Matthias C. M. Troffaes. Natural selection in aggregation or how evolutionary game theory may help in aggregating imprecise expert opinions. In *7th workshop on dynamics and computation, Iterated games and cooperation*, pages 35-6, Oct 2003.

NATURAL SELECTION IN AGGREGATION OR HOW EVOLUTIONARY GAME THEORY MAY HELP IN AGGREGATING IMPRECISE EXPERT OPINIONS PRELIMINARY THOUGHTS ON COMPETING EXPERTS

MATTHIAS C. M. TROFFAES

1. Introduction

This abstract connects two very distinct research fields: evolutionary games, and aggregating expert opinions described by imprecise probabilities. Indeed, evolutionary game theorists usually do not know about imprecise probabilities, and imprecise probability theorists have hardly ever heard of evolutionary games. Not surprisingly, there is no clear relation between the two fields. But, I argue that interaction between these fields might be promising. In fact, many very interesting issues arise when treating the aggregation problem as an evolutionary game. I discuss and try to overcome some of the conceptual difficulties that probably underly the non-existence of any literature connecting the two fields. Then I indicate how evolutionary games can be used to help aggregating *conflicting* opinions in a new, inspiring, and natural way.

Before starting my investigation, I feel that I must apologise for my extremely simplified and inaccurate discussion of evolutionary game theory, as I only very recently got to know about it. I however believe the discussion is sufficiently clear for imprecise probability theorists to understand the possible benefit of incorporating the idea of natural selection into aggregation.

2. Expert population as evolutionary game

An evolutionary game describes the process of natural selection using game theoretical ideas. Basically, the evolution of a large population of so-called *players* is studied. Each player repeatedly plays a *strategy*, and at every round, a player is replaced by a set of new players, called children, each child playing the same strategy as its parent did in the previous round. The number of children of a player is determined by (i) his own strategy, and (ii) the way strategies are distributed over the population. It is then studied how the distribution of strategies evolves through time. This model could describe for instance the evolution of an ecological system consisting of asexually reproducing animals and plants (players) with different types of genes (strategies), such as predator-prey systems.

This dynamical model can describe the expertise of a community of experts. Obviously, experts can be considered as players. The strategy of an expert consists of updating his "prior" expert model as he learns about other experts' opinions and new evidence provided by the world such as results of scientific studies, experiments *etc.* In this sense, any classical aggregation technique is an updating strategy. The children inherit the "posterior" expert model as their prior. The number of children is determined by how well the parent manages to make useful assessments, and avoids saying stupid things. (Children are not to be taken literally: they are understood to be new experts relying only on existing expert opinions in order to make assessments.) We take it for granted that more reliable experts are more likely to have more children.

3. Discussion, objections and possible resolutions

3.1. **Games, imprecise probabilities and the benefit of natural selection.** The idea of aggregation as an updating strategy is very old: it was used in the seventies, see for

This abstract presents research results of project G.0139.01 of the Fund for Scientific Research, Flanders (Belgium), and of the Belgian Programme on Interuniversity Poles of Attraction initiated by the Belgian state, Prime Minister's Office for Science, Technology and Culture. The scientific responsibility rests with the author.

instance [1], and has been heavily discussed in the literature, especially among Bayesians. Recently, a game theoretic approach to aggregating *imprecise* expert opinions was studied in [2]. In fact, already in the eighties it was argued that imprecise probabilities are much better suited to represent expert opinions than their classical counterpart [4], a belief that I share [3]. So the ideas of games and imprecise probabilities in aggregation are not new.

However, despite the vast amount of intensive discussions on aggregation found in the literature, there is no agreement on how expert opinions should be combined. The ultimate reason for this diversity is that what matters is not the exact method of aggregation, but how the aggregate is eventually *used*. I believe that the idea of natural selection might provide us with an interesting guide on what aggregation method is best for what use.

3.2. **Measures of competence through imprecise probabilities.** A competitive expert is able to make sufficiently precise assessments ("Saddam developed chemical and biological weapons in the '80s."), but at the same time not exaggerating the precision of this information ("He can now launch a nuclear missile within 45 minutes."). One *objective* way to assess expert competence is by comparing his assessments with a hypothetical perfect expert—one who knows everything that is going on in the expert field, and who is able to present us with an expert model that is both precise and reliable. Of course, such an expert hardly ever exists in the real world. (If he would exist, we would have no reason to rely on aggregation anyway.)

But my argument is that, in computer simulations, such a perfect expert can be introduced without any problem—although this expert remains purely hypothetical. The computer can easily compare any expert model with the hypothetical perfect model, derive a measure of expert competence from such a comparison, and favour the more competent experts through natural selection. In this way, evolutionary games provide us with a filter for competent strategies in a given expert environment—even if we do not know exactly how to measure this competence in reality because in reality no such perfect expert exists.

In fact, imprecise probabilities are the perfect candidate for comparing expert opinions. Because of their *unifying* character they are able to deal with many different expert representations, such as classical probabilities, belief functions, possibility measures, Choquet capacities, *etc.* in a consistent way. Moreover, imprecise probabilities provide a number of fundamental concepts that can be easily related to measures of expert competence.

3.3. **The use of simulating competing experts.** Studying the dynamics of this system might help us to describe the dynamics of expert information. Of much greater importance, it might give us insight into what aggregation methods are the better ones in a given domain of expertise. For example, should an expert only take into account new evidence provided by the real world, or should he also take into account beliefs of other experts? It might also give insight in what representations are best used in a given domain.

4. Conclusion

I identified a possible application of evolutionary games in aggregation. They might be used to trace the most competent expert strategies, or aggregation methods, in a given domain of expertise. Using linear-vacuous mixtures as expert models, and the imprecise Dirichlet model as an updating model, first simulations indicate that a simple population density weighted linear opinion pool performs generally the best, at least in the long run.

References

1. Peter A. Morris, *Combining expert judgments: a Bayesian approach*, Management Science **23** (1977), no. 7, 679–693.
2. Robert F. Nau, *The aggregation of imprecise probabilities*, Journal of Statistical Planning and Inference **105** (2002), no. 1, 265–282.
3. Matthias C. M. Troffaes, *Uncertainty and conflict: A behavioural approach to the aggregation of expert opinions*, Proceedings of 6th Workshop on Uncertainty Processing (WUPES 2003) (Jiřina Vejnarová, ed.), VŠE - Oeconomica Publishers, September 2003, pp. 263–277.
4. P. Walley, *The elicitation and aggregation of beliefs*, Tech. report, University of Warwick, Coventry, 1982, Statistics Research Report 23.

Onderzoeksgroep SYSTeMS, Vakgroep EESA, Universiteit Gent, Technologiepark Zwijnaarde 914, B-9052 Zwijnaarde, Belgium

E-mail address: Matthias.Troffaes@UGent.be