# Chapter XI
# Symbolic Computation for DS-CDMA Code Acquisition Using First Order Logic

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## ABSTRACT

*Code division multiple access (CDMA) is widely used because of its effectiveness to send multiple signal and confidentiality of career signal. We present a formulation of state-space problem of which solution is directed by redundant reasoning control method for semiheuristic and lightweight DS-CDMA code acquisition. The reasoning of the state-space problem provides us with the way to find a K bit synchronized sequence among K dephased sequences with less calculation cost, compared with serial search and matched filter. In this process, redundancy-restriction method, called weighting strategy, enhances the searching ability of FOL (first order logic) reasoning for the faster and lightweight code acquisition. The combination of weighting strategy and correlator enables us to achieve the peak-detection within K/3 times of calculating inner products and its measurement. Our system is evaluated by the reduced cost of proving state-space problem using weighting strategy and its robustness of using the proposal code acquisition framework. Experiment shows that the proposal method is robust if K/N sequences are grouped with N ranging from 3 to 5.*

## INTRODUCTION

Code division multiple access (CDMA) is widely used because of its effectiveness to send multiple signals and confidentiality of career signal (Viterbi, 1979). Therefore, CDMA is an important technique for multimedia communication. Synchronization is an important task for telecommu-

nication, especially for CDMA. In this chapter, we propose a symbolic computation for direct sequence CDMA code acquisition using FOL (first order logic) applying this puzzle:

"*the billiard balls and balance scale puzzle*"

There are $N$ billiard balls, $N - 1$ of which are identical in weight. The remaining ball–the odd one–has a different weight. We are not informed whether it is heavier or lighter. We have a balance scale for weighting the balls. Can we find which ball is the odd ball in $N/4$ weightings, and also find out whether it is lighter or heavier than the others? In the proposal system, this puzzle is formulated as state-space problem, which is solved by automated reasoning with some resolution strategies.

## Direct Sequence—Code Division Multiple Access (DS-CDMA)

Since 1990, as the usage of cellular phone has expanded, the market of wireless communication has been increased dramatically. Among many wireless communication systems, direct sequence code division multiple access is applied to represent low bandwidth wireless communication devices, such as cellular phones. In CDMA, all users send signals in the same bandwidth, simultaneously, with the unique code assigned to each terminal. Every user can coexist and transmit at the same time with smaller interface compared with TDMA and FDMA (Duel-Hallen, Holtzman, & Zvonar, 1995). This multiple-access system protects users from interference and jamming. These advantages are possible since the cross-correlations between the code of target user and one of the other users are small, while pseudonoise has a maximal value repeating itself every period. The receiver can decode information of each user when the code acquisition is completed, which means that we can detect the point where the correlation between the received signal and unique code in each terminal has maximal value. The perfect synchronization is an important task in any sort of telecommunication. Particularly in CDMA, the unique sequence must be synchronized precisely to the received signal. Unless a maximal output from the correlator is not acquired, each user in CDMA system cannot get the information.

## PN Sequence

As we discussed in the previous section, the pseudonoise plays an important role in the simultaneous usage of the same bandwidth. To achieve the immunity of interference, jamming, and radio multipath fading, the assigned code must have these properties:

- **Balance property:** Relative frequencies of 0 and 1 are each 1/2.
- **Run property:** Run lengths of zeros and ones are as expected in a Bernoulli sequence.
- **Shift property:** If the random sequence is shifted by any nonzero number of elements, the resulting sequence will have an equal number of agreements and disagreements with the original sequence. The m-sequence has the balance, run, and shift properties. The m sequences are almost ideal when viewed in terms of their autocorrelation function.

## Proposed Method

In this chapter, we formulate the state-space problem for DS-CDMA code acquisition. Typical state space decides if a state is reachable from another state or finds the shortest path between two states. We begin with the initial state and apply a kind of transition axiom to pass from one solvable state to another. In our model, the solution of the problem provides the way of code acquisition of PN sequences, of which properties are the balance, run and shift property.