NEW APPROACH OF ADAPTIVE BEAM FORMING USING NXP ARM7 MICROCONTROLLER IN CONJUNCTION WITH EMBEDDED CLONAL SELECTION ALGORITHM

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ABSTRACT

Clonal Selection Algorithm (CSA) is an emerging optimization tool for solving complex stochastic problem. It is another artificial intelligent tool that is inspired by biological process after neutral network and evolutionary algorithm. CSA extracts its idea from Burnet's Clonal selection theory which explains on how human immune system work. CSA can be used for pattern recognition as well as solving various multi objective optimization problems. In this paper, an adaptive beam forming with CSA firmware is put into NXP Semiconductor embedded microcontroller, LPC2131. Smart antenna system with adaptive beam forming has becoming a trend now because adaptive beam forming can improve signal to noise and interference ratio (SINR) as well as saving more energy. The advantage of using CSA for application of adaptive beam forming is its simplicity. Without the need of sophisticate digital signal processor, CSA is used to optimize the best power efficient of beam pattern. Processing power on embedded system is the bottleneck for this application because CSA work as other evolutionary algorithm which needs a lot of looping processes. However, this paper shows how the ARM7 core LPC2131 realizes this implementation.

Keywords: Adaptive beam forming, Embedded System, ARM7, Clonal Selection Algorithm, Artificial Immune System.

الخلاصة:

خوارزمية الانتقاء الوراثي CSA هي الاداة المنبثقة لحل مشكلة الستوكاستك العشوائية المعقدة وتعتبر أداة صناعية ذكية مستوحاة من عملية بايولوجيه بعد شبكه محايده وخوارزمية تطورية.لقد تم استخلاص فكرة الCSA من نظرية بيرنت في الانتقاء الوراثي والتي تفسر كيفية عمل جهاز المناعه البشريه.يمكن ان نستخدم الCSA كنموذج تمييز فضلا عن حل مختلف مشاكل الهدف المتعدد الامثل.في هذا البحث تم وضع التشكيل لشعاع التكييف مع الCSA في NXP مسيطر اشباه الموصلات المدمجه LPC2131.سوف يصبح نظام الهوائي الذكي مع التشكيل لشعاع التكييف هو الاتجاه او النزعه الحاليه والسبب هو ان التشكيل لشعاع التكييف يمكن ان يحسن الاشارة الى نسبة الضوضاءوالتداخل (SINR)،فضلا عن توفير المزيد من الطاقة. تمتاز عملية استخدام الCSA مع التشكيل لشعاع التكييف ببساطتها. الCSA تستخدم لتحسين أفضل كفاءة طاقة لنموذج الشعاع دون الحاجة لمعالج اشارة رقمي معقد.يعتبر تجهيز الطاقة في النظام المحكم هو عنق الزجاجة في هذا التطبيق والسبب يعود لعمل الCSA والتي تعمل كباقي خوارزميات التطور الاخرى التي تحتاج الى الكثير من حلقات العمليات.مع ذلك فان هذا البحث يبين ان ARM7 core LPC2131 يحقق هذا التطبيق.

1. INTRODUCTION

A lot of current mobile base stations around the country broadcast their signal to user equipments (UEs) to all the directions. This method of broadcasting is wasting energy and also limits the power utility of the equipment. One way to improve energy efficiency of mobile base stations is using beam forming type of antenna system. With beam forming, the base stations able to broadcast their signal to the location that contains UEs only. With beam forming, extra saved energy can be used to generate a sharper and further beam pattern. Besides, beam forming also increase the SINR by generation of null beam to interference signal. With beam forming alone can't fulfill the requirement of mobile base stations because most of the UEs are mobile. These UEs tend to move out of coverage area of the beam pattern. In other words, adaptive beam forming is needed instead of just beam forming. A lot of studies had been done to prove that adaptive beam forming is able to improve signal to noise ratio of telecommunication system in term of spatial filtering. There are number of ways to realize the adaptive beam forming. These include adaptive beam forming with Minimum Mean Square Error (Islam; Hafriz and Norfauzi. 2007), MUSIC, ESPRIT and adaptive beam forming using Genetic Algorithm (GA). Adaptive beam forming with GA is proposed by researchers (Laohapensaeng and Free. 2005) due to the ability of GA in optimizing the beam for best coverage with minimum resource usage.

Besides GA, recently there is an alternative optimizing tool from novel Artificial Immune System (AIS) (Dasgupta. 2008). As the name indicated, AIS is inspired by human immune system. Our immune system has the properties adaptable, i.e. it can recognize and respond to new foreign antigen, self protecting, i.e. it able to protect itself, self recognize, i.e. it can recognize which antigen belong to body and which isn't and also to memorize, i.e. it able to remember previous antigen that attack our body and response faster when it attacks again. These features had been harnessed by experts to develop some useful tools in solving engineering problem. AIS itself is divided into a few main fields such as Negative Selection Algorithms, Immune Network, Danger Theory, and CSA. Each of the field finds its application on specific problem (Hofmeyr and Forrest. 1999) (Iqbal and Maarof. 2005). As for CSA, it can be used as optimization tool (Babayigit; Guney and Akdagli. 2008)(Liu, Jiao, and Du. 2004)(Coello and Cort´es. 2005). This paper uses CSA to implement adaptive beam forming by optimizes the power usage from beam pattern. The whole implementation run on embedded system microcontroller, LPC2131 from NXP semiconductor(NXP Semiconductors.2010).

Next section will briefly talk about origin of CSA. Then third section explains how to apply the CSA in adaptive beam forming. The section following it describes on the microcontroller's features. All simulation results and discussion were put under section after it. Lastly; the conclusion summarized the paper's contents.

2. ARTIFICIAL IMMUNE SYSTEM - CLONAL SELECTION THEORY

Human body is a very complex structure. Scientists still yet fully understand human body even in this digital age. Human body allows us to run, walk, feel, see, hear and enjoy the environment. However, environment is always harsh, dust, danger and full of micro organism which can easily enter human body. It is human body immune system that works 24 hour per day to protect human body from all these intrusions. Understanding how immune system isn't an easy task for scientist. There are a lot of theories proposed to explain how human body immune system works. One of the most widely accepted is Clonal Selection Theory. Clonal selection theory had proposed by Australian immunologist Burnet to explain how immune system responds to infection. Figure 1 summaries on how immune system works according to Clonal Selection Theory in graphical way. Human body immune system consists of a lot of B cells or lymphocyte. These B cells come with a lot of different pattern type of receptors. Whenever foreign antigen attack human body, the B cells receptor will try capture and neutralize the antigen. However, only the best matching pattern of receptors with the antigen able to hold the antigens. After that, these B cells that matched with the antigen will clone a lot of the same B cells with the same receptors before they are destroyed together with the antigens. At the same time, these clones will go through a biological process call as soma hyper mutation. This type of mutation is different from genetic mutation because of the mutation rate. With soma hyper mutation, clones with better receptors pattern can be produced. Then, the B cells receptors will mature and become antibodies to protect human body in the future.

This innate biological process had inspired some computer experts and engineers to mimic the similar ways into programming which soon find its application in multi objective optimization issue and pattern recognition(De Castro and Von Zuben. 2000). It is named CSA to distinguish it from biological term Clonal selection theory.

3. ADAPTIVE BEAM FORMING WITH CSA FIRMWARE

In this paper, the adaptive beam forming problem is encoded and feed into CSA to calculate the optimized beam angles for a group of known user equipment (UE) locations. C language is used to write the adaptive beam forming with CSA firmware. To facilitate the CSA implements adaptive beam forming, 360 degree area is divided into 9 sectors. Each sector will be covered by a beam. Each of the beams can cover its previous sectors as well. This allows CSA to vary each beam width to give the best coverage for all UEs using least power consumption. Table 1 shows all the beam sectors coverage. Since the beams are allowed to cover previous, there might happen that overlapping beam generation as shown in Figure 2. This problem can be solved by using Eq. (1).

$$w_{m,\min} = w_{m,\min}\left(S\left(w - w_{1,\max}\right)\right) + w_{m-1,\max}\left(1 - S\left(w_{m-1,\max}\right)\right) \quad \ldots\ldots (1)$$

$$S(w) = \begin{cases} = 0 & if w \langle 0 \\ = 1 & if w \geq 0 \end{cases}$$

Where w is the coverage angle for beam

$\omega_{m,max}$ is the maximum coverage angle for beam.

$\Omega_{m,min}$ is the coverage angle for beam.

S (w) is a step function.

The equation mentions that if overlapping happen, $\omega_{m,min}$ will equal to maximum coverage angle of previous beam number. The flowchart of the program is shown in Figure 3. The first step of the program is random generation pool of solutions for the beam angles. This equals random generation of antibodies in CSA nomenclature. Next, the solutions will go through fitness evaluation and then are sorted according to their fitness value. The formula used to evaluate the fitness is shown on Eq. (2)

$$E(f) = \sum_{l}^{L} \prod_{m}^{M} U_{l,m} + \sum_{m}^{M} \left(W_m + \varepsilon P_m\right) \quad \ldots\ldots (2)$$

$$U_1 \begin{cases} = 0 \; if w_{m,\min} \leq UE\ 1 \leq w_{m,\max} \\ = 1 \; if w_{m,\min} \leq UE\ 1 \cup UE\ 1 \geq w_{m,\max} \end{cases}$$

$$W_m \begin{cases} = 1 \; if w_{m,\max} - w_{m,\min} \leq \rho \\ = 0 \; if w_{m,\max} - w_{m,\min} \geq \rho \end{cases}$$

$$\varepsilon P_m = p_m \times w_m \times 10^{0.25}$$

Where $E(f)$ is the fitness evaluation.

ρ is minimum separate on angle between antenna beams.

Pm is the Poynting power transmitted.

ε is the weight factor for Pm (ε =0.001 in this paper).

Wm is solid angle of antenna beam.

In short, the equation depends on the power usage from beam angles and number of its UEs coverage(Tiong; Ismail and Hassan. 2005).

After that, the solutions will be cloned. Number of clones from each solution is proportional to its fitness value. Higher fitness value will have more clones. Then, all the clones will go through mutation process. The rate of mutation is inversely proportional to fitness value. The mutation process will randomly choose some beams and regenerate their beam maximum angle and minimum angle randomly. Number of beams that is chosen for mutation is depended on the fitness value. Good fitness value will have less number of beams going for mutation. After mutations, the cloned and mutated solutions will be evaluated again and will replace its parent if the best clone fitness value higher than its parent fitness value. This will be repeated for all of the parent solutions. After that, the program checks if termination criteria is achieved. If it not true, then the whole program will replace some lowest fitness value parent solutions and process repeat again from cloning the solutions

4. NXP LPC2131 MICROCONTROLLER

Microcontroller LPC2131 is a 32-bits ARM7 core processor from NXP Semiconductor. NXP Semiconductor is former Philip which split off from his mother company since 2006. This company carries a lot different type of semiconductors from basic logic ICs to complex microcontroller. LPC2131 is one of the many microcontrollers from NXP. This microcontroller core uses ARM7TDMI core from ARM Company(ARM.2008). ARM7 series is a three pipelined core processor which allows the processor to run fetch, evaluation and execution of an instruction all together in one cycle. ARM processor had gradually found its markets in embedded system from small device such as heart beat calculator to medium size handheld device such as data acquisition equipment, telemedicine devices (Peng; Zhang; Zhang and Xia. 2009)(Miao; Miao; Bian and Zhang. 2005). ARM core microcontrollers are famous with their low power consumption ARM RISC core which able to execute one command each clock cycle. This is why ARM core microcontrollers are widely used in handheld devices that need to run on batteries.

NXP's LPC2131 microcontroller has ROM size 32Kbytes and RAM size 8Kbytes. The reduced instruction set computer (RISC) core is running at 60MHz. The microcontroller has timer module and two UART modules. Its other peripherals include 10 bits analog digital convertor (ADC), two Inter Integrated Circuits (2ICs), a PWM, two SSPs, two timers and a dedicated real time clock (RTC) with backup battery pin. Each timer module can be configured as four inputs capture or four output compare. LPC2131 also include a watchdog module which allows death loop program reset itself. NXP's LPC2131 superior to most of other semiconductor company ARM7 product because of its memory acceleration module. This module prevent slow access speed flash memory become the bottleneck of fast speed ARM7 core. Figure 4 shows the development board used for the simulation.

5. METHODOLOGY

The adaptive beam forming with CSA firmware that was burned into the ARM7 microcontroller was prepared in C language. Besides containing the adaptive beam forming CSA program, the C coding also includes timer driver and pre-defined UE location. The build in timer module is used to calculate total time use to run the adaptive beam forming with CSA. The result generated is obtained from software debugger window. Total ROM sizes used for the firmware is 15890 bytes. Total fixed RAM size used is 1kbytes. However, dynamic RAM size used 7 Kbytes with heap size used 6 Kbytes and the rest is stack size. The huge heap size is needed because of cloning process which will generate a lot more solutions.

6. RESULTS AND DISCUSSION

Table 2 shows the CSA parameters used for the simulation. Total UEs used for the simulation is 20 and the antibodies size which equivalent to the initial size of pool of solution is 8. The termination criterion is achieved after repetition 75 generations. Table 3 shows the optimization result from the simulation. Table 4 shows the pre-defined UE angles. Figure 5 shows beam coverage result and all the pre-generated UEs location in graphical view. These tables show that within 3 seconds, embedded CSA able to get the best power efficiency pattern which covers all the 20 UE locations which were indicated as red dot in Figure 5. The effect of implementation overlapping angle can be observed on UE number 13 and number 14 which have location 235° and 249° respectively. Both of the locations quite near to the boundary beam coverage angle, 240°. Result from coverage area of beam angle 6, which covered both UE 13 and 14 in one beam instead of two beams, proved that AIS can be used to improve power efficiency of adaptive beam forming.

7. CONCLUSION

This paper has discussed the implementation of adaptive beam forming using the new emerging optimization tool, CSA on an embedded system microcontroller LPC2131. In this paper, CSA is used to get the optimized beam angles by evaluation of the power usage of all beams. Besides, this paper also shows the realization of limited processing power embedded system running a CSA program.

8. REFERENCES

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Table 1: Adaptive Beam Antenna Coverage

Beam number	Coverage angle	Maximum coverage angle
0	0° – 40°	320° – 40°
1	40° – 80°	0° – 80°
2	80° – 120°	40° – 120°
3	120° – 160°	80° – 160°
4	160° – 200°	120° – 200°
5	200° – 240°	160° – 240°
6	240° – 280°	200° – 280°
7	280° – 320°	240° – 320°
8	320° – 360°	280° – 360°

Table 2: CSA parameters used for simulation result

Parameters	Parameter used by LPC2131
Number of Ues	20
Allowed processing time	< 3s
Antibodies sizes	8
Replacement sizes	4
Generation cycle	75

Table 3: Optimization result from CSA using LPC

Parameters	Results generated by LPC2131
Beam angle 0	358° – 36°
Beam angle 1	unused
Beam angle 2	82° – 100°
Beam angle 3	126°– 136°
Beam angle 4	164° – 186°
Beam angle 5	216° – 226°
Beam angle 6	226° – 252°
Beam angle 7	259° – 305°
Beam angle 8	322° – 332°
Fitness value	0.1507
Time taken	2.353 s

Table 4: Pre-defined UEs location

No.	UE (degree)
1	6
2	12
3	33
4	84
5	91
6	126
7	167
8	180
9	185
10	219
11	227
12	229
13	235
14	249
15	263
16	278
17	297
18	303
19	330
20	358

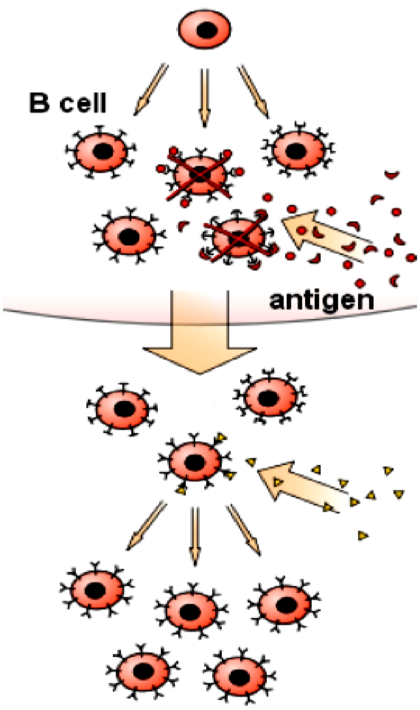

Figure 1: Clonal selection theory

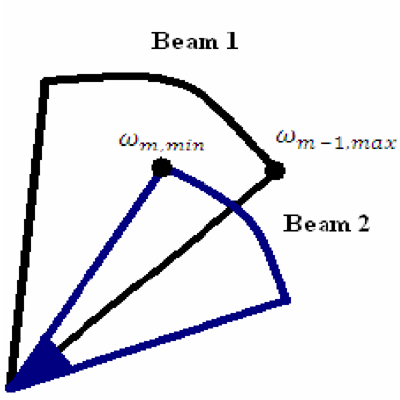

Figure 2: Overlapping beam angles

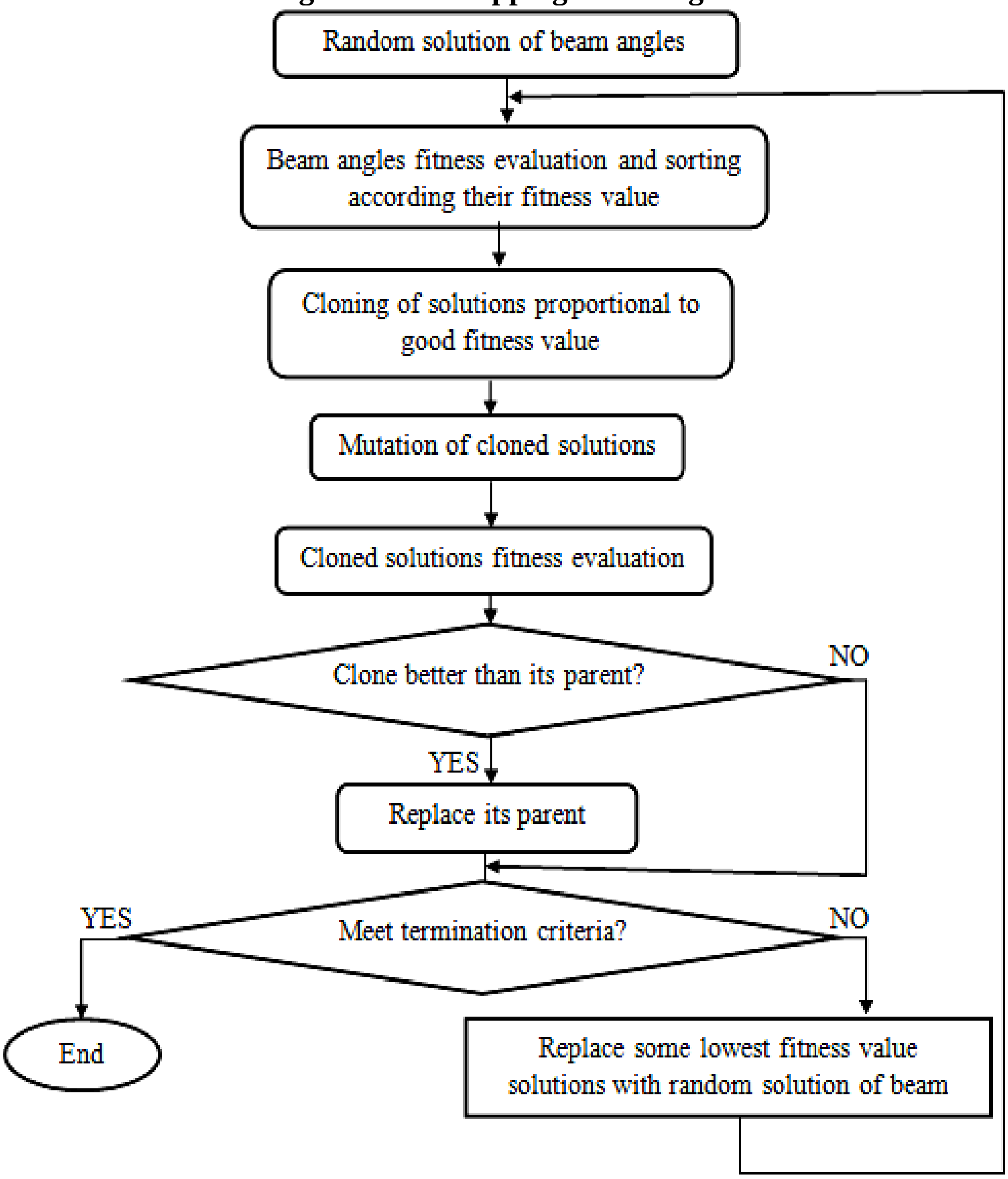

Figure 3: Adaptive beam forming with CSA flowchart

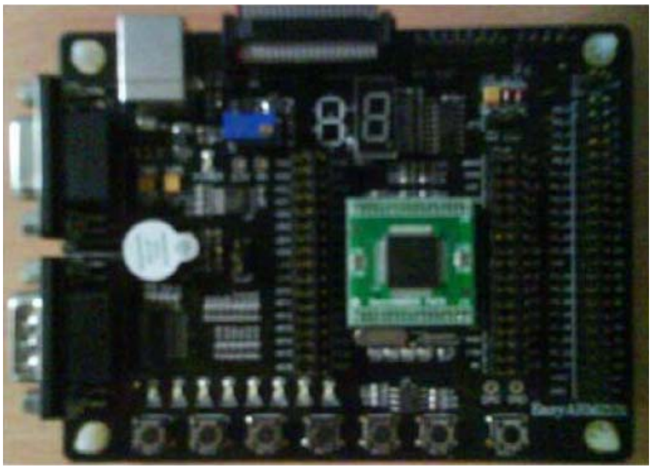

Figure 4: LPC2131 microcontroller development board

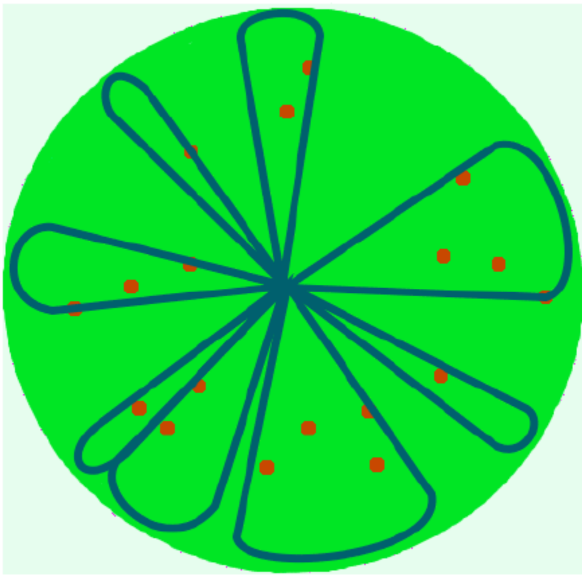

Figure 5: Beam coverage result