Particle-Wave Unification - An Object-Oriented Approach to Equilibrium-Based Computing

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Abstract – ***E****quilibrium-based computing is introduced and distinguished from truth-based computing. It is shown that object-oriented languages can be used for both equilibrium-based and truth-based programming. This observation supports the claim that any physical being must exist in certain dynamic equilibrium. The applicability of this approach is discussed and illustrated with Java and C++ code. It is shown that the equilibrium-based computing paradigm is applicable in both digital and quantum computing for particle-wave unification of matter and antimatter atoms.*

Keywords: Bipolarity; Equilibrium-Based Programming; Object Orientation; Particle-Wave Unification

1 Introduction

Traditionally, computer languages are classified into four different programming paradigms including imperative paradigm, functional paradigm, object oriented paradigm, and logical paradigm. These paradigms are all based on being and truth. Therefore, we classify them into truth-based programming paradigms. Scientific computing has been being-centered and truth-based.

It can be argued that truth-based programming is inadequate in modeling equilibrium and non-equilibrium conditions of beings. Based on this argument an equilibrium-based programming paradigm is introduced in this work. Philosophically, the new paradigm claims that any physical being must exist in certain dynamic equilibrium where bipolar dynamic equilibrium is the most fundamental form of any multidimensional equilibrium or non-equilibrium.

This work is organized into five sections: Introduction, Mathematical Foundation, Equilibrium-Based Programming with Object-Orientation, Application, and Conclusion.

2 Mathematical Foundation

2.1 Bipolar Sets and Bipolar Dynamic Logic

Truth-based mathematical abstraction follows Aristotle's "being qua being" metaphysics that asserts truth as the essence of being. The principle claims that the concept of an element in a set is self-evident without the need for proof of any kind and the properties of the set are independent of the nature of its elements. Classical logic is based on this principle. However, the principle may fail in the natural, biological and social worlds. For instance, the identity law A=A may not be able to hold in the quantum world due to quantum entanglement. And the independence of a set from the nature of its elements excludes any possibility of a formal definition for the ultimate being of all beings. This has led to nihilism and the indefinability of causality.

While classical set theory is based on truth and singularity, bipolar set theory is based on dynamic equilibrium and bipolarity [Zhang 1998, Zhang 2011]. The equilibrium-based approach follows the ancient Chinese YinYang cosmology and asserts bipolar dynamic equilibrium (including equilibrium, quasi-equilibrium, and non-equilibrium states) as the essence of being. Thus, bipolar sets present a major challenge to the principle of truth-based mathematical abstraction.

Ontologically, YinYang bipolarity is observable. While ether, monad, monopoles and strings are imaginable but so far not testable, dipoles are everywhere in the universe; particle-antiparticle pairs (-q,+q) and action-reaction (-f,+f) are believed the most fundamental elements of the universe; negative and positive energies form the regulating force of multiple universes [Hawking & Mlodinow 2010 p179-180]; competition and cooperation exist in any biological society; the Yin Yang 1 (YY1) genomic regulator protein with bipolar repression-activation functions is found ubiquitous in the cells of all living species [Shi, *et al.* 1991; Ai, Narahari & Roman, 2000; Palko *et al.* 2004**;** Zhou & Yik 2006; Wilkinson, *et al.* 2006; Kim, Faulk & Kim, 2007; Santiago, *et al.* 2007; Liu, *et al.* 2007; Vasudevan, Tong & Steitz 2007]; self-negation and self-assertion bipolar emotional equilibrium or disorder is a psychiatric reality [Zhang, Pandurangi and Peace 2007; Zhang et al 2011]; it is becoming scientifically evident that brain *bioelectromagnetic field is crucial for neurodynamics and different mental states* [Carey 2007] *where bipolarity is unavoidable.* In one word, any being or agent has to exist in certain dynamic equilibrium and bipolar dynamic equilibrium is shown to be the most basic type of equilibrium.

YinYang bipolar set theory leads to bipolar dynamic logic (BDL) which presents an equilibrium-based approach to mathematical abstraction [Zhang 1998a; Zhang & Zhang 2004a; Zhang 2011]. In bipolar sets the elements are bipolar agents such as dipoles, particle-antiparticle pairs, nature's action-reaction objects, genomic repression-activation capacities, social competition-cooperation relations, input-output of any system, self-negation and self-assertion abilities in mental health, in general, the negative and positive energies of nature (Fig. 1). This ontological claim positioned BDL in the context of logically definable causality for ubiquitous quantum computing and quantum intelligence.

BDL is defined on $B_1 = \{-1,0\} \times \{0,+1\} = \{(0,0), (0,+1), (-1,0), (-1,+1)\}$ – a bipolar quantum lattice in the YinYang bipolar geometry as shown in Fig. 2. The new geometry is background independent [Smolin 2005]. The background independent property makes quadrant irrelevant. The four values of B_1 form a bipolar causal set which stand, respectively, for eternal equilibrium (0,0), non-equilibrium (-1,0), non-equilibrium (0,+1); equilibrium (-1,+1). Evidently, each bipolar element can be used to code two bits of binary information (or one bit with a $\vee$ or $\wedge$ operation on the two poles in absolute values). Fig. 3 illustrates bipolar interaction and entanglement.

Equations (1)-(12) in Table 1 provide the basic operations of BDL. The laws in Table 2 hold on BDL. Bipolar universal modus ponens (BUMP) is listed in Table 3 which logically defines equilibrium-based bipolar causality.

An equilibrium-based axiomatization is shown in Table 4 which has been proven sound [Zhang 2011 Ch.3]. In BDL $\oplus$ and $\oplus^-$ are "balancers" that can, at the most basic level, be used as nuclear fusion operators; $\varnothing$, $\otimes$, $\varnothing^-$ and $\otimes^-$ are intuitive and counter-intuitive "oscillators" that leads to particle wave unification; & and $\&^-$ are "minimizers" that can, at the most basic level, be used as particle-antiparticle annihilation operators. The linear, cross-pole, bipolar fusion, fission, oscillation, interaction and entanglement properties are depicted in Figure 3.

The propositional BDL has been extended to a 1st order formal system [Zhang 2011 Ch. 3] in which equilibrium-based bipolar predicates can be used similarly as truth-based predicates. For instance, given bipolar agent A and let the bipolar functor (f^-,f^+) be self-negation and self-assertion abilities, $(f^-,f^+)(A)$ can denote the mental equilibrium or non-equilibrium of A; given bipolar agents A and B, and let the bipolar functor (r^-,r^+) be competition and cooperation relations, $(r^-,r^+)(A,B)$ can denote the relation between A and B.

Thus, BDL presents a causal logic for both digital and quantum computing. While the causal set quest for quantum gravity stopped short of going beyond classical truth-based set theory to reach logically definable quantum causality, bipolar sets and BDL as a formal bipolar equilibrium-based system presents a major step toward logically definable causality.

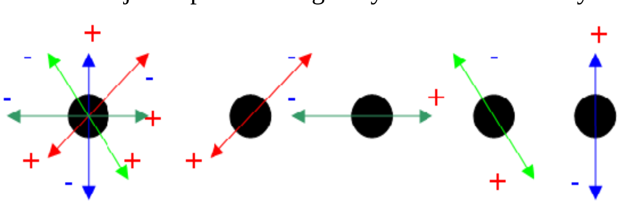

Figure 1. Multidimensional equilibrium or non-equilibrium deconstructed to bipolar equilibria/non-equilibria

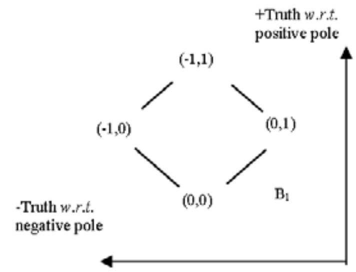

Figure 2. Hasse diagram of B_1 in bipolar geometry

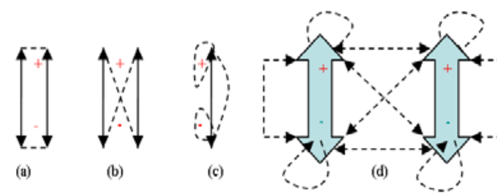

Figure 3 Bipolar relativity: (a) Linear interaction; (b) Cross-pole non-linear interaction; (d) Oscillation; (e) Bipolar entanglement

Table 1. YinYang Bipolar Dynamic Logic (BDL)
(Note: The use of |x| in this paper is for explicit bipolarity only)

Bipolar Partial Ordering: $(x,y) \geq\geq (u,v)$, iff $|x| \geq |u|$ and $y \geq v$; (1)

Complement: $\neg(x,y) \equiv (-1,1)-(x,y) \equiv (\neg x,\neg y) \equiv (-1-x,1-y)$; (2)

Implication: $(x,y) \Rightarrow (u,v) \equiv (x \rightarrow u, y \rightarrow v) \equiv (\neg x \vee u), \neg y \vee v)$; (3)

Negation: $-(x,y) \equiv (-y,-x)$; (4)

Bipolar least upper bound (blub):

$blub((x,y),(u,v)) \equiv (x,y) \oplus (u,v) \equiv (-(|x| \vee |u|), y \vee v)$; (5)

-blub: $blub^-((x,y),(u,v)) \equiv (x,y) \oplus^- (u,v) \equiv (-(y \vee v),(|x| \vee |u|))$; (6)

Bipolar greatest lower bound (bglb):

$bglb((x,y),(u,v)) \equiv (x,y) \& (u,v) \equiv (-(|x| \wedge |u|), y \wedge v))$; (7)

-bglb: $bglb^-((x,y),(u,v)) \equiv (x,y) \&^- (u,v) \equiv (-(y \wedge v), (|x| \wedge |u|)))$; (8)

Cross-pole greatest lower bound (cglb):

$cglb((x,y),(u,v)) \equiv (x,y) \otimes (u,v) \equiv (-(|x| \wedge |v| \vee |y| \wedge |u|),(|x| \wedge |u| \vee |y| \wedge |v|))$; (9)

-cglb: $cglb^-((x,y),(u,v)) \equiv (x,y) \otimes^- (u,v) \equiv -((x,y) \otimes (u,v))$; (11)

Cross-pole least upper bound (cglb):

$club((x,y),(u,v)) \equiv (x,y) \varnothing (u,v) \equiv (-1,1)-(\neg(x,y) \otimes \neg(u,v))$; (10)

-club: $club^-((x,y),(u,v)) \equiv (x,y) \varnothing^- (u,v) \equiv -((x,y) \varnothing (u,v))$. (12)

Table 2. Laws of bipolar equilibrium/non-equilibrium

Excluded Middle	$(x,y) \oplus \neg(x,y) \equiv (-1,1)$; $(x,y) \oplus^- \neg(x,y) \equiv (-1,1)$;
No contradiction	$\neg((x,y) \& \neg(x,y)) \equiv (-1,1)$; $\neg((x,y) \&^- \neg(x,y)) \equiv (-1,1)$;
Linear Bipolar DeMorgan's Laws	$\neg((a,b) \& (c,d)) \equiv \neg(a,b) \oplus \neg(c,d)$; $\neg((a,b) \oplus (c,d)) \equiv \neg(a,b) \& \neg(c,d)$; $\neg((a,b) \&^- (c,d)) \equiv \neg(a,b) \oplus^- \neg(c,d)$; $\neg((a,b) \oplus^- (c,d)) \equiv \neg(a,b) \&^- \neg(c,d)$;
Non-Linear Bipolar DeMorgan's Laws	$\neg((a,b) \otimes (c,d)) \equiv \neg(a,b) \varnothing \neg(c,d)$; $\neg((a,b) \varnothing (c,d)) \equiv \neg(a,b) \otimes \neg(c,d)$; $\neg((a,b) \otimes^- (c,d)) \equiv \neg(a,b) \varnothing^- \neg(c,d)$; $\neg((a,b) \varnothing^- (c,d)) \equiv \neg(a,b) \otimes^- \neg(c,d)$

Table 3. Bipolar Universal Modus Ponens (BUMP)

$\forall \phi=(\phi^-,\phi^+)$, $\varphi=(\varphi^-,\varphi^+)$, $\psi=(\psi^-,\psi^+)$, and $\chi=(\chi^-,\chi^+) \in B_1$,

$$[(\phi \Rightarrow \varphi) \& (\psi \Rightarrow \chi)] \Rightarrow [(\phi * \psi) \Rightarrow (\varphi * \chi)];$$

$$OR\ (\phi \Leftrightarrow \varphi) \Rightarrow (\phi * \psi \Leftrightarrow \varphi * \psi)$$

Two-fold universal instantiation:

1) Operator instantiation: $*$ as a universal operator can be bound to &, $\oplus$, $\&^-$, $\oplus^-$, $\otimes$, $\varnothing$, $\otimes^-$, $\varnothing^-$. $(\phi \Rightarrow \varphi)$ is designated (bipolar true (-1,+1)); $((\phi^-,\phi^+)*(\psi^-,\psi^+))$ is undesignated.
2) Variable instantiation:
$\forall x$, $(\phi^-,\phi^+)(x) \Rightarrow (\varphi^-,\varphi^+)(x)$; $(\phi^-,\phi^+)(A)$; $\therefore$ $(\varphi^-,\varphi^+)(A)$.

Table 4. From Truth-Based to Equilibrium-Based Axiomatization

Unipolar Axioms (UAs): UA1: $\phi\to (\varphi\to\phi)$; UA2: $(\phi\to(\varphi\to\chi))$ $\to((\phi\to\varphi)\to(\phi\to\chi))$; UA3: $\neg\phi\to\varphi)\to((\neg\phi\to\neg\varphi)\to\phi)$; UA4: (a) $\phi\wedge\varphi\to\phi$; (b) $\phi\wedge\varphi\to\varphi$; UA5: $\phi\to(\varphi\to\phi\wedge\varphi)$;	Bipolar Linear Axioms: BA1: $(\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow(\phi^-,\phi^+))$; BA2: $((\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow(\chi^-,\chi^+)))$ $\Rightarrow(((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\Rightarrow((\phi^-,\phi^+)\Rightarrow(\chi^-,\chi^+)))$; BA3: $(\neg(\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))$ $\Rightarrow ((\neg(\phi^-,\phi^+)\Rightarrow\neg(\varphi^-,\varphi^+)) \Rightarrow (\phi^-,\phi^+))$; BA4: (a) $(\phi^-,\phi^+)\&(\varphi^-,\varphi^+)\Rightarrow(\phi^-,\phi^+)$; (b) $(\phi^-,\phi^+)\&(\varphi^-,\varphi^+)\Rightarrow(\varphi^-,\varphi^+)$; BA5: $(\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow((\phi^-,\phi^+)\&(\varphi^-,\varphi^+)))$;
Inference Rule – Modus Ponens (MP): UR1: $(\phi\wedge(\phi\to\varphi))\to\varphi$.	Non-Linear Bipolar Universal Modus Ponens (BUMP) (* can be bound to any bipolar operator in Table 1) BR1: IF $((\phi^-,\phi^+)*(\psi^-,\psi^+))$, $[((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\&((\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+))]$, THEN $[(\varphi^-,\varphi^+)*(\chi^-,\chi^+)]$;
Predicate axioms and rules UA6: $\forall x,\phi(x) \to\phi(t)$; UA7: $\forall x, (\phi\to\varphi)\to (\phi\to\forall x,\varphi)$; UR2–Generalization: $\phi\to\forall x,\phi(x)$	Bipolar Predicate axioms and Rules of inference BA6: $\forall x,(\phi^-(x),\phi^+(x))\Rightarrow(\phi^-(t),\phi^+(t))$; BA7: $\forall x,((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\Rightarrow((\phi^-,\phi^+)\Rightarrow\forall x,(\varphi^-,\varphi^+)$; BR2-Generalization: $(\phi^-,\phi^+)\Rightarrow\forall x,(\phi^-(x),\phi^+(x))$

2.2 Bipolar Relations and Equilibrium Relations

As a causal set, a bipolar relation is characterized with bipolar values such as (0,0) for no relation, (-1,0) for conflict relation, (0,+1) for coalition, and (-1,+1) for harmonic relation, respectively. The *bipolar transitive closure* of a bipolar relation R is the smallest transitive bipolar relation containing R [Zhang 2003a; Zhang 2011, Ch. 3], denoted by $\Re$ and

$$\Re = R^1 \oplus R^2 \oplus R^3 \oplus .... \quad (13)$$

It is found that, let $X=\{x_1,x_2,...,x_n\}$ be a finite bipolar set, the $\oplus$–$\otimes$ bipolar transitive closure (denoted $\Re$) of R in X exists, is unique, and

$$\Re = R^1 \oplus R^2 \oplus R^3 \oplus ... \oplus R^{2n}. \quad (14)$$

Bipolar transitive closure is a causal structure. Bipolar reflexivity, symmetry and transitivity lead to the generalizations of equivalence relations to bipolar equilibrium relations [Zhang 2003a; Zhang 2011 Ch. 3] and fuzzy similarity relations to bipolar fuzzy or quasi-equilibrium relations [Zhang 2006; Zhang 2011 Ch. 5]. Based Eq. (14), algorithms have been devised for bipolar clustering from equilibrium relations. While an equivalence relation induces partitions of equivalence sets; an equilibrium relation induces partitions of coalition sets, conflict sets, and harmonic sets [Zhang 2006; Zhang 2011 Ch. 5]. Thus, the partitions from an expected equilibrium state could be used as predictions for decision support [Zhang 2003a,b].

2.3 Bipolar Quantum Linear Algebra

The bipolar lattice $B_1=\{-1,0\}\times\{0,1\}$ and the bipolar fuzzy lattice $B_F = [-1,0] \times [0,1]$ can be naturally extended to the real valued bipolar lattice $B_\infty = [-\infty, 0] \times [0, +\infty]$. B_1 and B_F are bounded and complemented unit square lattices, respectively; B_∞ is unbounded. $\forall (x,y),(u,v)\in B_\infty$, Eqs. 15-16 define two algebraic operations.

Bipolar Multiplication: $(x,y) \times (u,v) \equiv (xv+yu, xu+yv);$ (15)

Bipolar Addition: $(x,y) + (u,v) \equiv (x+u, y+v).$ (16)

In Eq. (15), $\times$ is a cross-pole multiplication operator with the infused non-linear bipolar causal semantics --=+, -+=+-=1, and ++=+; + in Eq. (16) is a linear bipolar addition or fusion operator. With the two basic operations, classical linear algebra is naturally extended to an equilibrium-based *causal algebra* named *bipolar quantum linear algebra* (BQLA) with bipolar fusion, fission, diffusion, interaction, oscillation, annihilation, and quantum entanglement properties [Zhang et al 2009; Zhang 2011 Ch. 7; Zhang 2012a]. These properties enable physical or biological agents to interact through bipolar quantum fields such as atom-atom, cell-cell, heart-heart, heart-brain, brain-brain, organ-organ, and genome-genome bio-electromagnetic quantum fields as well as biochemical pathways in energy equilibrium or non-equilibrium. These properties lead to the inception of YinYang bipolar atom [Zhang 2012a], bipolar quantum logic gates and quantum cellular combinatorics [Zhang 2013]. Quantum cellular combinatorics provides a modular graph theory for multidimensional bipolar cause-effect modeling (Fig. 1) of YinYang-N-element cellular automata [Zhang 2011 Ch. 8; Zhang 2012a].

3 An Object-Oriented Approach to Equilibrium-Based Programming

Logically, bipolar dynamic logic (BDL) presents an equilibrium-based non-linear dynamic generalization of Boolean logic from the truth-based domain or bivalent lattice {0,1} to the equilibrium-based domain or bipolar lattice B_1 = {(0,0), (-1,0), (0,+1), (-1,+1)}. This generalization provides a logical basis for equilibrium-based dynamic programming (EDP). Now our question is whether EDP can be realized with object-orientated languages such as in C++ and Java. Interestingly, the answer is positive.

3.1 C++ Class for Bipolar Variable

Bipolar variable, the basic concept of BDL and BQLA, is defined in the following C++ class with object-orientation:

```
class nppair {  // specify bipolar variable and its operations
   float lower_weight; // negative pole
   float upper_weight; // positive pole
public:
   // constructors
   nppair() { }
   nppair(float l,float u)
     {lower_weight = l; upper_weight = u; }
   void update(float l,float u)
     {lower_weight = l; upper_weight = u; }
   // getter and setters
   float& lower() { return lower_weight; }
   float& upper() { return upper_weight; }
   float lower() const { return lower_weight; }
   float upper() const { return upper_weight; }
   float& left() { return lower_weight; }
   float& right() { return upper_weight; }
   float leftt() const { return lower_weight; }
   float rightt() const { return upper_weight; }
   void  new_lower(float x) { lower_weight=x; }
   void  new_upper(float y) { upper_weight=y; }
   // operators
   void operator =(nppair& p) {
```

```
    lower_weight = p.lower_weight;
    upper_weight = p.upper_weight; }
  void operator *=(float d);
  void operator /=(float d);
  void operator *=(nppair& p);
  void operator +=(nppair& p);
  void operator -=(nppair& p);
  friend nppair operator *(nppair& p1,nppair& p2);
  friend nppair operator *(nppair& p1,float d);
  friend nppair operator /(nppair& p1,float d);
  friend nppair operator +(nppair& p1,nppair& p2);
  friend nppair operator |(nppair& p1,nppair& p2);
  friend npinterval operator ||(nppair& p1,nppair& p2);
  friend istream& operator>> (istream& ci, nppair& c){
    ci >> c.lower_weight;
    ci >> c.upper_weight;
    return ci; }
  friend ostream& operator<< (ostream& co, const nppair& c) {
      co << '(' << c.lower_weight << ' ' << c.upper_weight << ')';
         return co; }
  friend int contain1(const nppair& p1,float d);
  friend int contain2(const nppair& p1,const nppair& p2);
  friend npinterval;
};
```

3.2 C++ Class for Bipolar Vector or Matrix

Based on the class of nppair, a bipolar vector or matrix and its operations can be defined.

```
class npmatrix {  // bipolar matrix
  nppair* m;    // pointer to matrix in 1-d storage
  int rows;     // number of rows
    int cols;        // number of col
  float* rowEnergy; // pointer to row bipolar energy
  float* colEnergy;  // pointer to col bipolar energy
public:
  // constructor
      npmatrix() {}
  npmatrix(int r,int c){
  rows=r; cols=c; m = new nppair[r*c];
  rowEnergy = new float[rows];
  colEnergy = new float[cols];}
  npmatrix(int r,int c,nppair* m1) { rows=r; cols=c; m = m1; }
  // member operators and functions
  void clear();
  nppair& operator ()(int x) { return m[x]; } // 1-d getter
  nppair& operator ()(int i,int j) { return m[i*cols+j]; } //2-d getter
  float negativeEnergy();
  float positiveEnergy();
  float totalEnergy();
  float localImbalance();
  float globalImbalance();
  float localStability();
  float globalStability();
  nppair harmonyLevel();
  void operator *=(float d);  // multiply by d
  void operator /=(float d);   // divid by d
  void operator +=(npmatrix& m); // matrix addition
  void operator -=(npmatrix& m); //matrix subtraction
  void closure(int Tnorm);   // bipolar transitive closure with Tnorm
  friend npmatrix operator *(npmatrix& m1,float d);
  friend npmatrix operator /(npmatrix& m1,float d);
  friend npmatrix operator +(npmatrix& m1,npmatrix& m2);
  friend npmatrix operator -(npmatrix& m1,npmatrix& m2);
  friend npmatrix operator *(npmatrix& m1,npmatrix& m2);
  friend istream& operator>> (istream& ci, npmatrix& m);
  friend ostream& operator<< (ostream& co, const npmatrix& m);
  friend istream& inner_outer_i(istream& ci, npmatrix& m1, npmatrix& m2);
  friend ostream& inner_outer_o(ostream& co, const npmatrix& m1, const npmatrix& m2);
  friend istream& inner_outer_i(istream& ci, npmatrix& m1, npmatrix& m2, npmatrix& m3, npmatrix& m4);
  friend ostream& inner_outer_o(ostream& co, const npmatrix& m1, const npmatrix& m2, const npmatrix& m3, const npmatrix& m4);
  friend ostream& linguistic(ostream& co, const npmatrix& m1, const npmatrix& m2);
  friend ostream& linguistic(ostream& co, const npmatrix& m1, const npmatrix& m2, const npmatrix& m3, const npmatrix& m4);
  void randomize();   // assign random bipolar weights
  void normalizeRow();  // normalize row energy
  void normalizeCol(); // normalize row energy
  int normalized(); // check normalization
  void row_Energy(); // row energy
  void col_Energy(); // col energy
};
```

3.3 Equilibrium-Based but Object-Oriented

The C++ program examples for bipolar variables and vectors show that a bipolar equilibrium can be coded as an object class and a multidimensional equilibrium can be coded as a set of bipolar objects. Therefore, object-oriented languages can be used for equilibrium-based programming.

4 Applications

4.1 Bipolar Complementarity

Niels Bohr - a father figure of quantum mechanics - was the first to bring YinYang into quantum theory for his particle-wave complementarity or duality principle. When Bohr was awarded the Order of the Elephant by the Danish government, he designed his own coat of arms which featured in the center a YinYang logo (or Taijit symbol) and the Latin motto "contraria sunt complementa" or "opposites are complementary" (Fig. 4).

While Bohr's quantum mechanics recognized particle-wave complementarity, it stopped short of identifying the essence of YinYang bipolar coexistence. It is argued that without bipolarity any complementarity is less fundamental due to the missing "opposites" (Fig. 5) [Zhang 2011; Zhang 2013]. If bipolar equilibrium is the most fundamental form of equilibrium, any multidimensional model of spacetime such as string theory and superstring theory cannot be most fundamental.

In brief, action-reaction, particle-antiparticle, negative-positive energies, input and output, or the Yin and Yang of nature in general could be the most fundamental opposites, but man and woman, space and time, particle and wave, truth and falsity are not exactly bipolar opposites. This could be the reason why Bohr found causal description of a quantum process unattainable and we have to content ourselves with particle-wave complementary descriptions [Bohr 1948]. Since then, particle and wave as a YinYang duality has not reached unification. Now, equilibrium-based computing provides a basis for such a unification.

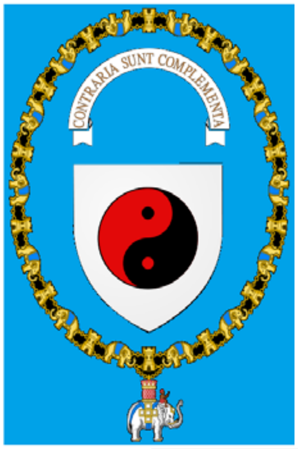

Figure 4. Bohr's Coat of Arms (Creative Commons file by GJo, 3/8/2010, Source: File:Royal Coat of Arms of Denmark.svg (Collar of the Order of the Elephant) + File:Yin yang.svg)

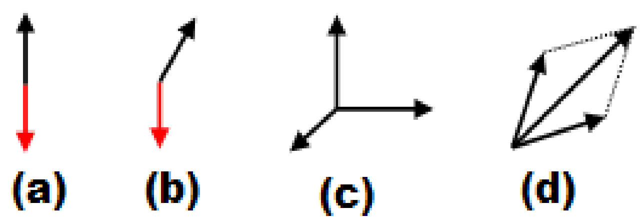

Figure 5. Fundamental and non-fundamental complementarities: (a) Fundamental; (b)-(d) Non-fundamental

4.2 Bipolar Quantum Logic Gates

Bipolar Energy Conservational Quantum Logic Gate. If the energy of every row and every column of a bipolar decimal matrix M of a quantum agent in Eq. (24) always adds up to 1.0, we call M a bipolar energy conservational quantum logic gate matrix.

Law of Bipolar Equilibrium or Symmetry: With Eq. (24), if M is bipolar energy conservational, any quantum agent's energy vector $E(t_1)=M \times E(t_0)$ at t_0 and t_1 can be characterized as satisfies Eq. (17).

$$|\varepsilon|\ (E(t_1))=\ |\varepsilon|\ (M \times E(t_0)) \equiv |\varepsilon|\ (E(t_0)) \qquad (17)$$

Evidently, any integer unitary quantum logic gate matrix must be energy conservational. Therefore, a unitary quantum logic gate in quantum computing can be deemed part of energy conservation and the concepts of equilibrium, symmetry, unitarity and reversibility in quantum computing are generalized to the equilibrium or non-equilibrium condition of any agent. This generalization illustrates the quantum nature of all agents in multidimensional bipolar equilibrium or non-equilibrium. [Zhang 2013]

4.3 Equilibrium-Based Algorithm

Two equilibrium-based algorithms are shown in C++ language in Table 5 for quantum cellular automata using bipolar quantum logic gates.

Table 5. Two C++ algorithms for testing energy equilibrium [Zhang *et al.* 2009]

```
//Algorithm A: Normalization of the Random Connectivity Matrix M
// (1) normalize the energy of each row and column of M to |ε|=1.0 as an equilibrium condition;
// (2) normalize the energy to |ε|>1.0 as a non- equilibrium condition for energy increase;
// (3) normalize the energy to |ε|<1.0 as a non- equilibrium condition for energy decrease;
//---------------------------------------------------------------------------
YinYangMatrix M(N,N); // create an N×N bipolar connectivity matrix
M.randomize();         // assign random weights to the elements of M
M.normalizeRows();  // normalize each row |ε|(M_k*)
M.normalizeCols().    // normalize each column  |ε|(M_*j)
//---------------------------------------------------------------------------
//Algorithm B: Test the three conditions :
//(1) ∀t , Y(t+1) = M(t)Y(t) – equilibrium
//(2) ∀t , Y(t+1) > M(t)Y(t) – energy increase
//(3) ∀t , Y(t+1) < M(t)Y(t) – energy decrease
//---------------------------------------------------------------------------
YinYangMatrix M(N,N); // create an N×N bipolar connectivity matrix
YinYangMatrix Yt0(1,N); // create column vector at t0
YinYangMatrix Yt1(1,N); // create column vector at t1
M.randomize();         // assign random link weights to M
M.normalizeRows();  // normalize each row |ε|(M_k*)
M.normalizeCols().    // normalize each column  |ε|(M_*j)
file1 >> Yt0;           // input col vector from file1
int times;
cin >> times;            // enter number of iteration
for (int i = 0; i<times;  i++){
Yt1 = M*Yt0;            // M multiply column vector
file2 << Yt1;             // output result vector to file2
file2 << Yt1.totalEnergy() << "\n";   // output energy to file2
Yt0 = Yt1;               // reassign for next iteration
}
```

4.4 Particle-Wave Unification

The object-oriented approach to equilibrium-based programming can be used to demonstrate particle-wave unification of both matter and antimatter atoms. At the most fundamental level we have $(-1,0) \otimes (-1,0) = (-1,0)^2 = (0,1)$ and $(-1,1) \otimes (-1,1) = (-1,1)^2 = (-1,1)$. $(-1,0)^n$ defines a bipolar oscillation. Such property provides a unifying logical representation for particle-wave duality of both matter and antimatter particles.

Generic Bipolar Agent: (1) $\phi(P)(f) = (-1,0)^n(3\times10^{12})$ can denote the fact "Particle P changes polarity three trillion times per second from particle to antiparticle or vice versa." P is a subatomic particle named B-sub-s meson discovered at the Fermi National Accelerator Laboratory [Fermi National Accelerator Laboratory, 2006]. Fig. 6a shows the graphical representation of P as a YinYang-1-Element with a negative reflexivity. (2) $\phi(A) = (-1,+1) \otimes (-1,0) = (-1,+1) \otimes (-1,0) = (-1,+1) \otimes (-1,+1)$ can denote the fact "Agent A is a has strong mental equilibrium of self-negation and self-assertion abilities who can bear with negative event, positive event as well as harmonic event." Fig. 6b shows the graphical representation of the strong equilibrium.

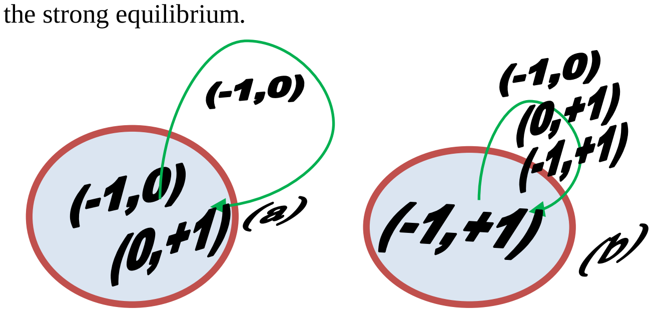

Fig. 6. (a) Oscillating particle-antiparticle; (b) Agent with strong mental equilibrium

Composite Bipolar Agents: Fig. 7 shows a YinYang-N-Element cellular automaton where each element is bipolar such as electron-positron as in matter atom or antimatter atom. In either case the bipolar energy can be characterized as $E(t_1)=M\times E(t_0)$ in equilibrium or non-equilibrium. Dramatically, each bipolar wave form is actually a bipolar element (object) in a collection of different bipolar states in an ordered sequence as shown in Figs. 7, 8 and 9. Thus, an N-electron matter atom or N-positron antimatter atom can be represented as the superposition of N such wave forms. The particle-wave forms are generated with Java programs in object-orientation. Thus particle-wave unification is realized.

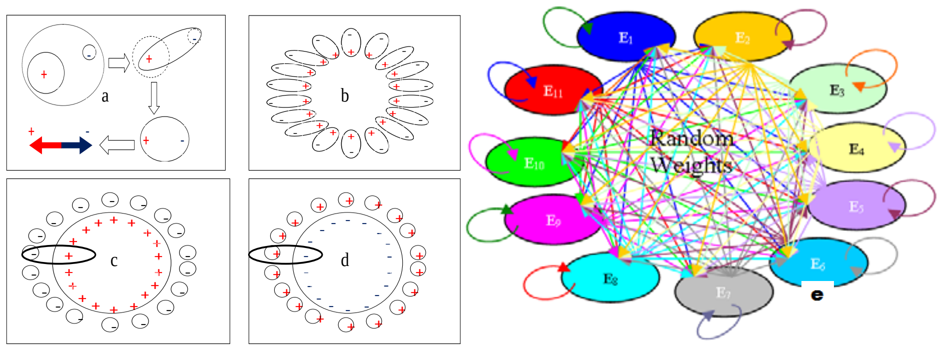

Figure 7. Particle-wave unification as a bipolar cellular automaton: (a) bipolar representation of a hydrogen; (b) bipolar representation of YinYang-n-elements; (c) Matter atom; (d) Antimatter atom; (e) Bipolar Quantum Cellular Automaton

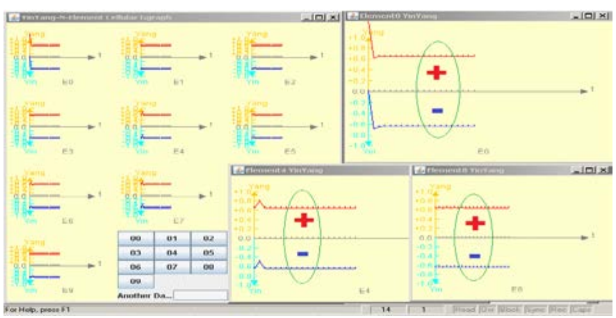

Fig. 8. Bipolar energy rebalancing to equilibrium after a disturbance to one element

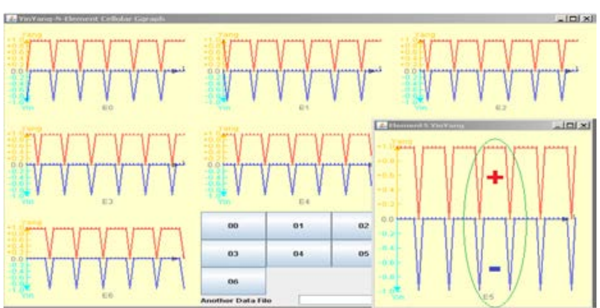

Fig. 9. Elementary bipolar energy oscillation under global equilibrium

5 Conclusions

Equilibrium-based programming has been introduced and distinguished from truth-based programming. It has been shown that object-oriented languages can be used for both equilibrium-based and truth-based programming. This observation supports the claim that any physical being or object must exist in certain dynamic equilibrium.

The applicability of equilibrium-based programming has been discussed and illustrated in scientific computing with C++ code and particle-waveforms from Java code to illustrate matter-antimatter and particle-wave unification. It is further expected that, based on BDL and BQLA, imperative, functional, object-oriented and logical programming paradigms can all be extended from truth-based to equilibrium-based programming paradigms.

From a different perspective, bipolar dynamic equilibrium as holistic truth does not exclude but generalizes truth from the bivalent domain or lattice {0,1} to the bipolar domain or lattice {(-1,0) × (0,+1)}. Since the universe (or multiple universes) can be deemed a dynamic equilibrium of negative-positive energies, particle-antiparticles, and action-reaction forces, the equilibrium-based programming paradigm is expected to bridge a gap between digital computing and quantum computing for programming the universe [Lloyd 2006] with applications in physical, social, biological, and mental worlds [Ball 2011][Zhang and Zhang et al 1989-2013].

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