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Spectrum Curricula: Design and Initial Results

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Abstract

Part of human adaptability is our ability to learn from instruction by other humans. Such instruction is typically an informal mix of demonstration and telling, presented by a situational expert who is not a teaching expert. If machines are to cooperate effectively with humans across a broad range of situations, they must exhibit human-like learning flexibility, even in the face of poor or ambiguous instruction. A key challenge, however, is how to effectively measure and compare the adaptability of machine learners. To address this challenge, we have developed the instrument of a *spectrum curriculum*(Beal, Leung, and Laddaga 2010): a suite of lessons, incrementally varying along a dimension of interest and presented in order from hardest to easiest. The adaptivity of a student is then expected to be characterized by its performance curve across the suite of lessons, with more adaptive students expected to show a smooth increase of comprehension as the quality of teaching improves. We have developed seven spectrum curricula for simulated RoboCup, and preliminary tests of human-adapted versions of four of those curricula support this theory.

Overview

Humans are remarkably adaptable, and part of that ability is their ability to give and receive instruction from one another, communicating important information even in the face of poor teaching or significant communication barriers. Moreover, informal instruction is pervasive throughout our daily lives: we are constantly encountering new situations where we are expected to learn local rules, customs, or effective information rapidly: e.g. starting a new job, playing a new game, visiting a foreign country. While humans are far from perfect, we tend to muddle through relatively well, and any machine expected to interact with humans across a broad range of situations must exhibit similar human-like learning flexibility.

A key challenge in conducting research in this area, however, is how to measure the adaptability of a learner (human or machine), particularly since informal human teachers tend to adapt to their students. We thus have introduced the notion of a *spectrum curriculum* in (Beal, Leung, and Laddaga 2010). This instrument is designed to evaluate the adaptivity of a student by presenting the student with a suite of lessons that all teach the same concept, incrementally varying across a dimension of interest and presented in order from hardest to easiest. The student's performance is measured before the first lesson and after each lesson, producing a performance curve.

The adaptivity of a student is then expected to be characterized by its performance curve across the suite of lessons. Highly adaptive students are expected to transition gradually from low to high performance across some subset of the lessons within the curriculum, since they can begin learning even from a somewhat mismatched teacher. A non-adaptive student is expected to show a radical jump at some point, likely late in the curriculum (or perhaps just fail to perform well at all), and a student that already knows the material is expected to perform well before the first lesson.

We have begun applying the notion of spectrum curricula by designing a set of spectrum curricula for the domain of RoboCup soccer simulations(Kitano et al. 1998). We have designed seven curricula, each of which teaches a different skill for playing a 3-on-2 keepaway game in a restricted portion of the soccer field(Beal, Leung, and Laddaga 2010). We have further adapted four of these curricula for human use, in order to validate the spectrum curriculum concept and gather a human baseline to compare against machine learners. Preliminary results from human learners show the expected gradual improvement, supporting the theory that spectrum curricula may be an effective instrument for measuring learner adaptivity.

RoboCup Spectrum Curricula

In (Beal, Leung, and Laddaga 2010), we presented the design of seven spectrum curricula for the RoboCup domain, addressing a variety of concepts, evaluation goals, instructional methods. The seven concepts are all binary decisions (e.g. "pass or don't pass?" or "which team-mate to pass to?"), with three for the "keeper" team, three for the "taker" team, and one (the "out of bounds" concept) used by both teams.

Curricula contain from 6 to 10 lessons each, incrementally varying from "hard" to "easy" along one of three properties of interest:

- Strength of assumptions about mutual knowledge (2)

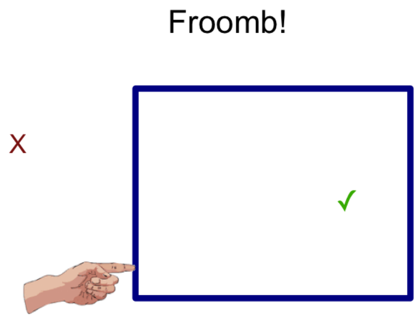

Figure 1: Lesson 3 for "Froomb," the concept taught by the human equivalent curriculum for "out of bounds")

- Distance of transfer between lesson and use in context (3)
- Detail of instruction (2)

and exercising some combination of three of the "natural instruction method"(Lefkowitz, Curtis, and Witbrock 2007) teaching modalities that have been identified in the DARPA Bootstrapped Learning project:

- learning from examples (6)
- learning from "telling" (2)
- learning from feedback (from the instructor or environment) (2)

As an example, we reproduce the description of the "out of bounds" curriculum from (Beal, Leung, and Laddaga 2010):

Out of Bounds Both keeper and taker players try to avoid going out of bounds. This spectrum teaches a function that is used to tell when a nearby location is illegal.
Spectrum Property: Strength of assumptions about mutual knowledge.
Natural Instruction Methods: Learning by Example
Test: 10 random locations
Lessons (Easy to Difficult):

- 50 labelled examples scattered randomly around the field
- 20 labelled examples scattered around the boundary (assumes values not near the boundary are indicated by the examples given)
- 8 labelled examples, one in and one out on each line (assumes a rectilinear area)
- 2 labelled examples, in or out, at opposite corners (assumes the area is aligned with cardinal directions)
- hint at the line, two labelled examples, one in and one out (assumes the line is the border)
- hint at the line, one labelled example in or out (assumes the other side of the line is the opposite value)

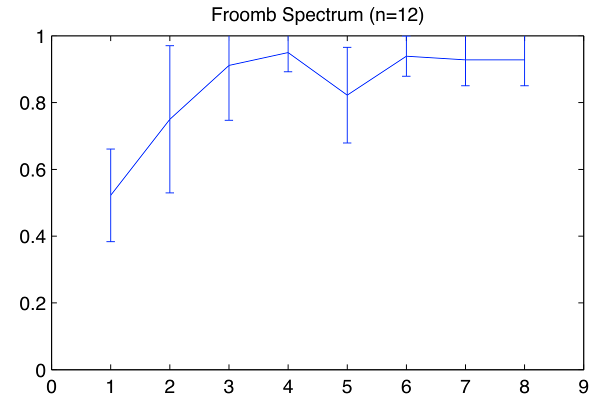

Figure 2: Performance curve for "Froomb" (human equivalent out-of-bounds lesson) with results from 12 subjects, where test 1 is before the first lesson, and test 8 is after the easiest lesson.

- only hint at the line (assumes interior of boundary is likely to be "good")

Experimental Design and Initial Results

To begin validation of the spectrum curricula concept, we prepared human-equivalent versions of four of the curricula ("out of bounds", "pass or don't pass?," "which team-mate to pass to?" and "taker preferred bounds"), replacing concepts that might trigger subject background knowledge with nonsense words and geometric shapes. Figure 1 shows a typical example of a human-equivalent lesson, in this case the third-hardest lesson for the "out of bounds" concept, relabelled as the nonsense word "Froomb."

Curricula were packaged into a JavaScript web-app and made available online. Subject were recruited via Amazon Mechanical Turk (with a reward ranging from $0.25 to $2.25 depending on performance) and from visitors at the 2010 AAAI Robotics Exhibition. We applied filters to screen out Mechanical Turk workers who were either dishonest or failed to follow protocol, and use only those participants that could report an approximately correct description of the concept after the entire curriculum. Initial human subject results are promising, demonstrating the type of gradual curve predicted for adaptive learners (Figure 2). We thus see support for the hypothesis that spectrum curricula may be an effective instrument for measuring learner adaptability.

References

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