GermanTeam 2003

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1 Introduction

The GermanTeam participates as a national team in the Sony Legged Robot League. It currently consists of students and researchers from the following four universities: the Humboldt-Universität zu Berlin, the Universität Bremen, the Technische Universität Darmstadt, and the Universität Dortmund. The members of the GermanTeam participate as separate teams in the national contests such as RoboCup German Open, but jointly line up for the international RoboCup championship as a single team. To support this cooperation and concurrency, the GermanTeam introduced an architecture that provides mechanisms for parallel development [8]. The entire information processing and control of the robot is divided into *modules* that have well-defined tasks and interfaces. For each module, many different *solutions* can be developed. Solutions for a module can be switched at runtime. Currently, for most modules various solutions exist. Approaches to a problem can thereby easily be compared and benchmarked.

This paper gives a brief overview of the current work of all four universities in the GermanTeam.

2 Vision

Many past image processing approaches in the color labeled RoboCup domain utilize a static color table to color segment the camera image. Creating such a color table is a time consuming, tedious job. Furthermore, a color table created for a certain lighting situation will produce unsatisfactory results when lighting conditions change.

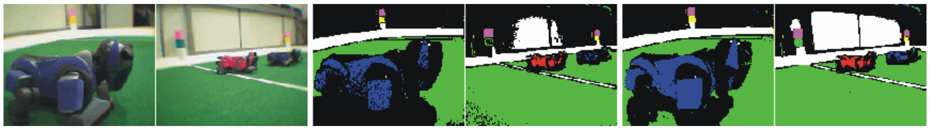

Fig. 1. Color classification of two camera images (left) as done by a conventional YUV-approach (middle) compared with an optimized classification (right)

On the one hand, we developed an evolutionary chrominance-space optimization: Starting from the TSL-chroma space, we evolve an optimized transformation, such that the main colors (green, pink, yellow etc.) are located in easy-to-separate subspaces [1]. This reduces the algorithmic complexity of color segmentation and improves classification accuracy significantly, since the evolved chrominance space is robust against luminance variation (cf. Fig. 1).

A different approach utilizes a qualitative color table where colors are labeled with respect to a reference color [5]. The reference color is calibrated using simple geometric heuristics in the camera image (cf. Fig. 2). We use green as a reference color because it is found in all images. The color calibration is done in real time providing the vision system with auto-adaptation capabilities. In the color calibration process, simple heuristics are used to ensure that only pixels that are thought to be green are used; pixels not satisfying these strict conditions are omitted. The qualitative approach to classify colors means that rather then segmenting individual pixels, edges are classified. Classification of edges can be done reliably even when using relatively vague color information. Similar to [9], only pixels on a grid are classified to increase performance.

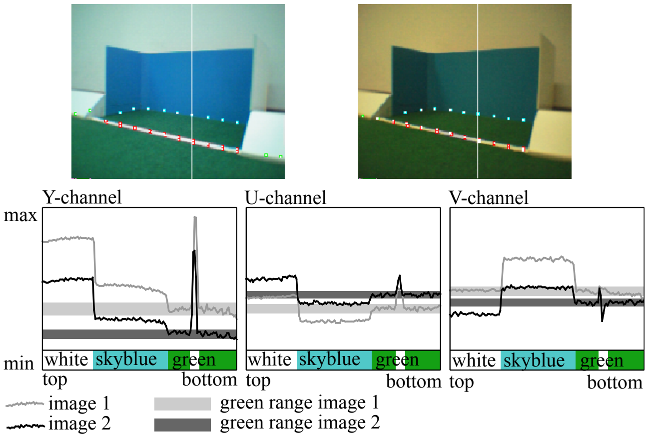

Fig. 2. *Top row.* Images recorded under different lighting conditions with a highlighted scan line and recognized points (border, field line, goal). Left: day light, right: artificial light. *Bottom row.* Intensities of the YUV-channels along the scan line for both images. The gray bars show the range of green after auto-adaptation for left and right image.

3 Localization

Already in 2002, the GermanTeam had a robust and precise localization method based on the famous Monte-Carlo localization approach [2]. For instance, it enabled the robots to autonomously position themselves for a kick-off. The method relies on the recognition of colored landmarks and goals around the field. However, as there are no colored marks on a real soccer field, the GermanTeam developed a Monte-Carlo localization approach that is based on the recognition of edges between the field and lines, goals, and the border. The method especially takes account of the fact that different types of edges provide different information on the robot's position and that they are seen with variable frequency. During experiments, in which the position calculated by the robot were compared to one delivered by an external reference, it proved to reach an average error of less than 10.5 cm on a continuously moving robot, and it was able to reach goal positions with an average error of less than 8.4 cm [10].

4 Behavior Control

Since 2002 the GermanTeam uses a layered state machine approach to encode the behavior of the robots. The behavior is described in the XML-based *Extensible Agent Behavior Specification Language* (XABSL) [7, 6]. In the architecture, an agent is built of a hierarchy of behavior modules called *options* that contain state machines for decision making. The options are ordered in a rooted directed acyclic graph with *basic behaviors* at the terminals of the graph. Starting from the *root option* the state machine of each option is carried out to determine which option is activated on a subsequent level. The state machine of that activated option then is invoked and so on until a basic behavior is reached and executed.

On the level of the basic behaviors in the XABSL option graph, the GermanTeam developed a variety of *continuous basic behaviors* based on superimposed potential fields. This allows for performing a variety of behaviors at the same time, e.g. approaching the ball, avoiding other players, and not entering the own penalty area.

5 Locomotion

We examined the locomotion of the quadruped robot; the emphasis was on creating, optimizing and merging of motions. A Fourier-Series Expansion was performed on the motion commands used in the robot gait. It was found that omitting higher order terms has very little, at times even positive effect on the robot's performance yet yields a greatly reduced parameter set describing the motion. The parameter reduction is desirable for creating and optimizing motions. Furthermore, the acquired frequency space representation allows for simple creation of new motions by merging and for transitions from one type of motion to another.

On the other hand, we are currently working on the implementation of optimal gait trajectories, which are solutions of an optimal control problem involving a dynamical model of the robot and several boundary and nonlinear implicit conditions [4, 3]. Efficient dynamics algorithms like Articulated Body Algorithm are used to evaluate the dynamics of the full three dimensional dynamical model efficiently. The problem formulation for generating stable gaits that minimize time or energy subject to the legged robot dynamics leads to an optimal control problem, which is solved numerically by a parameterization, collocation and sparse nonlinear optimization approach. First experiments have started and lead to an improvement of the model by avoiding slipping and taking into account more detailed characteristics of the motors. These optimizations are computed offline. The resulting optimized trajectories are then reproduced on the robot.

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