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Curricula of the course on modelling behaviour of human and animal-like agents

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Abstract

Intelligent virtual agents (IVAs) are agents imitating behaviour of a human or an animal, graphically embodied in a 2D or 3D virtual world. In our university, we have established a novel interdisciplinary course, including a practical seminar, on modelling behaviour of such agents. The course focuses on action selection from the perspective of artificial intelligence, computer games, and ethology, but covers also various introductory topics from cognitive psychology and neurobiology. This paper details the curriculum of the course.

Introduction

Intelligent virtual agents (IVA) are typically conceived as software agents (Wooldridge, 2002) imitating the behaviour of a human or an animal, embodied in a 2D or 3D virtual world. First true IVAs started to emerge about a decade ago. Today, this field is becoming matured. Various kinds of applications feature IVAs, including commercial videogames games, serious games, industrial applications, cultural heritage applications, virtual reality environments for cognitive science research, and computational ethology simulations (see e.g. Orkin, 2006; Aylett et al., 2005; Magnenat-Thalmann et al., 2006; Burgess, 2002; Bryson et al., 2007, respectively; see also Prendinger and Ishizuka 2004). Consequently, the community is increasingly growing. As this happens, an issue how to educate its new members, in most cases undergraduate students, starts to demand attention (Brom et al, 2008). Educational issues seem to be well addressed by neighbouring disciplines, namely computer graphics, robotics, and software agents; consider e.g. the number of summer schools and introductory books available for these domains, the RoboCup platform, or the special educational track at the Eurographics conference. While the classes directly focused on IVAs have already started to emerge, and some of the class materials are available on-line, e.g. (Aylett, 2008; Dignum and Westra, 2008), the reports on advances in education directly related to IVAs are scarce.

In this paper, we describe the curriculum of a one-term theoretical course on *Modelling Behaviour of Human and Animal-like Agents* (Brom, 2008), highlighting main lessons learned from teaching perspective. The course was created in 2005 primarily for undergraduate computer science students, but it was also adopted for a high-school workshop and for a summer school. While primarily focussing on modelling behaviour of IVAs in the context of interactive entertainment applications such as videogames and virtual storytelling, the course also provides students with limited knowledge of cognitive and behavioural sciences, including theories of emotions, perception, and memory, natural neural networks, and basics of ethology, presenting a starting point for students considering studying these subjects in the future. As far as we know, there is no single book covering the whole curricula.

During 2008, this theoretical course has been augmented with practical seminar, during which students learn to program their own virtual characters. Students develop their characters for Unreal Tournament 2004 (UT04) (Epic, 2004), but instead of using Unreal Script, the native scripting language of the UT04, they use a special purpose toolkit Pogamut 2 we developed (Kadlec et al., 2007). Pogamut 2 was intentionally created to facilitate start with IVAs, both for educational and research purposes, and it is freely available to download[1].

The primary goal of this paper is to discuss the curriculum of the course in order to facilitate either development of a similar course or extending a course that is already running. In this respect, the paper is most similar to the work of de Melo et al. (2006), who reported on augmentation of a course on *Autonomous Agents and Multi-agent Systems* with a practical seminar using Counter Strike 3D game. We depart from this work in that our course is directly focused on *IVAs* behaviour and we use a different toolkit for the practical seminar.

The paper first details the background of the course and then focuses on its curriculum, highlighting the main lessons learned. The description of the teaching methodology and the general discussion follow in the complementary papery (Brom et al., 2008), which also reports on the curriculum of the practical seminar using the toolkit Pogamut 2.

The Course

Background. The course was created at Charles University in Prague at the faculty of Mathematics-Physics, the computer science study program, in 2005. From then, the course was taught every year in the summer term. The theoretical part of the course comprises 13 lesson units, one unit amounts to 90 minutes. In 2008, the practical seminar has been added (6 lessons units) (Brom et al., 2008). At the end, each student must create his/her own IVA, which presents about half of the student's evaluation.

The course is tailored to computer science students at least in their fourth term of bachelor studies, after they attended several courses on programming (10.5[2]), mathematics (17), general IT skills (8.5), and algorithms (5.5). Most of them have only limited knowledge of other topics. Many are recruited from technical high-schools. Every year, the course is attended by about 30 – 50 students (about 15% of the total number of students of one grade).

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1 The toolkit is available for download at http://artemis.ms.mff.cuni.cz/pogamut.

2 Normalised number of courses on a given topic; "1 course" equals 13 lesson units (i.e. 13 x 90 minutes). The course presented in this paper, with the practical seminar, amounts to 1.5.

Objectives. Objectives of the course are (1) to introduce the field of interactive applications featuring IVAs, (2) to teach students to develop behaviour of IVAs, (3) to boost their interest in related disciplines, namely in artificial intelligence, autonomous agents, and behavioural sciences. At our faculty, there are many other courses where the students can learn about other aspects of IVAs, most importantly courses on computer graphics, computational linguistic, artificial intelligence (AI), autonomous agents (AA), and computer games development (Fig. 1). While there is no given order in which to attend these courses, the questionnaire administered in 2008 showed that our lecture is the entry-level point for the subjects of AI and AA for 60% students (either the first or the only lecture related to AI). Computer graphics, on the other hand, is studied mostly earlier than or in parallel to our course. Note, however, that from the point of view of IVAs, some courses that would give students a broader context are missing; most notably social sciences and human-computer interaction.

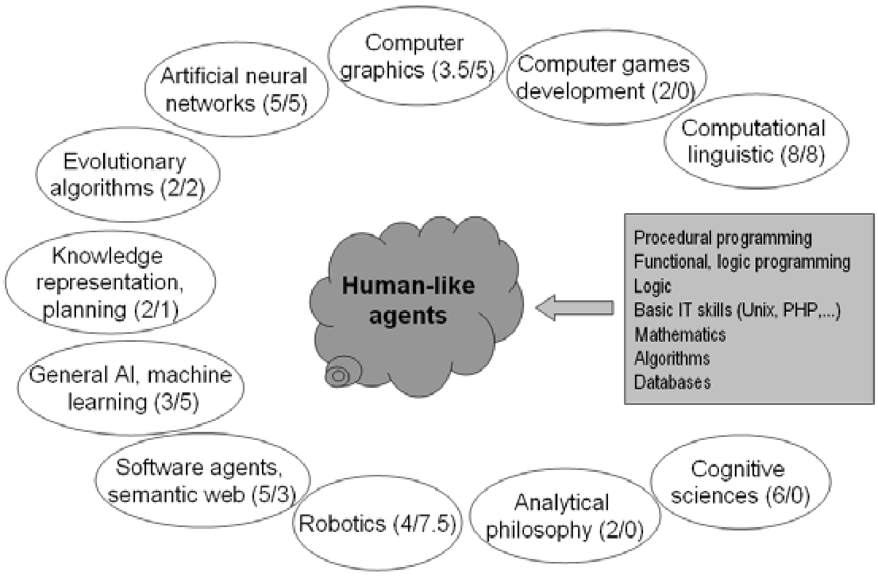

Figure 1. The curricular context of the course. Prerequisites are depicted in grey. The number of introductory courses and advanced courses are given in normalised numbers (see Note (2)).

Curriculum overview. Conceptually, the course comprises an introductory lecture, three theoretical blocks, and the practical seminar. The curriculum of the theoretical part is overviewed in Tab. 1. In general, the course starts with relatively concrete models for controlling behaviour and proceeds to more abstract ones. The course has more possible orderings of lectures, specifically within the block on advanced topics (Fig. 2). We will now discuss each part of the course in turn.

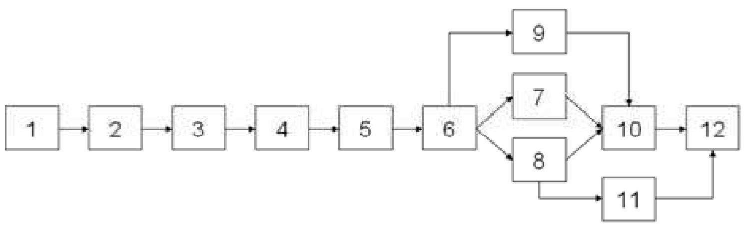

Figure 2. Possible ordering of lecture parts.

Table 1. The curriculum of the course.

Block	Topic	Units
	(1) Introduction	1
Concrete models of action-selection.	(2) Reactive planning: hierarchical if then rules with priorities, hierarchical finite state machines, fuzzy rules, probabilistic finite state machines.	2
	(3) Artificial and natural neural networks, reinforcement learning, evolutionary algorithms.	2
	(4) Behavioural science models: "Psycho-hydraulic" model of Konrad Lorenz, Tyrrell's free-flow hierarchy, classical and operant conditioning, imprinting.	1
	(5) Path-finding, steering, abstract terrain representations.	1
Conceptual notions, architectures, representation.	(6) Architectures: symbolism vs. connectionism, layered architectures, notion of deliberation. BDI, planning.	1
	(7) Multi-agent systems introduction: types of agents, communication.	1
	(8) Representation: logic, deictic representation, Gibson's affordances, smart objects.	0.5
Extras, broader context	(9) Artificial emotions.	1
	(10) Storytelling: emergent narrative, plots representation, level-of detail AI, role-passing.	1
	(11) Perception and memory.	0.5
	(12) Unified theories of cognition.	1

(1) Introduction. The knowledge of many students on IVAs is minimal, they typically think that IVAs belong only to the domain of computer games. Thence, it is crucial to demonstrate the broad scope of the field and to introduce the main technical issues. Most notably, interactive drama (Mateas, 2002), serious games (Aylett, 2005), cultural heritage applications (Magnenat-Thalmann et al., 2006; Burgess, 2002; Bryson et al., 2007), films (Softimage, 2008), cognitive science research (Burgess, 2002), cognitive-behavioural therapy (Herbelin, 2005), technical applications (Badler et al., 2002), and computational ethology (Bryson et al., 2007; Guerin and Kunkle, 2004) are introduced. Students most welcome live state-of-art demonstrations. The last two examples are important for drawing distinction between *plausibility* in the sense of a natural science, e.g. ethology or physics, and *believability* (Loyall, 1997). The Netlogo examples (Wilensky, 1999) help with clarifying the notion of *emergence*. The notion of *autonomy* has to be stressed. The survey of main issues, such as navigation, action selection, knowledge representation, emotional modelling, and story generation, helps to outline the content of the rest of the course.

(2) Reactive planning. Capitalising on the notion of rapid development, this part of the course help students to see how some action selection issues can be promptly solved. Specifically, if-then rules, decision trees, hierarchical finite state machines, and their fuzzy and probabilistic derivatives are introduced – good texts are (Champandard, 2003; Bryson, 2001; Brom, 2005). Students appreciate concrete mechanisms and concrete solutions. Since they are not able to produce counter-examples readily, they tend to regard these special-purpose mechanisms as abstract and general. While it is useful to give the concrete examples in which these methods fail, it is ineffective to try to give students any abstract,

background knowledge, at this moment. From the teaching process perspective, these concrete mechanisms will actually serve as a ground upon which the students will represent in their minds more advanced and/or general knowledge.

(3) Neural networks and evolutionary methods. This part extends the notion of reactive planning introducing neural networks and evolutionary methods. The control architecture of animals from the computer game Creatures (Grand et al., 1997) is an excellent material for this part for several reasons. First, it helps to explain both of the topics. Second, the neural networks used in Creatures are more biologically plausible than typical artificial neural networks, which helps with introducing the distinction between biological and artificial neurons. Third, the game can be demonstrated during the course on-line, including some technicalities (e.g. activity of some neurons). This lecture also helps with making links towards the domains of machine learning and computational neurobiology.

(4) Behavioural sciences models. It is useful to introduce the action selection problem from the perspective of behavioural sciences. This demonstrates rich cross-fertilisation between the disciplines, and reminds students of the believability—plausibility distinction. The excellent material is the Tyrrell's free-flow hierarchy architecture (1993). Not only it presents the bridge between IVAs and ethology, it also helps the students to understand some limitations of Creatures' neural networks. On the other hand, it can be demonstrated that outcome similar to Tyrrell's can be produced by reactive rules (Bryson, 2000).

The basic notions of ethology and behaviourism can be introduced, such as fixed action patterns, appetitive vs. consumatory behaviour, classical and operant conditioning, or imprinting. Other architectures that can be introduced at this point are (Lorenz, 1950; Miller et al., 1960/1986; Blumberg, 1996).

(5) Path-finding. This lecture first stresses the notion of representation, in particular terrain representation (e.g. Hancock, 2002; Isla, 2005; see also Isla and Blumberg, 2002). Also firstly, this lecture introduces the idea that thinking about IVAs at several levels of abstraction is beneficial by drawing the distinction between low-level steering and high-level path-planning (A*). The suggested materials are sections on path-finding in the book series AI Game Programming Wisdom (Rabin, 2002; 2004; 2006; 2008), and of course (Reynolds, 1987). Our experience is that students appreciate an introduction to more advanced path-finding algorithms, e.g. hierarchical versions of A* (Botea et al., 2004), or D* (Stenz, 1995).

(6) Architectures. Technically, so far, the students have been taught special-purpose solutions. Now, their knowledge should be unified within more abstract, conceptual frameworks. This helps them to see the models' individual advantages and disadvantages. Notions of goals and intentions, basically Belief-Desire-Intention (BDI) (Bratman, 1987), should be introduced, reactive approach confronted with planning, symbolism with connectionism. Layered architectures and hybrid approach should be introduced. The notion of behavioural-oriented design can be discussed (Bryson, 2003). A welcomed example demonstrating that BDI can be really implemented in various ways is the hybrid control architecture of Black & White creatures (Evans, 2002), which also reminds the students of reinforcement learning.

(7) Software agents. To frame the notion of IVAs in a broader context and to discuss the topic of communication, it is vital to introduce the concepts of intelligent software agents and multi-agent systems (Wooldridge, 2002; Franklin and Greasser, 1997).

(8) Representation. Capitalising on the lecture on path-finding and the notion of planning, this lecture pushes the topic of representation forward. In particular, the students should become familiar with the notions of affordances (Gibson, 1979; Brom et al., 2006), smart objects (Kallmann and Thalmann, 1998), deictic representation (Agre and Chapman, 1987), and logical representations (Russel and Norvig, 2003; ch. 7, 8). More general representations, such as frames and bayesian networks can be introduced, the notion of semantic web discussed (Dokulil et al., 2007).

Storytelling (10). The high-point of the course is storytelling for many reasons. Most importantly, students start to understand that IVAs cannot exist without virtual worlds and vice versa, in other words that IVAs and virtual worlds constitute an intertwined couple, a sort of marionette theatre in a service of a user. Through this metaphor and the notion of a story manager (e.g. Magerko, 2006; Mateas, 2002) students can understand how to *systematically* abandon the concept of strong autonomy. These notions also help with introducing the concept of role-passing (McNamee et al., 2002; Brom, 2007), a reminiscence of schema (Bartlett, 1932), and level-of-detail AI (Brom et al., 2007). At this moment, it is also possible to introduce the distinction between affordances for IVAs, i.e. representations, and affordances for users and authors (Mateas, 2002), i.e. mediators of users' experiences and author's intentions, respectively. Additionally, the notion of emergent narrative (Aylett, 2000) reminds students of the idea of emergence and the concept of story construction reminds them of planning.

(9, 11, 12) Cognitive Sciences Extras. Every year, many students are surprised that when developing an IVA, despite the IVA is intended to be believable but not psychologically plausible, it might be a good idea to look at what psychologists say about real humans. For example, the students are amazed that mechanisms of attention can really help with limited computational resources. In sum, these lectures help the students to understand that a "mind" of an IVA comprises not only an action selection mechanism, but also various additional "circuits". Concerning literature, these lectures mostly capitalise on state of the art works (e.g. Aylett et al., 2005, 2007; Ho et al., 2008, Mata and Aylett, 2007; Kim et al., 2005) and general cognitive science literature (e.g. Baddley, 1986; Ortony and Collins, 1988; Sternberg, 1996). It is beneficial to at least touch general cognitive architectures, e.g. Soar (Newell, 1990), ACT-R (Anderson, 2007), and LIDA (Franklin et al., 2005). It is also possible to include a bit of social sciences and cultural modelling (e.g. Davis et al., 2008). Our experience is that it is better to give these lectures after the students are already familiar with IVAs architectures and action selection.

Discussion and Conclusion

This paper has described the curricula of a university course on *Modelling Behaviour of Human and Animal-like Agents* and has overviewed the main lessons learned from the educational perspective. As already said, this course also has a practical seminar, in which students extend their theoretical knowledge by building their own virtual characters, a vital experience. The curriculum of this seminar is overviewed in the complementary paper (Brom et al., 2008).

Apart from the main subject of the course, students also learn basics of ethology, cognitive sciences, and artificial intelligence, developing a background knowledge on which they can build during their future education. This point is important given the interdisciplinary nature of the filed of virtual agents. Another important point is that modelling behaviour of IVAs helps to increase general programming skills of students, most importantly, they start to better understand the concepts of agents oriented programming and parallel programming. On the other hand, some issues related to social sciences and human-computer interaction are missing at the curricula of the course. This drawback is due to the limited number of lessons an individual course at our faculty can have.

Generally, the course, including the practical seminar with the toolkit Pogamut 2, is appropriate (with some modifications) for a summer school, or high-school computer science students. This has been actually demonstrated, as detailed in Brom et al. (2008). This paper also discusses the teaching methodology underpinning the course in depth. For space limitations, suffice it to say now that this methodology follows this line: to start with a concrete models and to proceed to more abstract ones, while incrementally immersing students to a broad context of the discipline. We believe that this line should be followed for similar courses as well.

The lecture materials and the Pogamut 2 are freely available for download (Brom, 2008).

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