Appendix A

Glossary

The meanings and definitions given here are supplied purely as an aid for understanding the text of the thesis. They are not intended to be context free definitions of terms. Words in *italics* refer to additional entries in the glossary. Where appropriate, references are made back to more detailed explanations in the text of the thesis. Where another author's work is cited this refers to more detailed coverage of the concept which may be of use to the interested reader but is beyond the scope of the work presented here.

Agent: "An Agent is anything that can be viewed as *perceiving* its environment through sensors and acting upon that environment through *effectors*" [144], p31.

Altruism: Behaviour that is not consistent with being *selfish*. An example might be helping an unrelated individual reproduce at the expense of one's own reproductive success.

Artificial Life: An inter-disciplinary area of study which is concerned with the synthesis of life-like processes. Computational simulation models are often used as tools to explore such processes.

Artificial Society: A computationally implemented or simulated set of interacting *agents* within an environment that captures an abstract or possible societal state of affairs. This can be contrasted with a real society - actual societal states of affairs realised in biological substrates.

Bounded Rationality: Mechanisms of action selection which fall short of *rational action* due to computational, knowledge and/or time limitations (amoung others). Boundedly rational action is the result of applying *utility* maximisation *heuristics*.

C4.5: A machine learning classification algorithm developed by Quinlan [139]. C4.5 is the direct descendant of the original ID3 decision tree induction algorithm. The algorithm induces (from sample data) a decision tree which can be used to classify unseen data into one of a set of specified classes.

Co-operation: Co-ordinated action of several *agents* (minimally two) producing a beneficial result for each agent.

Culture: A set of beliefs, behaviours and norms propagated over time via social learning mechanisms.

Cultural Attribute: A term introduced by Alexrod [7] indicating cultural units (*memes*) which have no direct behavioural impact on the *agents* with which they are associated. Such attributes are essentially *tags*.

Cultural Evolution: The notion that culture may be understood as an evolutionary process.

Cultural Group: A set of agents hosting a set of common cultural units (*memes*).

Cultural Group Selection: The hypothesis that cultural evolutionary mechanisms can select for individuals that act for the good of the group and hence sacrifice self-interest. See *Group Selection*.

Darwinian Evolution or Algorithm: Any process by which *replicators* produce differential numbers of copies which include some degree of variation by random mutation. Over time, the *replicators* which make more copies will predominate. Sometimes such a process is characterised by the phrase "survival of the fittest".

Distributed Artificial Intelligence (DAI): The application of artificial intelligence to computationally distributed entities (see Jennings [97]).

Drone: A software utility for automatically executing a set of simulation runs systematically varying *exogenously* defined parameters over multiple machines and collating the results [11].

Egotist: See *selfish*.

Emergence: An observable phenomena or property of a system which is not easily reducible to the specified mechanisms which define the system.

Endogenous Parameter: An internal parameter of a system for which the value is derived from within the system.

Evolutionary Economics: A branch of economics which models economic actors as *optimising agents* in some evolutionary process. See Binmore [13], [14].

Evolutionary Process or System: Any process or system in which replicators are differentially reproduced based on fitness.

Exogenous Parameter: An external parameter of a system for which the value is set from outside the system. The internal processes of the system do not effect the value of such a parameter.

Explicit Fitness Function: The operation of a traditional *genetic algorithm* (GA) requires the specification of an explicit fitness function. The fitness function is applied to each *replicator* to determine reproductive success.

Exploitation: Some action(s) such that one *agent* (or set of agents) benefits at the expense of another agent (or set of agents).

Fitness: A measure of the reproductive success of a *replicator* in an evolutionary system.

Fitness Function: Some function applicable to a *replicator* which returns the fitness of the replicator.

Game Theory: A body of theory founded by von Neumann and Morgenstern [160] used principally by economists to determine the best possible strategy an agent can choose in a given *game*. Games are defined as utility payoffs over the strategies chosen by all the agents in the game (at least two). The best outcome for any agent is that outcome which results in the greatest payoff. Since payoffs are dependent on the strategies selected by all agents in the game, in many games it is not always possible to determine a "best" strategy for all situations irrespective of other agents strategy choices.

Genetic Algorithm (GA): A method of evolution based loosely on genetic evolutionary mechanisms. Essentially (in the context of *agent* models) behavioural rules are reproduced and mutated based on some measure of reproductive success (a *fitness*

function). Additionally, forms of sexual recombination are often employed. See Davis [34] for more details.

Group Functional Behaviour. Behaviour by individuals which has utility for a group rather than just the individual. In an extreme form such behaviour may be detrimental to individual utility (i.e. involve *altruism*). It is often argued that *group selection* may produce this kind of behaviour.

Group Selection: The hypothesis that evolutionary selection can occur at the level of a group rather than simply at the individual level. It has been used to explain the perceived *altruism* often observed within groups of animals and humans. Group selection selects for behaviours that are good for the group rather than the individual - *group function behaviour*. Recent writers have attacked this hypothesis in its application to genetic evolution [35].

Heuristic: A procedure or mechanism of action selection which is not certain to produce to best result (relative to goals) but is tractable and reasonable given the constraints and situation.

Hill-climbing: A *heuristic* optimisation method. A term applicable to many variants of local search which attempt to climb gradients in a space based on local information to optimise some target function. A simple form of hill-climbing is implemented in the *SampTool* software (see chapter 7).

Implicit Fitness Function: Any evolutionary process in which *fitness* is not explicitly defined a priori may be said to operate via an implicit fitness function. Such an implicit function emerges from replicator interactions with the environment and other replicators.

Individual Rational Action: The selection of an action (or set of actions) by an individual based on maximisation of individual *utility*.

Iterated Prisoner's Dilemma (IPD): The repeated playing of the *Prisoners' Dilemma* game between the same agents in one session. Repeated games allow for more sophisticated strategies (meta-strategies) to be applied by agents based on past interactions. For example it is possible to "punish" non-co-operative behaviour by reciprocating defection in future rounds. In such games and under certain conditions *reciprocal co-operation* can emerge. See Axelrod [5].

Kin Selection or Kin Altruism: The theory that selfish evolutionary selection can produce altruistic behaviours between individuals closely related to one-another, hence sharing many of the same genes. See Hamilton [79].

Label: see *tag*.

Macro Properties: Large scale properties of a system (e.g. the death rate in a society).

Meme: A unit of culture, a cultural *replicator* (a belief, behaviour or norm) passed between individuals via imitation or communication. Unlike genes, memes can be propagated horizontally within generations and between unrelated individuals. The word was originally coined by Dawkins [35].

Meme Bundle or Meme-Complex (memeplex): Some set of *memes* often found together and often transmitted together as a unit.

Memetic Kin: Individuals who may not be genetically related but who share some "significant" number of *memes*.

Memetics: The study of memetic processes (see *memes*).

Micro-Macro Link: The linkage between *micro properties* and *macro properties*.

Micro Properties: Small scale properties of a system (e.g. individual circumstance leading to individual death in a society).

Multi-Agent Systems (MAS): Systems which comprise a number of interacting *agents*.

Neural Network: A computational method of mapping input patterns to output patterns. Neural networks are loosely based on theories of physiological brain organisation. They are subsymbolic adaptive systems which "learn" mappings between input and output patterns.

One-Shot Prisoner's Dilemma: A single game of the *Prisoner's Dilemma* (as opposed to the *Iterated Prisoner's Dilemma*). A one-shot game precludes the application of more sophisticated meta-strategies.

Optimising Agent: An agent that always attempts to maximise its utility. This can be contrasted with a *satisficing agent*.

Patch Based Model: A series of mathematical models developed within evolutionary biology which denote the movement of organisms between distinct "patches" in an environment. Under various conditions of inter-mixing, migration rates and spatial topologies altruistic behaviour can be selected for by evolution [163], pp.110-116.

Prisoner's Dilemma (PD): A game theoretic (see *game theory*) abstraction of a social dilemma in which game interaction involves each agent selecting from two alternative strategies (either co-operate or defect). When all agents co-operate the overall payoff to all agents is the highest and is distributed equally. However, any agent which defects gains a relative payoff advantage at the expense of any co-operating agent. see

section 2.1.1 of chapter 2 for a more detailed description of the game.

Rational Action: The selection of an action (or set of actions) producing the maximum of *utility* (see *individual rational action* and *socially rational action*).

Rational Agent: An *agent* which practices *rational action*.

Reciprocal Altruism or Reciprocal Co-operation: The theory that apparent altruism can occur between individuals given that the altruistic favour is returned in the future. See Trivers [158].

Replicator: Some unit with the ability to produce copies of itself. Copies are deemed to be equivalent by some defined metric.

Replicator Dynamics: The assumption that for a given population of replicators of various types each type will increase in number by a quantity proportional to the product of the existing proportion of that type in the population and its fitness relative to the average fitness of the entire population. More formally in the context of a *game* where types represent pure strategies: $\frac{dz_i}{dt} = z_i \left[F(i) - \overline{F}\right]$ where z_i is the i^{th} pure strategy and $F(i)$ is the average payoff for all strategy i and $\overline{F}$ is the average payoff for the whole population. Such a simplified assumption does not take account of finite populations or mutation events. Essentially then, the assumption of the replicator dynamics is that any replicator which has fitness above the population average will tend to increase and conversely any replicator with below average fitness will tend to decrease. This assumption is generally applied to *agents* in *evolutionary economics*.

SampTool: A *Drone*-like software utility constructed for this thesis which additionally implements random sampling and *hill-climbing* over a set of *exogenously* defined parameters. See chapter 7.

Satisficing Agent: An *agent* that attempts to achieve a satisfactory level of utility rather than always to increase *utility*. Once a satisfactory level of performance is achieved the agent no longer attempts to improve on its performance. This can be contrasted with an *optimising agent*.

Selfish: A subset of behaviours which maximise individual *utility*. From an evolutionary perspective, where utility is equated with *fitness*, the units of evolution which predominate are those which out reproduce others. Given that mutation can introduce a selfish variant then non-selfish units are always susceptible to being out-reproduced by selfish mutants.

Socially Rational Action: The selection of an action (or set of actions) by an individual based on maximisation of the *utility* for a social unit. Such a form of action has been advanced as a way of sustaining *group functional behaviour*.

Social Learning: The acquisition of potentially useful knowledge, skills and behaviours from others within a society. This may be mediated via direct instruction or imitation.

StereoLab: An artificial society simulation model which implements a cultural evolutionary process of stereotype construction. The model is introduced in chapter 6 and experimented with in chapter 8.

Stochastic: A non-deterministic element (variable or process). In a computer model a stochastic process will generally be modelled by using a pseudo-random number generator.

SwapShop: An artificial society simulation model based around a cellular automata model of the spread of cultural attributes. This is an extension of the ACM [7] to include resource sharing behaviour. See chapter 5.

Tag: An observable (surface) feature attached to an agent. In the computational experiments presented in this thesis a tag is initially set to some arbitrary value but may evolve into something that comes to have meaning.

TagWorldII: An artificial society simulation model which captures a co-operation producing group formation process via biasing of *game* interactions based on *tag* similarity. See chapter 9.

Trust: The concept that an agent may expose itself to exploitation by another in order to achieve *co-operation*.

Utility: A measure of the value of one or more actions to an agent (or set of agents). In the context of *Darwinian evolution* the *utility* of some action is proportional to the fitness gain it produces. In a more general context, the utility of an action to an agent may be determined as the contribution of the action to the achievement of some goal (or set of goals).