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# Improving Evolved Communication with Imitation

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Abstracting the process of communication as a series of exchanges in a game whereby one or both parties may profit has led to a number of informative models of emergent communication. Moves transacted in this game are the selection of a topic and a signal to represent it by the speaker, and the interpretation of this signal as a topic by the listener; reward to each is based on the agreement between topics. This framework has been adapted for use in a formal analysis of evolved communication (Oliphant, 1997), in modeling emergent communication in a simulated population where the "topic" is a complex of local and global states (MacLennan & Burghardt, 1994), and as a protocol by which situated autonomous agents learn to communicate (Steels & McIntyre, 1997). In all these varieties of models, successfully sustained communication arises under the conditions of symmetric reward: speaker and listener benefit equally when they agree on the topic of a signal.

In many natural situations, however, the benefit to both communicating parties is not so evidently symmetric; typical examples are alarm calls and food announcements, which are apparently altruistic. In general, any signaling favors the receiver because the sender contributes some information without requiring a subsequent reward. This paper describes two implementations of simulated evolution with just such one-sided, receiver-only benefit. In the first, stable communication evolves, but with far below optimal quality, or with unnatural characteristics. The population may be partitioned into disjoint subsets which understand members of the opposing set, but not their own, or exploitative receivers arise which profit by listening, but send no signals of their own. An improved model is sought which still retains the natural reward bias for receivers.

Underlying the abstraction of the signal exchange game is the assumption that signal production and recognition are independent processes, separately represented, and incapable of influencing the other except indirectly through their mutual contribution toward evolutionary fitness. An alternative assumption is that signal form and content are not independent, but linked in a bidirectional (Saussurian) relationship which permits each process to more directly determine the other. Hurford (1989) showed that using this relation alone as a learning strategy (with no reward required) is strong enough to give rise to good, if not optimal, communication. One mechanism that may realize this bidirectional relation in nature is observational imitation: the pre-communicative young observe adult signal-response pairs and repeat them in later life.

A weaker, "unidirectional" form of this Saussurian assumption is proposed here, and examined in a second

implementation. A signal's content is permitted to condition the validity of its form, but only when the signal is received. This is done by modifying the initial model so that the sender selects a signal as usual for a topic, and agreement is then measured by how well it matches what the receiver would have sent in the presence of the same topic. In effect, the receiver takes the perspective of the sender in order to select its response. Reward in the form of increased fitness accrues to the receiver in proportion to agreement; the sender is always unaffected. The amount of this content-form dependence evolves along with the other aspects of the system, ranging from none at all (the same condition as the original model) to complete (the relation is always enforced).

This revised implementation always evolves toward maximal content-form dependence on the part of the receiver, which results in quantitative and qualitative improvements to the communication which emerges. Optimal communication, lost when symmetric reward was removed, is now consistently achieved, and anomalous patterns of communication no longer appear: a more typical system of communication emerges from more typical conditions of reward. The pronounced improvement is likely due to the fact that the receiver is not only the principal beneficiary in communication, but is also responsible for helping secure consistency between signal and content. In a natural system this unidirectional relation may be realized by perspective-taking imitation (Whiten & Ham, 1992) rather than observational imitation. The evolution of this type of imitation, then, may enable the development of effective communication without reliance on symmetric rewards.

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