Recursive Distinctioning, Tetracoding and the Symmetry Properties of Chiral Tetrahedral Molecules

By Martin A. Hay

Abstract
This paper describes the material I presented at the Convention on Recursive Distinctioning (RD) in Clayton MO on September 16-18, 2016. It is in several parts. The first part seeks to teach how to build control systems for coding and processing information about relationships in the four relationship states (00), (01), (11) and (10) described in Joel Isaacson's US patent number 4,286,330 on tetracoding and RD. It takes as its starting point the work of Joel Isaacson on RD, of Louis Kauffman on quaternions and iterants and Bernd Schmeikal on polarity strings, and it integrates this with my own work based on an analysis of the symmetry properties of chiral tetrahedral molecules.[1] It also relates to work of Moshe Klein and Yale Landsberg, who, like me, seek to draw a distinction between different zeroes. The subsequent parts of the paper describe applications of such systems that have already been prototyped or could be, including a new kind of game embodying rights and obligations that can be played under control of left and right musculature and may potentially be useful in the treatment of brain injury or stroke, a new kind of voting system and a new kind of system for controlling the exchange of goods and services that does not involve the use of an imaginary store of value of any kind (money or credit).

Relationship States

We teach our children to construct their world view based on the principle of a balance (weighing scales). A balance can be tipped to the left, balanced or tipped to the right. An object can be positioned to the left, in the middle or to the right. A number can be negative, zero or positive. Socially a person can be in debt (owe money), in balance or in credit (own money). However, the building blocks of all our constructs are distinctions:[2] the same or different. The three possible positions of a balance and the three different kinds of number: positive, zero and negative, are all constructed out of combinations of same and different. A way to do this was worked out a long time ago,[3] but is very little known. The same and different are coded as 0 and 1. The three positions of a balance are treated as left, right ordered pairs of 1s and 0s. -1 is treated as (10); balance as (00) and +1 as (01). The addition of +1 (01) to -1 (10) affords (11), which cancels down to (00). The 1s are tallied as in 1 + 1 = 2, but the 0s are not, as in 0 + 0 = 0 and 0 + 1 = 1. Thus, our models of the world are constructed out of three relationship states: (10) – different on the left, not the right; (00) = (11) – no difference between the left and the right; and (01) – different on the right, not the left.

---

[1] *Journal of Space Philosophy* 5, No. 1 (2016); Terry Marks-Tarlow, Martin A. Hay, and Herb Klitzner, "Quaternions, Chirality, Exchange Interactions: A New Tool for Neuroscience?" *Society for Chaos Theory in Psychology & Life Sciences* 23, No. 1. (2015): 8-14; Bernd Schmeikal, "Four Forms Make a Universe," *Advances in Applied Clifford Algebras* 25, No. 1 (2015): 1-23; Joel Isaacson and Louis H. Kauffman, "Recursive Distinctioning" (2016), arXiv:1606.06965 [physics.gen-ph].

[2] G. Spencer-Brown, *Laws of Form* (London: George Allen and Unwin, 1969).

[3] D. E. Littlewood, *The Skeleton Key of Mathematics: A Simple Account of Complex Algebraic Theories* (New York: Harper Torchbooks, 1960).

This number coding based on the principle of a balance (+1, 0, -1) is ubiquitous in science and technology, as well as in the coding and processing of information about economic relationships. Voting systems in effect weigh the votes for one candidate against those for another, such that voting for no candidate (00) has the same effect as a vote for every candidate (11). In the exchange of goods and services and taxation, an individual may be in a state of debt (owes money), credit (owns money) or balance (neither owns nor owes money). The three states encode mutual relations between two individuals and a resource. For every credit there is a counterpart debt. Every time a good or service is provided without another good or service being provided in return, the receiving party goes into a state of debt and the providing party into a state of credit.

Human societies have been coding and processing information based on the principle of a balance for hundreds if not thousands of years, but biology does not actually work this way. The perception of presence and absence are both active constructs. A neuron can fire in response to the presence or the absence of a stimulus. It follows that biology does not distinguish presence and absence in the same way that numbers that can be tallied, 1s, are distinguished from numbers that cannot, 0s. Each kind can be encoded in the firing of one or more neurons. Accordingly, instead of representing the same and different in terms of 0 (which cannot be tallied) and 1 (which can be tallied), it appears more appropriate to use + and -. This issue of when the same or different can be tallied is important and is revisited later.

Joel Isaacson's US patent number 4,286,330[4] discloses tetracoding: a way of encoding mutual relationships in four relationship states, A (00), B (01), D (11) and C (10), each of which is defined in terms of its relations to its two neighbours.

A (00): both neighbours are distinct (0) from the state;

B (01): the left neighbour is distinct (0) and the right neighbour is indistinct (1) from the state;

D (11): both neighbours are indistinct (1) from the state; and

C (10): the left neighbour is indistinct (1) and the right neighbour is distinct (0) from the state.

This way of encoding mutual relationships works on a principle fundamentally different from that of a balance. It draws a distinction not only between two antisymmetric states (10) and (01) as in voting for one candidate, not another or debt and credit, but also between two symmetric relationship states (11) and (00), as in active and passive abstention in voting, or an object that belongs to neither or both members of a relationship. It works on the principle of order, as I will explain later.

My own international patent application, publication number WO2012/069776 discloses a chiralkine system.[5] The system is encoded in four relationship states: two

[4] Joel D. Isaacson, "Autonomic String-Manipulation System," US Patent 4,286,330, August 25, 1981, www.isss.org/2001meet/2001paper/4286330.pdf.

antisymmetric: A (↑↓ or + -) and C (↓↑ or - +) and two symmetric: D (↑↑ or + +) and L (↓↓ or - -). These can be mapped to the four states disclosed in US Patent Number 4,286,330.

D (↑↑ or + +) → A (00): both neighbours are distinct (0) from the state;

A (↑↓ or + -) → B (01): the left neighbour is distinct (0) and the right neighbour is indistinct (1) from the state;

L (↓↓ or - -) → D (11): both neighbours are indistinct (1) from the state; and

C (↓↑ or - +) → C (10): the left neighbour is indistinct (1) and the right neighbour is distinct (0) from the state.

In a chiralkine system, relationship states are manipulated pairwise based on the principle of order: A turns C into L and C turns A into D.

Coding in Biological Systems, Chirality

In the genetic code of living systems, information is coded in a polymer of four bases known as DNA. Each polymer is an ordered combination of four bases: adenine (A), thymine (T), guanine (G) and cytosine (C). These bases can pair up as in A to T and G to C such that each strand of DNA can pair up with its complement. Each polymer of DNA encodes for the production of a polymer of amino acids, in particular a peptide of protein. Each amino acid is encoded by a particular sequence of three bases (triplet) in the DNA polymer.

An amino acid can be represented by the general chemical formula (Figure 1):

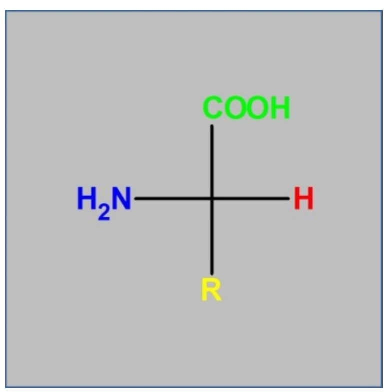


Figure 1. The formula of an amino acid.

in which R represents a general group. Each molecule of an amino acid has a tetrahedral shape. The central carbon atom (not shown) is bonded to four different

[5] Martin A. Hay, "Chiralkine," US Patent Applications, Publication Nos. 2013/0221616 (2013), 2016/0199725 (2016); Martin A. Hay and Frances G. Boul Hay, "Technology Alternative to Money for Enabling Equitable Trade," US Patent Application, Publication No. 2014/0195379.

atoms or groups: a hydrogen atom, an amino group (NH_2), a carboxyl group (COOH) and a group R (other than glycine, where R is itself a hydrogen atom). For example, when R represents a methyl group, the amino acid is alanine.

Amino acids can form chains in which the carboxyl group of one amino acid forms a peptide bond (CONH) with an amino group of an adjacent amino acid. In this way, amino acids can form peptides and proteins, which have many different functions in living organisms. It is worth noting that an amino acid can be in one of four states: unbound on the amino and carboxyl groups; bound on the amino and carboxyl groups; bound on the amino, not the carboxyl group and bound on the carboxyl, not the amino group. However, this paper focuses on another property of amino acids: their handedness, or chirality.

The word "chiral" comes from the Greek word for hand. Amino acids are chiral molecules. Four different objects can be arranged in 3D space in two mirror-opposite ways, like the wrist, thumb, first finger and second finger of the hands (Figure 2).

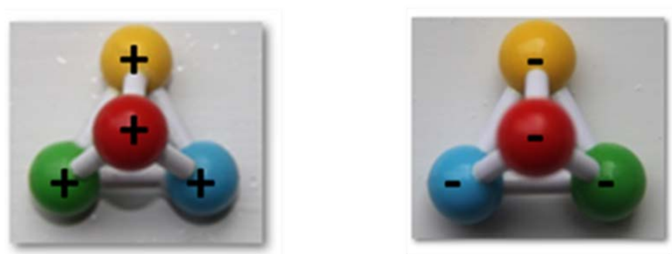


Figure 2. Mirror-image models of chiral tetrahedral molecules.

In an amino acid, the four different objects are the hydrogen atom, R group, amino group and carboxyl group bonded to a central carbon atom. They point towards the corners of a tetrahedron. All the amino acids in the human body are of one handedness.

Most people find it very difficult to visualise shapes in 3D space, and even more difficult to visualise how the components of a shape move as the shape is rotated. Chemists use a technique known as the Fischer projection[6] to distinguish between the two forms of a chiral tetrahedral molecule. A Fischer projection sets out the four components of a tetrahedral molecule as if they lie at the ends of a cross. The two components positioned horizontally are deemed to project towards (+) the viewer and those positioned vertically are deemed to project away (-) from the viewer. By convention, the carboxyl group of an amino acid is positioned above and the R group below (Figure 3).

[6] S. Capozziello and A. Lattanzi, "Chiral Tetrahedrons as Unitary Quaternions: Molecules and Particles Under the Same Standard," *International Journal of Quantum Chemistry* 104 (2005): 885-39; Francisco M. Fernández, "On the Algebraic Structure of Central Molecular Chirality," Journal of Mathematical Chemistry 54 (2016): 552-58.

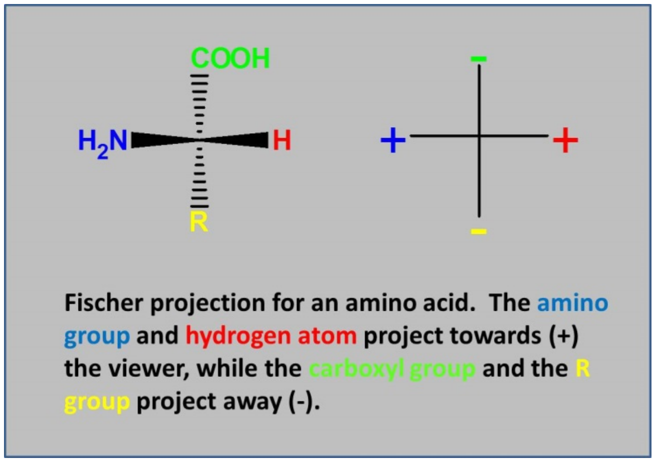


Figure 3. Fischer projection for an amino acid.

When the amino group is positioned on the left and the hydrogen is positioned on the right, the amino acid is said to be in the L configuration. When the amino group is positioned on the right and the hydrogen is positioned on the left, the amino acid is said to be in the D configuration. All amino acids in the human body are in the L configuration (Figure 4).

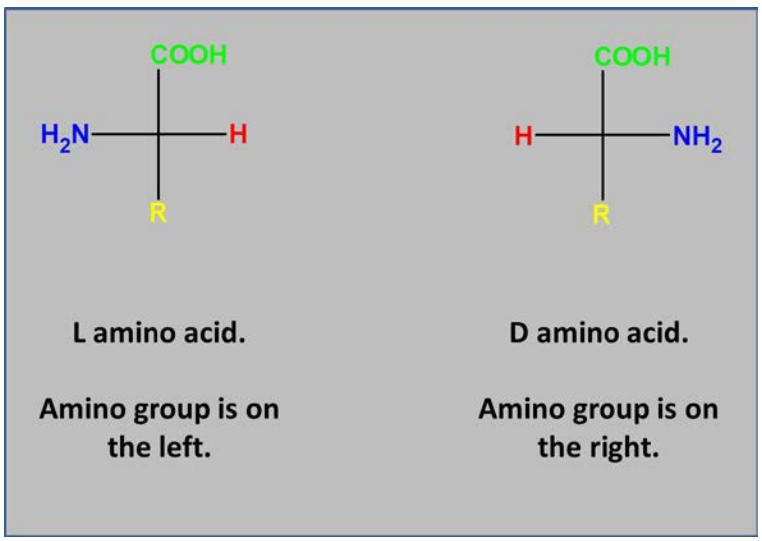


Figure 4. L and D amino acids.

Instead of viewing an amino acid with both the amino group and hydrogen atom projecting towards (+) the viewer, we can also look at the amino acid with just the hydrogen atom projecting towards (+) the viewer and the other three groups projecting away (-). The order of the R group, amino group and carboxyl group is clockwise for the L amino acid and anticlockwise for the D amino acid. However, if the D amino acid is viewed from the opposite side (in effect reversing all the signs), then the order of the R group, amino group and carboxyl group is the same as that for the L amino acid viewed from the opposite side (Figure 5).

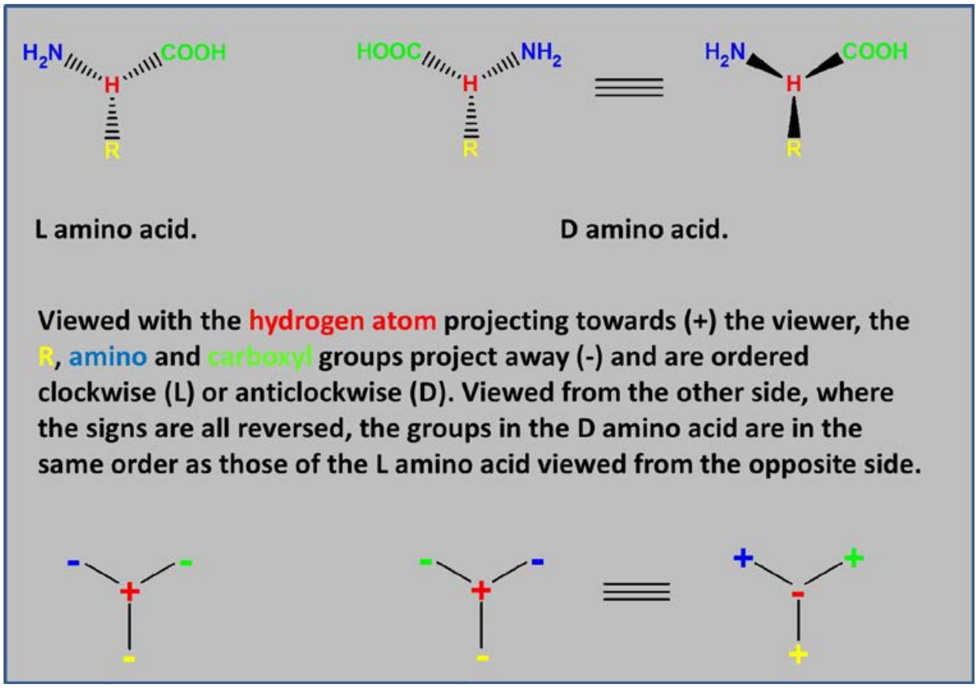


Figure 5. The effect of viewing amino acids with the hydrogen atom projecting towards the observer.

The significance of the signs and their utility in the coding of relationships will become clear below.

The two different forms of an amino acid, L and D, are called enantiomers. It is not possible to superimpose the four groups of one enantiomeric form on those of the other, no matter how you rotate the molecule. This can be imagined by taking a disc having a black side and a white side and marked to match up with three of the four objects of one enantiomer on one side and three of the four objects of the other enantiomer on the reverse side (Figure 6).

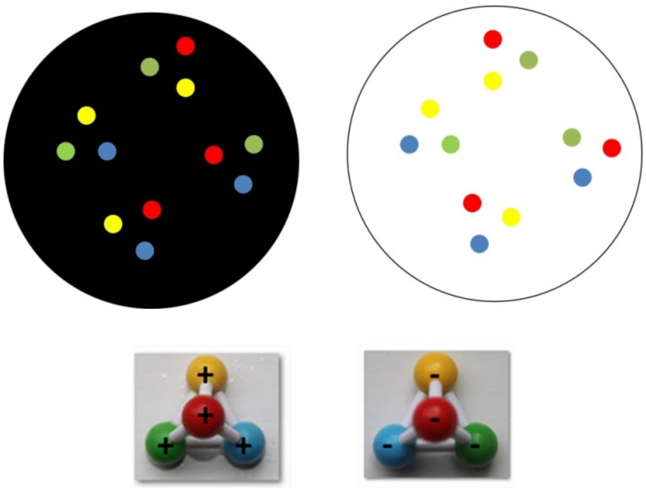


Figure 6. Enantiomers of L and D amino acids.

The two enantiomers are mutually exclusive (XOR). The eight objects of the two enantiomers if taken together (interpenetrating) would point to the corners of a cube (Figure 7).

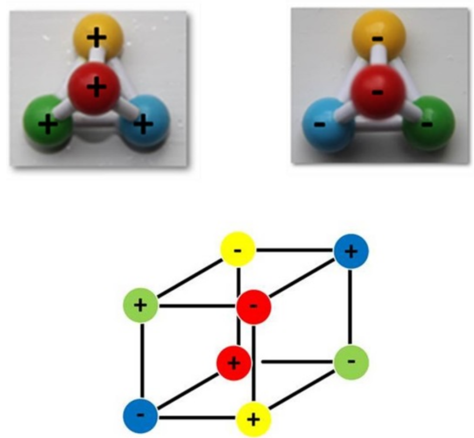


Figure 7. Forming a cube from the enantiomers of a chiral tetrahedral molecule.

Each face of a cube corresponds with a Fischer projection of a chiral tetrahedral molecule, i.e., with two groups projecting towards (+) and two away (-) from the viewer. There are 24 such projections: four for each of the six faces, and they correspond with the 24 different ways in which four different objects can be permuted (4 x 3 x 2 x 1). Each corner corresponds with a view of a chiral tetrahedral molecule with one or three groups projecting towards (+) the viewer and three or one groups projecting away (-).

The cube can be combined with quaternion mathematics to code relationships. The quaternions were invented by William Rowan Hamilton.[7] They are composed of four ordered elements 1, i, j and k, each of which can be positive or negative, and each of which conforms to the following multiplication rules (Figure 8):

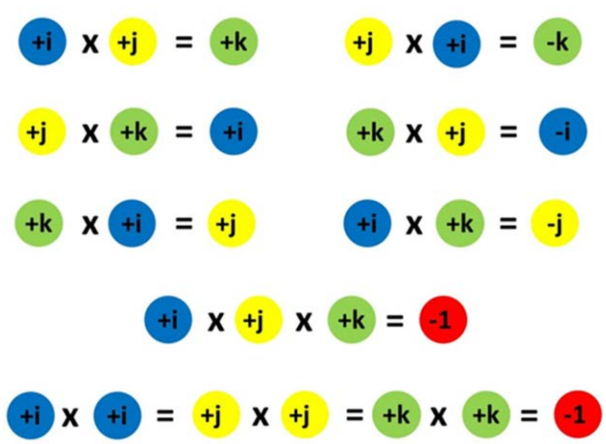
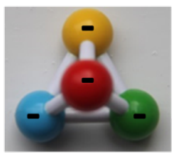
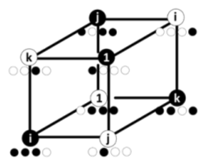
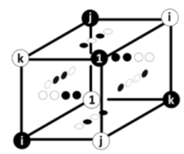
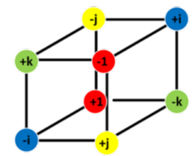


Figure 8. Quaternion multiplication rules.

[7] Herb Klitzner, "Quaternion Connections to Social Robotics, Compassion and Aesthetics," Presentation to the New York Academy of Sciences, June 2016.

We interpret each face of a cube as a quaternion, sorting the four vertices of the face into the order red, blue, yellow, green and noting the sign of each. All the faces and corners of the cube then conform to the quaternion multiplication rules. For example, if we start with the code +1 -i -j -k and multiply each element by +i we get +1 +i +j –k, which is +i. We can call a sequence of polarities, such as + + + -, an iterant or a polarity string (Table 1).

Table 1. Polarity Strings for Quaternions

Quaternion	Corner	Face	Cube
			
+1	+1 -i -j -k		+1 +i +j +k
-1	-1 +i +j +k		-1 -i -j -k
+i	+1 +i +j -k	-1 +i -j +k	
-i	-1 -i -j +k	+1 -i +j -k	
+j	+1 -i +j +k	-1 +i +j -k	
-j	-1 +i -j -k	+1 -i -j +k	
+k	+1 +i -j +k	-1 -i +j +k	
-k	-1 -i +j -k	+1 +i -j -k	

Each of the signed quaternions ±1; ±i; ±j and ±k has two associated iterants. These can be sorted into two complementary tables as shown below (Table 2). Imagine that each polarity is one side of a two-sided coin (+ and -). One table is the other table viewed in a mirror, as if a mirror is being used to enable both sides of the coins to be seen at the same time.

Table 2. Iterants for Quaternions

Face →

Corner ↓

	1	i	j	k
1	+	-	-	-
i	+	+	+	-
j	+	-	+	+
k	+	+	-	+

Face →

Corner ↓

	-1	-i	-j	-k
-1	-	+	+	+
-i	-	-	-	+
-j	-	+	-	-
-k	-	-	+	-

The diagonals, top left to bottom right, identify each quaternion (±1; ±i; ±j or ±k) coded by the two iterants in its respective row and column. The eight rows constitute the corners of a cube and the columns ±i; ±j and ±k constitute the faces. Each polarity in a table that is not in a diagonal changes sign with the exchange of row and column co-ordinates, but each polarity in a diagonal (shown in colour) does not. For example, +i corner, +j face is +, and +j corner, +i face is -, but +i corner and +i face is +.

We can assign the letter coding from Recursive Distinctioning (RD) to pairs of polarities in the iterants: A (+ +); B (+ -), C (- +) and D (- -). In all rows and two of the four columns, the four letters run in sequence A, B, D, C read in a clockwise or an anticlockwise ring. B and C are never adjacent, nor are A and D. It is as if B (+ -) turns into D (- -) and C (- +) turns into A (+ +). The letters are paired A with D and B with C, like A with T and G with C in DNA. For example, we have D B A C and its complement A C D B (Table 3).

Table 3. Pairings of Letter Codes

Face →

Corner ↓

	1	i	j	k
1	B		D	
i	A		B	
j	B		A	
k	A		C	

Face →

Corner ↓

	-1	-i	-j	-k
-1	C		A	
-i	D		C	
-j	C		D	
-k	D		B	

We can also create a second pair of tables by exchanging the corner and face axes (Table 4). This gives us:

Table 4. Iterants for Corner and Face Axes

Corner →

Face ↓

	1	i	j	k
1	+	+	+	+
i	-	+	-	+
j	-	+	+	-
k	-	-	+	+

Corner →

Face ↓

	-1	-i	-j	-k
-1	-	-	-	-
-i	+	-	+	-
-j	+	-	-	+
-k	+	+	-	-

The face representations (±i; ±j or ±k) constitute a group of six iterants: a pair of triplets. Chiralkine systems are coded in these triplet pairs. The members of a triplet exhibit an interesting property. In any column, the sign of any two polarities indicates the sign of the third polarity. On the table on the left, - signifies same and + signifies different. For example, if the iterant for +i (- + - +) is compared with that for +j (- + + -), comparison of the signs produces (- - + +), which is +j. Comparison of any of the iterants with itself produces (- - - -), which is -1. On the table on the right, + signifies the same and - signifies different. For example, if the iterant for -i (+ - + -) is compared with that for -j (+ - - +), comparison of the signs produces (+ + - -), which is -j. Comparison of any of the iterants with itself produces (+ + + +), which is +1. Thus, each triplet combined with the code for its “opposite missing face” constitutes a quaternion group in which + and - have a consistent “same” or “different” meaning. States in a family can be tallied (add the polarities for each “same” sign in a column, not those of the “different” sign, to determine quantities of each state present). This is illustrated below (Table 5).

Table 5. Tallying Polarities of Quaternions

Corner →

Face ↓

	1	i	j	k
1	+	+	+	+
i	-	+	-	+
j	-	+	+	-
k	-	-	+	+
Σ	3-	1-	1-	1-

Corner →

Face ↓

	-1	-i	-j	-k
-1	-	-	-	-
-i	+	-	+	-
-j	+	-	-	+
-k	+	+	-	-
Σ	3+	1+	1+	1+

For example, +1i +3j +7k is 11, 1, 3, 7. On this side, we do not tally the +. We can work with just two symbols: + and -: we do not need a third symbol, 0. This can be exploited to construct quantitative systems, as is described later. The pattern also calls to mind human colour vision.[8] I do not possess any specialist knowledge of human colour vision, but offer the following thoughts. The modern theory of human colour perception is based on an understanding that there are three different kinds of cone, which have different sensitivities to light across the visual spectrum, and that excitatory and inhibitory signals produced by these combine to give the full range of conscious experience of colour, black and white. In descriptions of the theory, the colours red, green and blue are often assigned to these cones, but this is not quite accurate, because perceived colour is defined by a relationship. There are four objects in this relationship: the three cones and a fourth object: excitation/inhibition. Thus, three oppositional pairs of states arise out of this relationship: black/white; red/green and

[8] Michael Kalloniatis and Charles Luu, “Colour Perception by Michael Kalloniatis and Charles Luu,” Webvision: The Organization of the Retina and Visual System, webvision.med.utah.edu/book/part-viii-gabac-receptors/color-perception/. See also www.youtube.com/watch?v=VeDOpGRMZ7Y.

blue/yellow. If +i (- + - +), +j (- + + -), and +k (- - + +) are taken to code for red, blue and black (3, 1, 1, 1) and their complements -i (+ - + +), -j (+ - - +) and -k (+ + - -) are taken to code for green, yellow and white (3, 1, 1, 1), then equal amounts of red, blue and black could code for white (+ + + +) and equal amounts of green, yellow and white could code for black (- - - -). Put another way, when three components are present in equal amounts, such that a colour is indistinguishable, the perception could be white or black (colourless).

We can again assign the letter coding from RD to pairs of polarities in the iterants: A (+ +); B (+ -), C (- +) and D (- -) (Table 6).

Table 6. Coding Pairs of Polarities

Face ↓ / Corner →	1	i	j	k
1	A		A	
i	C		C	
j	C		B	
k	D		A	

Face ↓ / Corner →	-1	-i	-j	-k
-1	D		D	
-i	B		B	
-j	B		C	
-k	A		D	

The letters are paired A with D and B with C, like A with T and G with C in DNA, but each table contains only triplets (as in transfer RNA, which codes for an amino acid). To get from A to D and back to A again, the cycle is A → C → B → D → B → C → A, oscillating between the two tables. It corresponds with rotating the cube about opposed corners so as to cycle through all six faces (Figure 9).

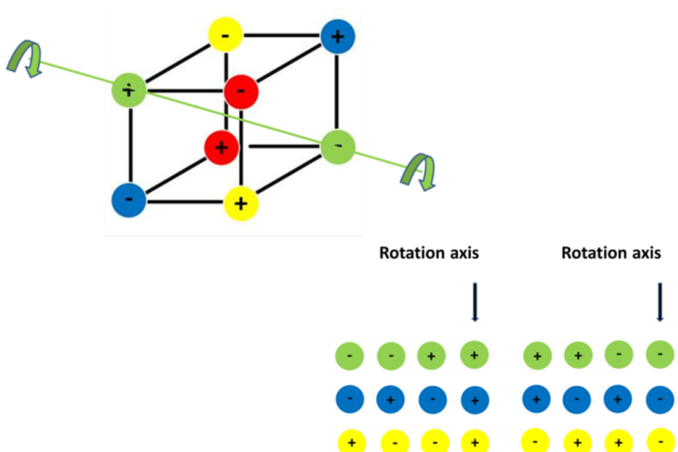


Figure 9. Rotating the cube.

This can be exploited to produce control systems, as I describe later.

Before I move on, I would like to take this opportunity to explain why this way of coding relationships is fundamentally different from that based on a balance. I have Moshe Klein and Yale Landsberg[9] to thank for helping me to develop this.

In arithmetic, which works on the principle of a balance, the order in which +1 and -1 are combined to afford zero does not matter. It is like the mixing of yellow (say +1) and blue (say -1) to give green. The same green is obtained whether yellow is mixed into blue or blue into yellow: +1 turns -1 into the same zero that -1 turns +1 into (Figure 10).

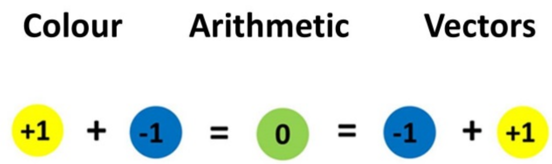


Figure 10. Commutative arithmetic is like mixing yellow and blue into green.

We now imagine a new system in which yellow mixed into blue affords a different green from blue mixed into yellow: where the order in which steps are performed matters.

In Figure 11, I have used the letters that define the four states in a chiralkine system (A, C, D and L) rather than those used in RD (A, B, C and D).

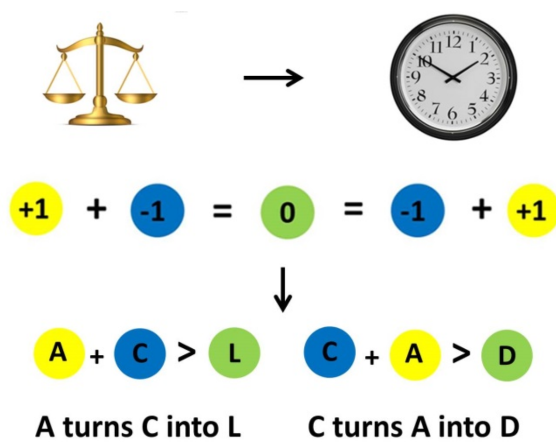


Figure 11. Re-engineering coding from the principle of a balance (commutative) to the principle of order (non-commutative).

This sets up a cycle. It can be visualised as rotation through a Möbius strip. A Möbius strip has two sides locally and one side globally. Imagine the yellow, blue and green discs arranged along a strip which is given a half twist then joined to form a Möbius

---

[9] Oded Maimon and Moshe Klein in collaboration with Yale Landsberg, "Consciousness – The Fifth Dimension – Unity of Mathematics," Poster presented at the meeting of the Science of Consciousness 2016 in Tucson, Arizona, April 25-30, 2016; Moshe Klein and Oded Maimon in collaboration with Yale Landsberg, "The Mathematics of Soft Logic," Paper presented at the 2016 International Conference on Artificial Intelligence and Robotics (ICAIR 2016), July 13-15, Kitakyushu, Japan.

strip. As you go around the strip (two full 360 degree rotations), each colour is visited twice; like the head (+) and tail (-) of a coin.

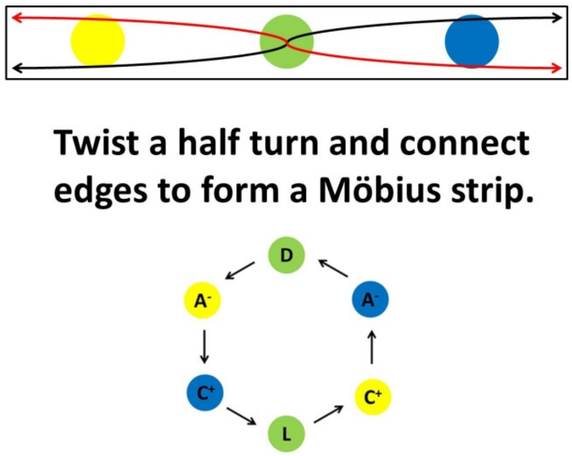


Figure 12. The colour sequence on a Möbius strip.

It does not matter which way you go around the cycle (clockwise or anticlockwise) as long as you are consistent. If you do not maintain the distinction between the two different orders, then you revert to operating on the principle of a balance, where D and L are the same green (Figure 13).

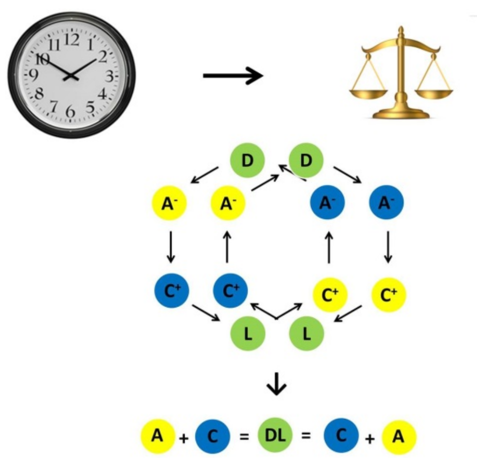


Figure 13. The colour sequence on two superposed Möbius strips of opposite chirality.

Chemists use the term *resolution* to describe the separation of the two enantiomers of a chiral molecule from a 1:1 mixture of the two, known as a racemic mixture. So, the resolution of a 1:1 mixture of the two enantiomers of an amino acid DL affords the D enantiomer separate from the L enantiomer. The switching in coding of relationships from the principle of a balance to the principle of order is a resolution of zero. It breaks the symmetry of the equation +1 -1 = 0 such that there are now four distinguishable states: (10), (01), (00) and (11). *Resolution of Zero* is also the title of a novel I wrote several years ago to try to get across this very concept in a non-mathematical way.

Necker Cube Effect

In this section, I relate the coding of relationships in iterants to the Necker cube effect.

If you look at the hexagon in the centre of Figure 14, you can perceive it as a cube. Your perception of the cube can switch. It depends whether the point where the diagonals meet is deemed to project towards you or away from you.

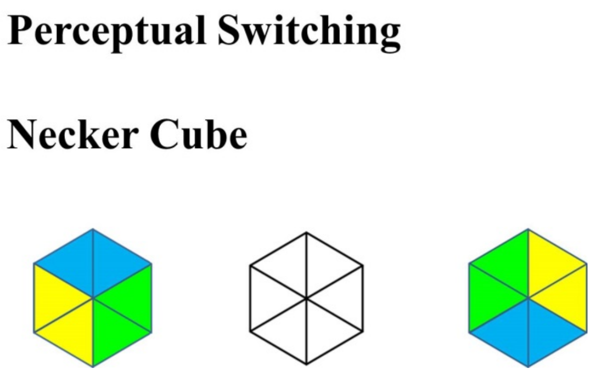


Figure 14. Perceptual switching: The Necker cube.

We can relate this to the symmetry properties of a chiral tetrahedral molecule as shown below (Figure 15).

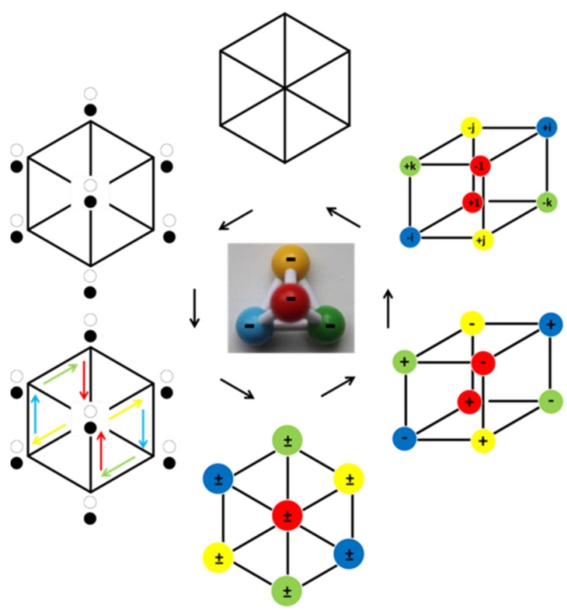


Figure 15. Symmetry properties of a chiral tetrahedral molecule related to the Necker cube effect.

First look at the hexagon at the top, then, going anticlockwise to the next hexagon, imagine each vertex being coded by a coin which could be heads (+) or tails (-). Now imagine assigning a colour to each vertex, as in the four objects in the chiral tetrahedral molecule shown in the middle of the picture. At this stage, each colour could be (+) or (-). Now allow the central red colour to split as between (+) and (-), giving the perception of a cube. The signs of the colours now sort into opposed (+) and (-). You can imagine sliding the chiral tetrahedral molecule over the cube and seeing how it and its enantiomer fit. Each face of the cube is coded by a different permutation of the four colours. When they are ordered red, blue, yellow, green, these provide the six iterants for the faces of the cube. Putting this all together, we can now see how the coding in the six iterants is in one enantiomer, not the other (Figure 16).

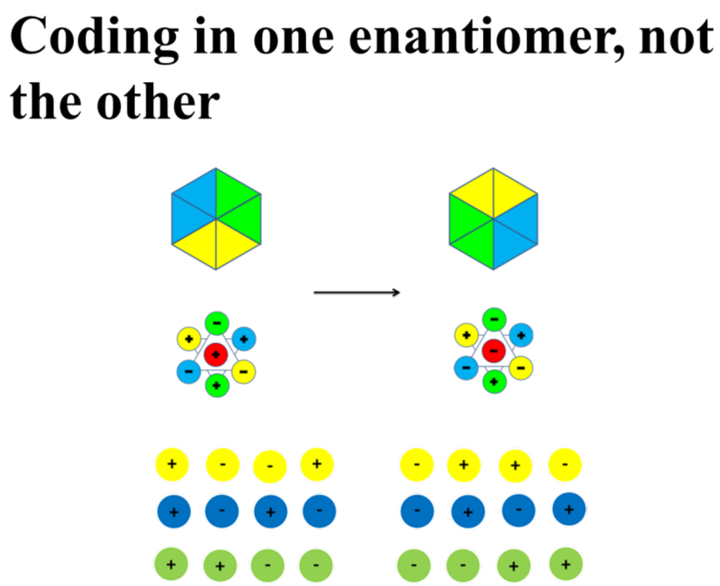


Figure 16. Coding in one enantiomer, not the other.

Polarity Flips and State Changes

Each change in a relationship state can be treated as a flipping of one or more polarities in a quaternion iterant. It corresponds with rotation of a cube from one face to another. State changes can be coupled together by co-ordinating polarity flips in a complementary manner. This corresponds with complementary rotations of cubes. It can be thought of as working a bit like money, but in which each side of a relationship gives and receives a coin. I think of it in terms of two legs walking one body (Figure 17).

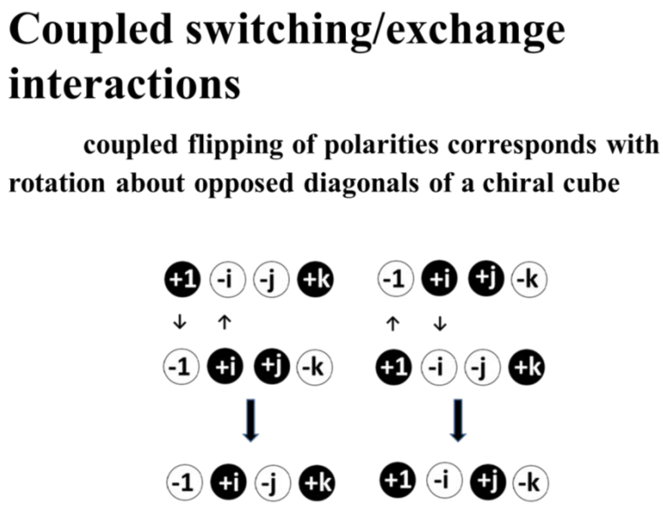


Figure 17. Coupled switching/exchange interactions.

This co-ordinated flipping of polarities can be used to build a control system.

When I was a young child, I started to call my feet "George and Henry". My family asked me to identify which foot was "George" and which was "Henry". I explained that the two feet are me, so they are both called "George and Henry". It is the same as with a Möbius strip, which has two sides locally, but one side globally. The flipping of polarities is like the crossing of two walking feet. In the quaternion model, each quaternion is itself and a combination of itself and the others, and it oscillates between presentations. Today, I would say that "I" am a quaternion. My perception of what "I" am as distinct from you, and what is mine as distinct from yours, switches, and this switching can be modelled using polarity flips.

Conclusion

I have described qualitatively and quantitatively how to code and process information about relationships in four relationship states to enable the construction of control systems. In the following sections I describe potential applications of this control system.

Game and Possible Treatment for Stroke

The game can be played on game board divided into 8 x 8 token spaces (Figure 18).

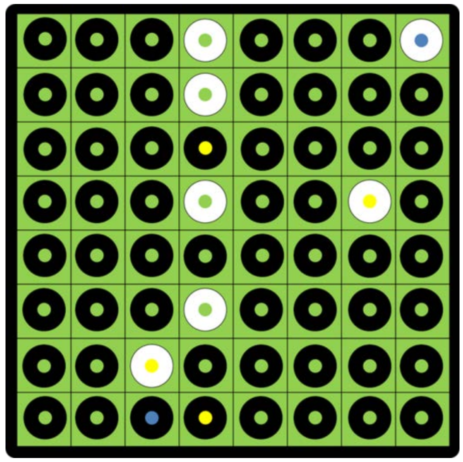


Figure 18. Game board.

Each token space can be owned by neither player, owned exclusively by one player (not the other) or owned jointly by both players. The object of the game is to be the first to secure ownership of a chain of token spaces linking opposed sides of the game board. Players compete by deploying tokens to change the ownership states of the token spaces.

Each token in the game corresponds with one of the six iterants coding a face in the cube. Accordingly, there are six tokens. A white token with a green centre indicates that a token space is jointly owned (+ + - -), i.e., a + + or L state. A black token with a green centre indicates that a token space is owned by neither player (- - + +), i.e., a - - or D state. A black token with a yellow or blue centre indicates a token space that is owned by the player of that colour, not the player of the other colour. It is a + - or C state. A white token with a yellow or blue centre indicates a token space that is owned by the player of the other colour, not the player of that colour. It is a + - or A state. The six iterants are thus of four kinds of relationship state, as in RD (Figure 19).

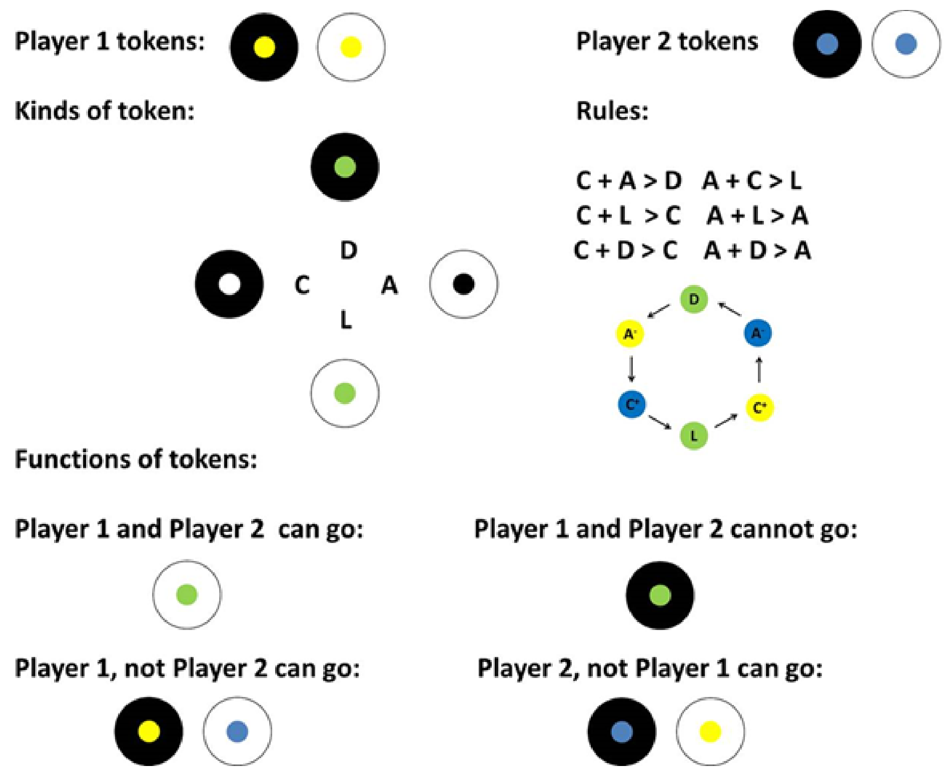


Figure 19. Kinds, rules and functions of tokens in game.

Each player starts with a set of C and A tokens of the same colour (yellow or blue). Thus, the tokens played by yellow player are in states C (+ - - +) and A (- + - +), while those for blue player are in states C (+ - + -) and A (- + + -). In a move, a player deploys one of each kind of token. Deployment of a token in a token space changes the state in that token space, depending on the starting state. An A token played on a C token changes the state into L, but changes a D or L state into A (itself). A C token played on an A token changes the state into D, but changes a D or L state into C (itself) [C turns A into D and A turns C into L]. Thus, one part of the player's move is selfish (for the player's benefit) and one part is altruistic (for the opponent's benefit). However, when a player uses an A token to change his or her opponent's C token to an L token, the effect is to change the ownership state from exclusively the opponent's to joint ownership. It is analogous to forcing an opponent to share ownership of something, like when a government collects taxes to invest in public services or nationalises an industry. Players quickly learn to use the altruistic part of their move (playing an A token) to convert their opponent's C spaces into shared, L spaces. Figuring out a way to counter this led to the discovery of another feature of the six iterants that may have applications in the development of artificial intelligence.

When players look at the game board, they see the six different kinds of relationship states, for example as explained below. It is possible for two other people to play another separate, but connected game by interpreting the functions of the tokens differently. I call these other people hunters, because their objective is to hunt down L tokens and convert them directly into D tokens (a state change that the players cannot effect in one move – it corresponds with jumping directly from one local side of a Möbius strip to the other). The hunters cannot see the yellow and blue tokens. In an electronic version, the players and hunters would see different displays on different screens. As the players convert C states into L states, the hunters simply see L states appearing. When the hunters capture and convert L states into D states, the players simply see L states turning into D states. The effect of this conversion is symmetric on the players in that the state change is from both own to neither own a token space. The game for the hunters can be made more interesting by providing that the A and C states present an obstacle to their movement. To them, the world is then in three states, like +1 (unblocked), 0 (prey) and -1 (blocked), which is how we teach our children to see it. There appears to be a parallel here between the workings of the conscious and unconscious mind.

In the game, the A and C tokens can be deployed using musculature on the left and right sides of the body, for example the left and right hands. In an electronic version of the game, players could effect state changes using a game controller having buttons adapted to receive inputs from the two hands. It could also be played using a neural headset positioned to pick up when a player visualises contracting either, both or neither of the left and right hands.[10]

The skeletal musculature, which controls rotation about joints, is organised into antagonist pairs, the members of which are known as the flexor and extensor. There are four basic states: both contracting (+ +), neither contracting (- -), flexor, not extensor contracting (+ -) and extensor, not flexor contracting (- +). These states are analogous to the ownership states denoted by tokens in token spaces of the game. Each of us can imagine contracting our own muscles (which can be detected using a neural headset) or those of another person (which presumably could also be detected using a neural headset). It would thus seem plausible that a person could code all six relationship states (equivalent to motion in 3D) using mental imagery of contracting their own or another person's left and/or right muscles. For example, the states could be right, not left, me, not you (+ - + -); right, not left, not me, you (+ - - +); not right, left, me, you (- + + -); not right, left, not me, you (- + - +); right, left (+ + - -) and not right, not left (- - + +). Presumably the limbs of a robot could be controlled in this way as well. Thus, a dynamic link can be made between the co-ordination of movement of the body by the left and right skeletal musculature and states of ownership (property rights).

Playing the game forces the two sides of the brain to co-operate when planning strategy. (I think that the two parts to each move correspond in some way with comparing to the left and to the right in RD.) I imagine that this could be exploited to assist patients who have suffered from brain injury or stroke to recover, by using the healthy side of the brain to support restructuring of the damaged side. The brain is plastic, so lost functionality can eventually be assigned to healthy tissue. I would very much like to see the game coded, so that this idea can be tested, for example using a

[10] Karl LaFleur et al. have shown that a quadcopter can be controlled in flight in two dimensions simply through mental imagery of clenching the left and/or right hands. See "Quadcopter Control in Three-Dimensional Space Using a Non-Invasive Motor-Imagery Based Brain-Computer Interface," *Journal of Neural Engineering* 10 (2013): 1-15.

brain scanner. There is good precedent for using virtual reality games in the treatment of stroke.[11]

Playing the game also teaches the interdependence of rights and obligations, and could therefore be a useful tool in schools and colleges when teaching ethics and social responsibilities. In modern society, it is very easy to focus only on one's rights, and lose sight of the need to fulfil one's obligations, upon which the rights of others depend.

Conclusion

The six iterants, each composed of two + and two -, can be interpreted as being of four kinds: A (+ -), C (- +), D (- -) and L (+ +); of three kinds (yellow, blue and green) or of two kinds (black and white). Different functions can be assigned to them, depending on how they are interpreted. These functions can be related to the co-ordination of movement effected by the left and right skeletal musculature and to the perception of identity (the sense of me as distinct from you; and mine as distinct from yours). They can be integrated in a system of interdependent sub-systems, as when players and hunters play separate, but connected games. The game might potentially prove useful in the treatment of brain injury and stroke.

Voting System

In a conventional voting system, voters distinguish their preferred candidate by marking a ballot with a cross. The marks are then coded and processed as ordered pairs of numbers: 1, 0; 0, 1; 1, 1 and 0, 0. In effect the votes are weighed against one another on the principle of a balance.

A vote for one candidate is compared with a vote for another candidate by treating the two as mirror pairs of ordered pairs:

1 0	
$\underline{0\ 1}$	Add the 1s, not the 0s
1 1	
	Then cancel the 1s
0 0	
	+1 -1 = 0

Votes that cancel have the same effect as abstention, passive or active. The system is coded in three states: +1, 0 and -1. Passive (accept all options) and active (reject all options) abstention could be distinguished by treating states (0, 0) and (1, 1) as distinct, leading to a four-number coding and processing system, but the operating principle for processing the information would need to be changed from that of a balance to order (Figure 20).

[11] G. Saposnik et al., "Safety and Efficacy of Non-Immersive Virtual Reality Exercising in Stroke Rehabilitation," *Lancet Neurology* 15, No. 10 (2016): 1019-27. doi:10.1016/S1474-4422(16)30121-1.

Tetracoding and Order

1, 0 0, 1   **A B C D**
1, 1 0, 0

↓

Quaternions

1, 0, 0, 1	**0, 1, 1, 0**
0, 1, 0, 1	**1, 0, 1, 0**
0, 0, 1, 1	**1, 1, 0, 0**

Figure 20. Tetracoding and order.

Tetracoding votes and processing them on the principle of order as quaternions enables distinctions to be drawn between like and dislike, as between passive and active abstention. A population of voters can reject the most popular candidate or the entire list of candidates, forcing the drawing up of a candidate list based on new distinctions. It empowers voters to challenge the status quo controlled by two dominant opposing parties or orthodoxies.

The voting system works like perceptual shifting (Figure 21).

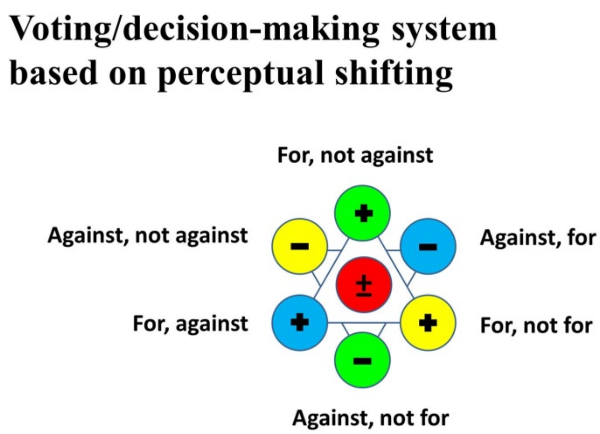


Figure 21. Voting/decision-making system based on perceptual shifting.

Each vote is made up of several parts. It is composed of iterants/polarity strings (Figure 22).

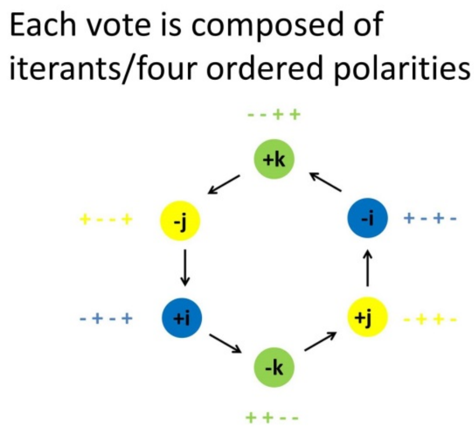
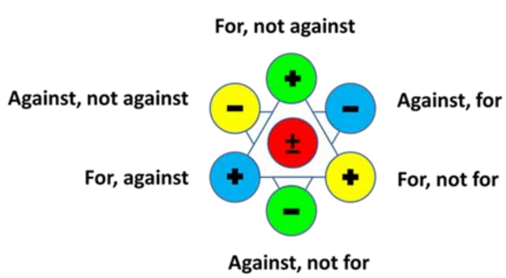


Figure 22. Composition of votes.

Each voter looks twice at a list of candidates, once in a mindset of which they find most acceptable and once in a mindset of which they find most objectionable. They mark their most liked candidate, then also mark whether they accept that candidate or they passively or actively abstain. Then they mark their most disliked candidate, and also mark whether they reject that candidate or they passively or actively abstain. Thus, they make four marks in total.

This is an example of a hypothetical vote with four candidates, A, B, C and D (Figure 23).



Candidate	For	Not against	Not for	Against		Against	Not for	Not against	For
A	16	9	2	5		20	14	1	5
B	23	17	3	3		17	13	2	2
C	16	7	6	3		51	45	4	2
D	45	8	0	37		12	12	0	0
Totals	100	41	11	48		100	84	7	9

Figure 23. Results of a hypothetical vote.

Conventionally, a candidate winning a majority of for, not against votes would win an election. With tetracoding, the majority of voters actively over passively abstaining could exceed that of a winning candidate, indicating that a new vote with a different candidate is needed. A candidate winning a majority of for, not against votes in the right vote could be rejected by voters in the left vote, indicating overall lack of confidence in that candidate. Without these safeguards, there is a risk that a candidate who does not actually have the support of voters could win power, potentially leading to social unrest and an unstable state.

This voting system provides much more information about voters' attitudes than a conventional system. It needs testing. Its adoption might lead to the creation of stronger democracies.

In general, the strongest performing candidate in this voting system is one who scores very high on the right ballot and very low on the left ballot.

This system could be used in primaries, for the selection of candidates to put forward in elections. It could also be used in iterative decision making, where votes are taken and analysed, then the candidate list is redrawn and the vote repeated. It could be used by students seeking input from peers, family, friends and teachers on career options. It could be used to gather feedback on performance in business, as in annual staff appraisals. It could be used in market research to pick up information about people's attitudes to products competing in a marketplace. It could also be used in dispute resolution, for example where two nations are in dispute about whether a particular area of land or sea belongs to them.

Prototype code for this new kind of voting system has been written and is available for testing by schools, colleges, universities, businesses and organisations interested in alternative voting systems. Examples of results of test votes can be provided on request.

Conclusion

Prototype code for a new kind of voting system based on tetracoding has been produced and is available for experimentation.

Exchange Interactions and Coupled Cycles: Elements of a Control System for an Economy and a Social Robot?

In RD, relationship states are coded in four states through application of a process known as tetracoding. In this process, a state is compared with the state to its left and also the state to its right (two comparisons). The resultant state is obtained by combining those comparisons and identifying if the state is 11, 00, 10 or 01. The process thus looks at relationships from both sides.

To code relationships between people, we first draw a distinction between the self (me) and you. We code this in an ordered pair of numbers, as in tetracoding.

The self (identity) coded in ordered pairs of numbers

Me, not you	1, 0
Not me, you	0, 1
Me, you (us)	1, 1
Not me, not you	0, 0

Next, we draw a distinction between mine and yours. We also code this in an ordered pair of numbers, as in tetracoding.

Property rights coded in ordered pairs of numbers

Mine, not yours	1, 0
Not mine, yours	0, 1
Not Mine, not yours	0, 0
Mine, yours	1, 1

Now we merge these tetracodes into quaternion iterants. It is as if the eight concepts of me, not me, you, not you, mine, not mine, and yours, not yours form the corners of a cube in which me, you, mine and yours and not me, not you, not mine and not yours form the corners of the enantiomers of two chiral tetrahedrons (Figure 24).

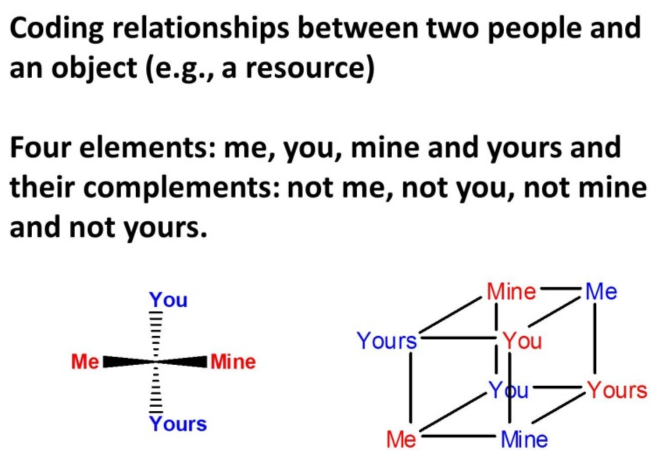


Figure 24. Coding relationships between two people and an object.

Mine and yours can now be coded from each person's perspective (Figure 25).

Mine from my perspective, yours from your perspective

Me	Mine	You	Yours
+	+	-	-
-	-	+	+

Yours from my perspective, mine from your perspective

Me	Mine	You	Yours
-	-	+	+
+	+	-	-

Figure 25. Coding mine and yours.

For example, we can code the ownership of a good, such as bread, from both perspectives (Figure 26):

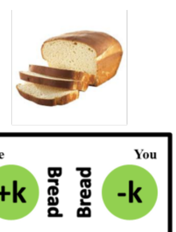


Figure 26. Coding ownership of a good as mine to me and yours to you.

We can now control the exchange of goods and services through coupled state changes mediated through polarity flips. Figure 27 illustrates this for the transfer of ownership of bread from me to you coupled with the transfer of peas from a third party to me and a transfer of oranges from you to another third party.

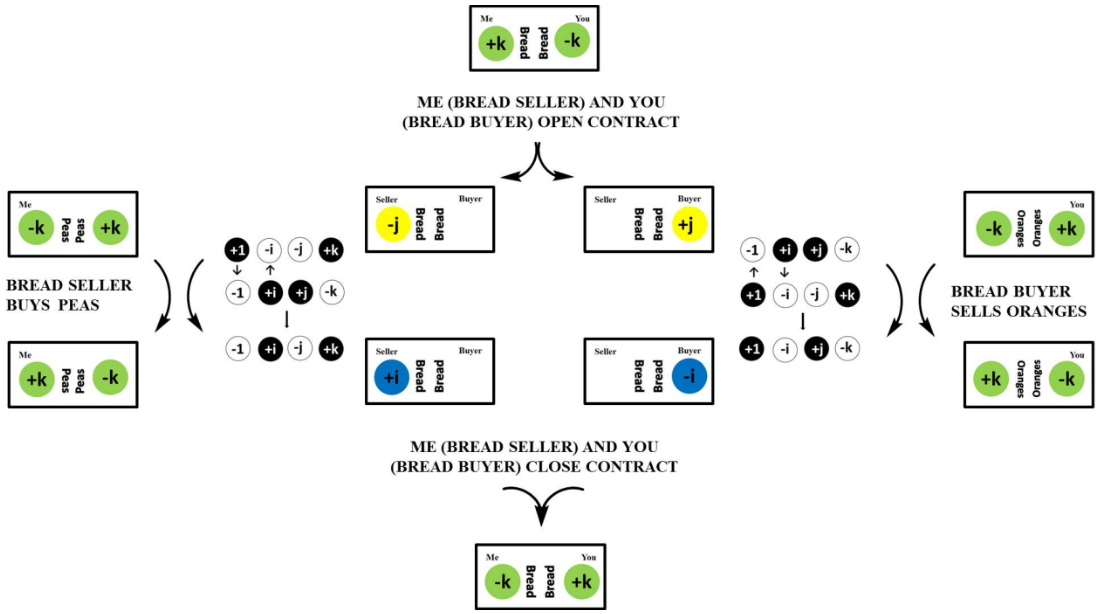


Figure 27. Coding transfers of ownership of peas and oranges each in one step coupled with transfer of ownership of bread through a transition state.

Prototype code has been written.[12] The dashboard for a user looks like this (Figure 28):

Contracts as Seller	Contracts as Buyer
No. of units created as Seller (+ - - + units)	No. of units created as Buyer (- + + - units)
No. of units exchanged as Seller (- + - + units)	No. of units exchanged as Buyer (+ - + - units)
No. of units redeemed as Seller (+ + - - units)	No. of units redeemed as Buyer (- - + + units)

Figure 28. Coding exchange in quaternion iterants.

The code may be inspected by going to chiral.gets.cc/login.aspx. Log in as “clienta” using password tusq500. Full interactive demonstrations are available on request.

In the exchange, all steps are under quaternion control. At no stage does any person exchange a good or service for an imaginary store of value (money or credit).

[12] Algorithm and computer code development: Initial exploratory work by Michael Linton, Bruno Vernier (Seedstock Community Currency, Vancouver, BC, Canada), Frances and Martin Hay (UK). Code created by Indrajeet Singh and Himanshu Shukla (Sanskriti IT Solutions, India) in association with Richard Logie (GETS, Scotland) and Frances and Martin Hay (UK).

The system should integrate very well with electronic locks for securing goods undergoing transfer of ownership, for example on a drone or spacecraft transporting the good, and mobile phones used to instruct state changes and receive electronic keys (e.g., a bar code) for opening locks on completion of ownership transfer.

Figure 29 is reproduced from UK patent application number GB1613983.4, which is directed to the use of electronic locks in a delivery robot or drone, to control access to goods while they are in a transition state of ownership. The popular TV and film series *Star Trek* imagines a society that no longer needs to use money. The new way of coding and processing information about ownership relationships described above could potentially realise that vision.

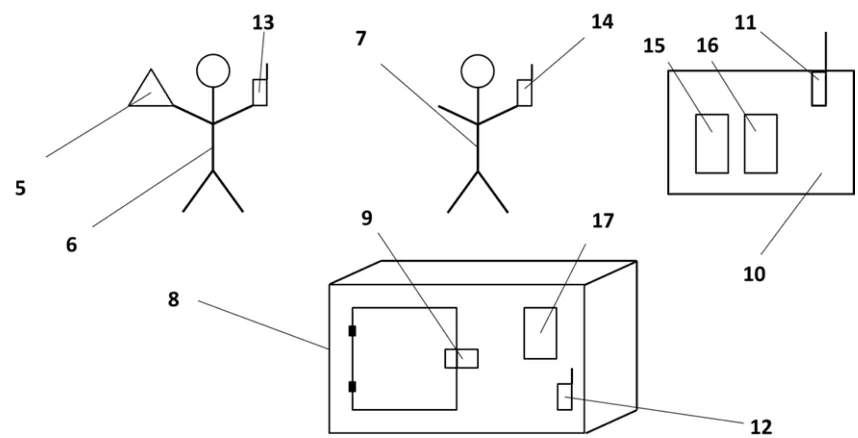


Figure 29. Illustration of a moneyless society utilising electronic locks and cell phones under quaternion iterant control.

Overall Conclusions
A new way of coding and processing information about relationships based on tetracoding and iterants/polarity strings has been described which has many potential applications. Research and development partners, whether in schools and colleges, universities, government organisations or businesses, are actively being sought.

****

About the Author: Martin Hay read chemistry at Oxford, with a little anthropology on the side, then went on to pursue an international career supporting the research-based pharmaceutical industry as a British patent attorney, European patent attorney, and US patent agent. However, immediately after completing his Master's thesis on a chiral synthesis, he spent some time training to be a UK chartered accountant. He found that the ideas he had developed through studying chirality and human belief systems did not fit with the methodology of double entry bookkeeping.

He felt that social relationships needed to be coded in four states, two always opening up as two close down, which would mean that there need to be two “balance” positions:

(0, 0) and (1, 1) in addition to the conventional debit (1, 0) and credit (0, 1) positions. After closing down his patent business in 2009, he returned to this idea and through a series of international collaborations developed a chiral quaternion model for coding social relationships based on the symmetry properties of chiral tetrahedral molecules. This model is embodied in a cube, as shown in his photograph, where each corner and face is coded as an iterant.

Editors' Notes: We thank Martin Hay for this addition to the ongoing RD research through his chiralkine systems work. Chiralkine analysis is a new, experimental technology that processes information about economic relationships between people and resources in a way that treats both sides in a fair and equitable manner. Its purpose is to solve the problem of rising inequality and trade imbalances, which are side-effects of the existing technology. It can be used to control the exchange of goods and services, taxation, and voting. This article gives readers social and economic examples based in RD fundamentals. We plan to experiment with Martin Hay's chiral voting system to survey the Space community for research preferences. ***Bob Krone and Gordon Arthur*.**