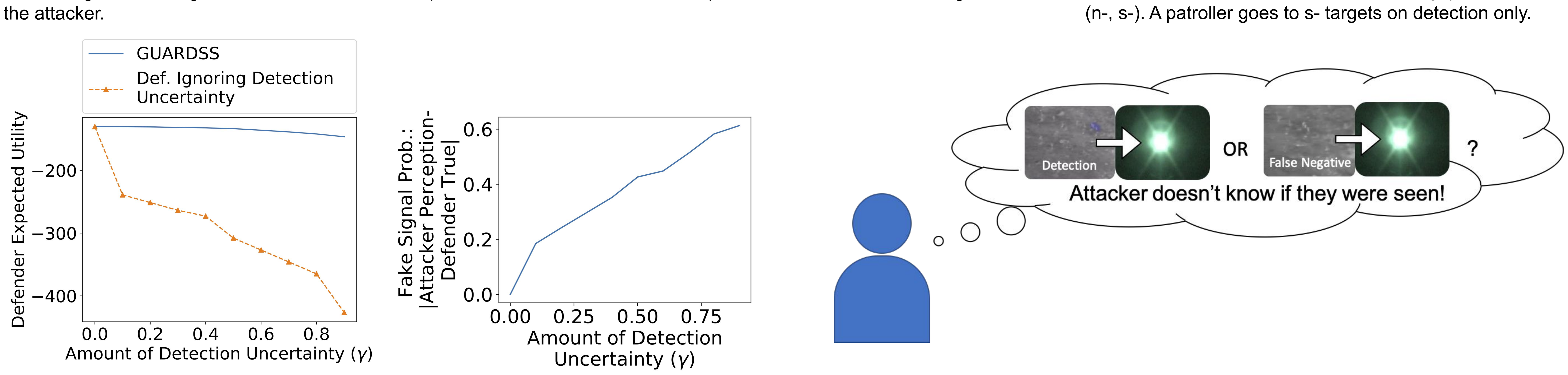

Fig. 5: (Left) shows defender expected utility when the amount of detection uncertainty (e.g., false negative rate, γ) varies. The defender expected utility is much worse when the defender ignores uncertainty, but improves when GUARDSS is used. (Middle and Right) When the attacker sees a signal, although he can calculate the conditional probability of seeing a fake signal, he does not know for sure whether the signal is due to a real detection or is indeed fake. The defender, however, knows whether it was a real detection. We illustrate this informational asymmetry by plotting the difference between the probability of seeing a "fake" signal given a warning signal (attacker's perception) and the probability of sending a fake signal (defender's true action). This difference increases as uncertainty increases, and hence results in the much smaller drop in defender utility in strategies from GUARDSS as detection uncertainty grows, than the drastic drop we observe in strategies generated when ignoring uncertainty.

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