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Design of a Self-Control Mechanism for an GDA-Based Tutor Module of an Intelligent Tutoring System

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Outline

- Theoretical Model of cognitive control of the study
- Intelligent Tutoring Systems
- Model of Self-control for a GDA-based Tutor Module in an ITS
- Illustrative Example
- Conclusions

Models of cognitive control

- ✓ **Cognitive control** Self-control makes part of the metacognitive abilities as self-regulation of an autonomous system. self-control can include setting goals in processes of automatic responses or drives, setting essential parameters, interrupting, and changing ongoing processes. It is often conceptualized as an opposite term to automaticity.

- ✓ These processes comprise various components, including **working memory,** such as the capacity of guidance and adequacy of **attentional resources, inhibition** of inappropriate responses in certain circumstances, and monitoring behavior of the organism's mental states (Buehler, 2018).

(Koechlin & Summerfield, 2007)

(Shimamura, 2002)

(Stuss et al., 1995)

(Zelazo et al., 1997)

(Christoff et al., 2003)

Models of cognitive control

- Information theory → $H(a) = -log_2 p(a)$
- Processing of stimulus → mutual information $I(s, a)$ using → $I(s, a) = log_2[p(s, a)/p(a)p(s)]$
- $Q(s) = H(a) - I(s, a) = -log_2 p(s)$ → $Q(s)$= cognitive control

Koechlin, E., & Summerfield, C. (2007). An information theoretical approach to prefrontal executive function. *Trends in Cognitive Sciences*, *11*(6), 229-235. https://doi.org/10.1016/j.tics.2007.04.005

Intelligent Tutoring System

Intelligent Tutoring Systems (ITS) → Interactive learning environment → mechanisms of individualized teaching and feedback (Almurshidi et al., 2016)

ITS → tutor module (Rongmei & Lingling, 2009) → Pedagogical model → most adequate pedagogical strategy to facilitate the learning of students (da Silva, 2012).

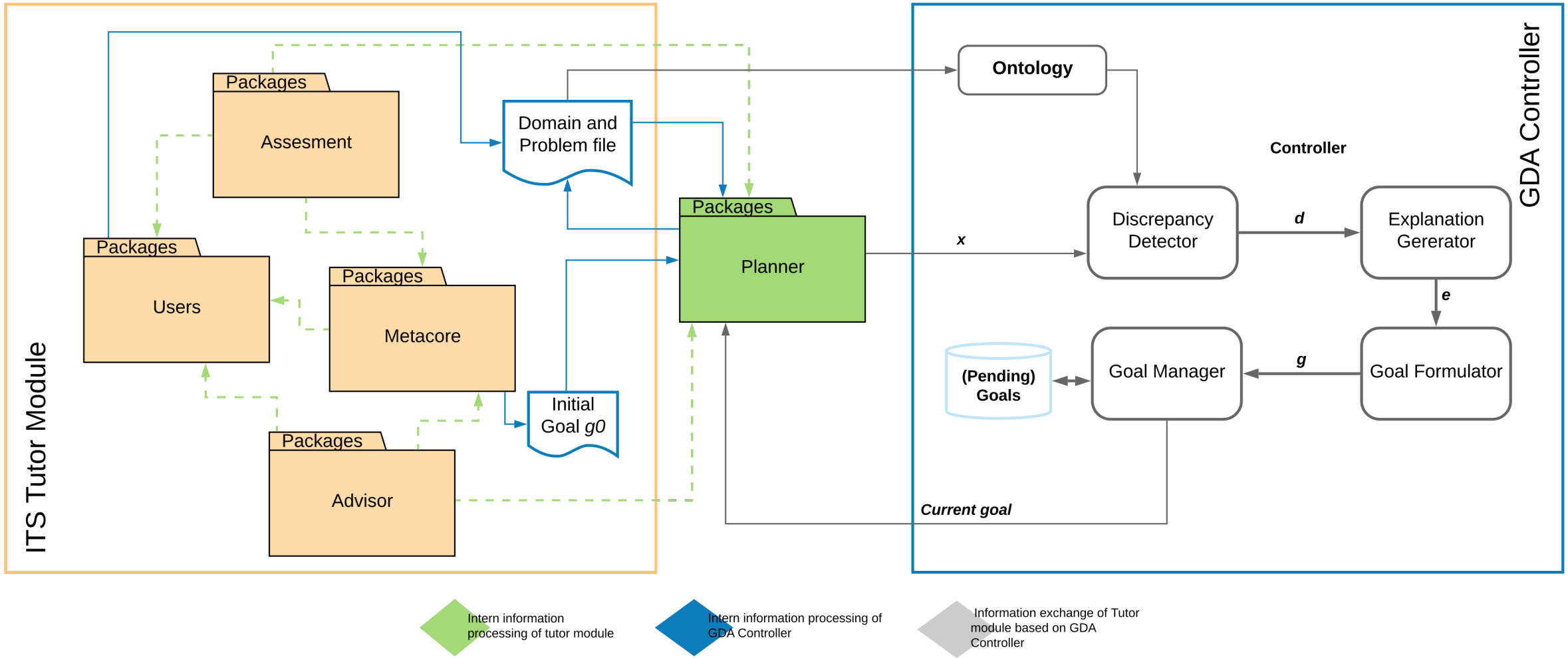
ITS → personalizing its pedagogical strategies can → instructional plans → performance and interests of the learner.

Pedagogical theories → teaching strategies and pedagogical knowledge rules → pedagogical model (Caro & Jiménez, 2014). Pedagogical model → instructional plans → resources of learning lessons → GDA controller to promote achievement learner' learning objectives (Gómez et al., 2021).

Model of Self-control for a GDA-based Tutor Module of an ITS

- ✓(Gómez et al., 2021) GDA controller → selection of new goals in each learning lesson.
- ✓ITS -> Initial goal → Planner → Metacore Package.
- ✓*Metacore Package* → Information traces.
- ✓*Planner* -> Domain D → problem P → g0 → plan π=< a_i , a_{i+1}. . . a_n >
- ✓*Planner* → expectations x → *Discrepancy Detector.*

GDA Controller



GDA Controller with self-control mechanism

In this study, a **self-control** mechanism is proposed to improve this selection process of resources, so that it can be less automatic.

It can be regulated considering the performance and interests of the students determined by the interaction history with the system.

The **GDA controller** facilitates the selection of new goals in each learning lesson of the ITS.

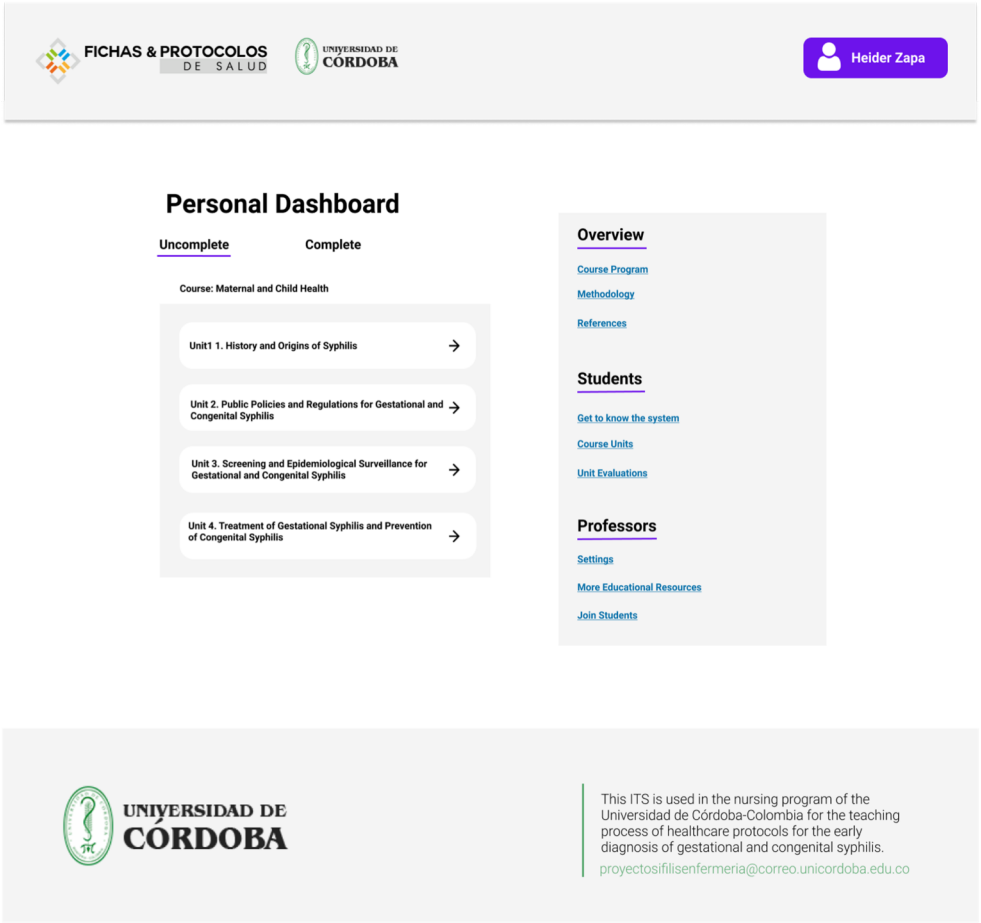
Thus, just before creating new goals using the GDA controller, the ITS will have the possibility of self-regulating this process considering previous episodes of performance and interest of the learner.

- Koechlin & Summerfield (2007) → self-control → temporal framing of actions and events involved in the selection process.
- Stimulus → Student Profile $S_p = < S_i , S_s^l, S_d, S_s^p >$
- Initial goal g_0 → *Planner* from the *Metacore Package. Planner* → plan constituted by D and P. Both S_p and C_s^s make part of D
- $C_s^s =< C_i , C_l^c , C_l^s >$ it is the selected course by the student
- The Planner generates a plan $\pi = < a_i , a_{i+1} \ldots a_n >$. This plan π comprises the principal action regulated by the self-control mechanism.

Algorithm 1 The SelectAction procedure describes the reactive control of the system. Also, the cognitive control procedure shows the code that uses the system for processing the cognitive control conditions.

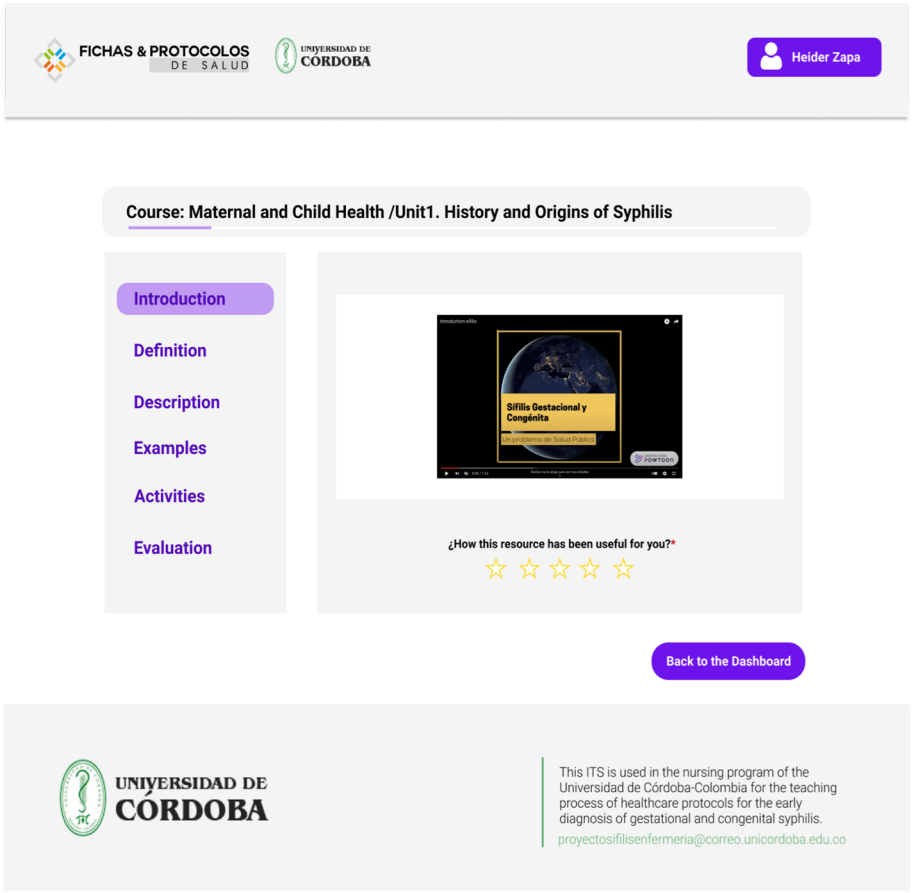
1. global $K_b = [\,]$ $I_m = [\,]$ ⇒ The Knowledge base contains all plans created by the system
2. procedure SelectAction (S_p)
3. i ← 0
4. While i < EOF (K_b) ⇒ All case base is examined
5. $R_c \leftarrow log_2\left[p(S_p, K_b[i].\pi)/p(K_b[i].\pi)p(S_p)\right]$ ⇒ Reactive control between S_p and π is inquired
6. $I_m[i] \leftarrow R_c$
7. i++
8. o ← pos (max (I_m))
9. $return(K_b[o].\pi)$ ⇒ The plan with the highest mutual information is selected
10.
11. procedure CognitiveControl (δ, s^π, h, S_p) ⇒ δ is performance, s^π is score, h is interaction history
12. $t \leftarrow$ SelectAction (S_p) ⇒ Reactive behavior of the ITS is invoked
14. $Q_c \leftarrow -log_2 p\,(t) -$ max (I_m) ⇒ Key feature of cognitive control: contextual control plus remaining information conveyed by past events.
15. $Q_f \leftarrow \; Q_c + p(\delta) + p(s^\pi)$+ p (h)
16. $return\,(Q_f)$

Lesson plan presented to a student according to his profile using the automatic response mechanisms



Information solicited by the planner is complemented by intern codification in PDDL language used to build the domain and the problem in the reasoning process of the ITS.

Result of the cognitive control mechanism in the ITS reasoning process



Pedagogical strategies selection process has been developed considering the performance and other control conditions. These control conditions are related to loading and selection of resources.

Resources are shown to the student for the third time. At that moment, the system is waiting for the response of the student to use the GDA mechanism. Finally, the data are saved in the trace of the student.

Conclusions

This paper presented the computational implementation of a theoretical approach of control cognitive in a GDA-based tutor module of an ITS. The study allowed the integration of the cognitive control mechanisms into a GDA controller component in the ITS tutor module packages. The GDA controller enables the tutor module to determine when new goals should be selected and decide which goals should be pursued at each learning lesson.

Tutor module must know the student profile, and courses in which the student is enrolled and associated with the resources of these courses. Also, GDA controller enables the ITS tutor module to incorporate additional techniques for responding to unforeseen situations.

This mechanism facilitated the selection of pedagogical strategies considering the student's performance, score, and interaction history.

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Thank you!