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PARAMETER DEPLOYMENT AND SEPARATION FOR SOLVING PHYSICAL CONTRADICTIONS

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Abstract. Physical contradiction is at the heart of TRIZ contradiction problem solving. The essence of a physical contradiction is that for two objectives, we have two contradictory demands on the same parameter of the same system. As part one of the two-part Parameter Manipulation approach to solve physical contradiction, this paper proposes a systematic new method to solve physical contradictions using the parameter deployment and separation.

By defining the local system to include the components directly at the immediate relevant components of the physical contradiction, the proposed parameter deployment systematically deploys the two objectives and the contradictory parameter into their respective causing constituent parameters. The essence of parameter separation is to assign the two contradictory requirements, either at the objective level or at the contradictory parameter level, to be satisfied by separate constituent parameters or distinct value ranges of a constituent parameter. Out of the 25 initial cases, with parameter deployment and separation, it was found that on average the number of solution ideas generated increased from 5.08 by all existing separation methods to 12.28 by parameter domination and parameter separation proposed by this paper - a net increase of 149%. Solutions conceivable by existing methods are all included in this set of problem solving strategies. With the addition of parameter transfer, the average number of solution ideas increased about 10 times compare to the number of ideas generated by all existing methods. In addition, all existing problem solving strategies constitute only 3 categories of strategies out of the 17-plus problem solving strategies proposed by this integrated set of parameter manipulation.

Keywords: physical contradiction, parameter deployment, parameter separation, parameter transfer, TRIZ, Systematic Innovation

1 INTRODUCTION

1.1 Research Background and Objectives

Physical contradiction (PC) is at the heart of all problematic contradictions. At present, all methods to solve physical contradictions are based on either separation principles, by-passing contradictions, or satisfying contradictions. The majority of them at the end converted to inventive principles to solve the problems [1][2][3]. The deficiencies of the existing methods to solve physical contradictions include:

1) Various existing methods appear to be independent and are lack of synergy among them.
2) Most of existing methods at the end converted to the inventive principles. That means that the problem solver need only to examine the selected inventive principles. Many times, the 40 inventive principles are not enough to inspire good specific solutions.
3) There is no detail thinking process which can lead the problem solver to reach solutions systematically and algorithmically.
4) All the existing separating principles focus on the solving problem at the contradictory parameter level. Solving physical contradictions at the objective level has not been considered for problem solving. Even though solving problem at the objective level implies solving the corresponding technical contradiction, the methods proposed for solving at the objective level is completely different from the traditional way of contradiction matrix and inventive principles to solve technical contradictions. Note that technical contradictions and their corresponding physical contradictions are at different abstractions of the same problem. Solving at objective level is problem solving using the elements of physical contradiction. When the corresponding physical contradiction is solved, its corresponding technical contradiction is also resolved.

This research established a systematic thinking process which generates 17-plus strategies to solving physical contradictions of which all the existing methods constitute only 3 of the 17-plus strategies identified by this research. Furthermore, all the 17-plus problem solving strategies are under the same set of theory based on parameter manipulation. Due to space limitations, this paper focuses on the first part of the full strategies as parameter deployment and parameter domination/separation which contains 6-plus strategies [4]. A sequel will focus on parameter transfer which contains 11-plus strategies [5][6][7].

2 Foundations of Physical Contradiction and Parameter Manipulation

2.1 Formulation of Physical Contradiction

A physical contradiction occurs when one parameter cannot satisfy two incompatible demands in order to achieve two objectives at the same time. Model of physical contradiction can be expressed as:

- To O1, P should be +P. But, (Statement 1)
- To O2, P should be -P.

Where "O1" and "O2" are two disparate objectives, "P" is the contradictory parameter which causes the problem. "+P" and "-P" represent the two incompatible demands which need to be satisfied at P in order to achieve O1 and O2. Taking desk area as an example, the below statements express the physical contradiction.

- To accommodate more stuffs on the desk, the area of the desk should be big. But,
- To occupy less space in a room, the area of the desk should be small.

This paper proposes the systematic methods of:

1) Parameter deployment: to assist users to identify all relevant parameters which contribute directly to the physical contradiction, and
2) Parameter separation/domination: To separate the contradictory demands either at the objective level or the contradictory parameter level to solve the physical contradiction, or, to enhance a compatible parameter so that the O1 and O2 can be satisfied simultaneous as explained in section 2.3.

To solve physical contradiction, the relevant parameters influencing, or affecting, the two objectives O1 and O2 or the contradictory parameter P need to be investigated. By deploying the O1, O2, and P into their corresponding causing constituent parameters, all the parameter separation or domination strategies to solve the physical contradiction can be systematically and so far most comprehensively identified thus ideas to solve the physical contradiction can be generated. The acts of identifying all immediate causes for achieving O1, O2, or P relies on deploying the O1, O2, P into their causing constituent parameters as explained below.

2.2 Definition of Systems

In order to define the scope of parameter deployment, the concept of "center components" and "local system" are defined.

The center components of a physical contradiction are the components whose attribute defines or owns the O1, O2, or P as in section 2.1 Statement 1. For example, the physical contradiction "To improve the effectiveness of nail penetration, the hammer should be heavy; To carry the hammer easily, the weight of the hammer should be light". O1: effectiveness of nail penetration, center component is nail; O2: Carrying the hammer easily. The object/tool of the function is hammer/hand. In this case, we can pick either the object (hammer) or the tool (hand) of the function as the center component as it does not affect the identification of the Local System described in the next paragraph. For most disadvantages, the object owns the constituent parameter. Hammer should be heavy/light, center component for the hammer's weight is the hammer. The set of center components carries the parameters of core issues (O1/O2, P).

The local system (LS) of a physical contradiction consists of all center components and the components which directly contact with the center components. In this case, it will include the nail, the hammer, the hand holding the hammer, and the wood that the nail is going to penetrate. In a sense, the local system is the operating zone in traditional TRIZ with the condition that this operating zone is defined at the minimum system/components which DIRECTLY affect the problem. The local system defines the immediate problem area from where all immediate causes of the physical contradiction can be identified and the immediate scope from which the problem solving resources can be drawn. It is then the scope of parameter deployment. Note that the influence of any external factors affecting the problem must be transmitted via some local system parameters/component(s) to the problem point which is at the center components. The definition of the local system allows us to have a definitive scope for identifying ALL immediate causing factors of the problem on which we can separate the satisfactions of the contradictory demands at either O1/O2 or P level.

2.3 Parameter Deployment

The Generic Form of Parameter Deployment

The two objectives can be shown in the following generic forms:

- $O1=fn(P_j, \ldots ; E_i^1, \ldots ; Z_k, \ldots)$ Eq. 1.1
- $O2=fn(Pj, \ldots ; E_i^2, \ldots ; Zk, \ldots)$ Eq. 1.2

The contradictory parameters can be shown in the following generic form:

- $P_j = fn(X_{j1}, X_{j2}, X_{j3}, \ldots, X_{jm})$ Where $j = 1, 2, \ldots, J$ Eq. 2

Where notation, *fn(…),* represents function of (…). The first semi-column, ;, denotes the delimitation between the contradictory constituent parameters and exclusive parameters. The second semi-column delimits the exclusive parameters and the compatible parameters.

In the generic forms above, "*P*" represents "contradictory parameter" of the two objectives, O1 and O2. "E" represents "exclusive parameter" of each objective, and "Z" represents "compatible parameters of the same direction" of the two objectives. More detail symbol definitions are shown in Table 1.

Table 1. Definitions and Descriptions of Each Parameter Categories

Symbol	Definition	Description
C_b^a	Constituent Parameter for O1/O2	● C_b^a represents the b-th causing constituent parameter within the local system influencing the corresponding objective O1 when a=1, or objective O2 when a= 2. ● C_b^a can assume any role such as P (for O1/O2), E (as exclusive parameter), or Z (Compatible parameter)
P_j	j-th Contradictory Parameter	● P_j represents the j-th common but contradictory parameter of the two objectives. To achieve O1, P must be +P; But, to achieve O2, P must be –P. +P and –P are two incompatible demands on P. ● It is possible to uncover additional contradictory parameter, P_j, as a results of parameter deployment. If there is only one P, $P_1 \equiv P$ is the explicit original contradictory parameter. ● Each additional P_j will provide 4 more strategies for problem solving via separation and 6 more strategies for problem solving via parameter transfer. Explained later.
E_c^a	Exclusive Parameter(s)	● Constituent parameters that are exclusive to either O1 or O2 but not both. ● E_c^a represents the c-th exclusive constituent parameter of objective O1 (a=1) or O2 (a=2).
Z_k	Compatible parameter(s)	● Z_k represents the k-th common constituent parameter of the two objectives having demands on Z_k toward same direction to achieve O1 and O2. For example, both O1 and O2 desire Z_k to be the larger the better.
X_{jm}	Constituent Parameter for P_j	● The m-th constituent parameter(s) of the contradictory parameter, P_j. When $j = 1$, $X_{1m} \equiv X_m$.

2.4 The Essence of Problem Solving Strategies with Parameter Manipulation

Two aspects for parameter manipulations are discerned: manipulation targets and manipulation modes. In terms of manipulation target, it is observed that previous solutions by parameter separations to solve physical contradictions were mainly about separating demands on the contradictory parameter with different value range of its certain Constituent Parameter, X_m. For example, when X_m assumes space, it is the Separation by space; when X_m assumes Time, it is the separation by time; When X_m assumes system level, it is the separation by system level, etc. In this sense, all existing parameter separation methods fall into one category of "within parameter separation (designated as IPV strategy later) of the proposed strategy by this research. Separating parameters to satisfy the two contradictory objectives was not taken into consideration by traditional separation principles. Therefore, this paper proposes two hierarchies of parameter manipulation targets to achieve: separation of parameter for two contradictory demands on the same contradictory parameter (P) and separation of parameters to satisfy two contradictory objectives (O1 and O2).

Three distinct modes of parameter manipulation are defined in Figure 1. They are: Parameter Domination, Parameter Separation, and Parameter Transfer.

With combinations of different **Manipulation Modes** and different **Target Levels of Satisfaction**, 17-plus strategies of solving physical contradiction can be conceived. Figure 1 defines the Strategy Symbols for Parameter Separation and Transfer. The first letter of the strategies indicates the mode of manipulation (I: separation with**I**n parameter, C: separation a**C**ross parameters, T: parameter **T**ransfer). The second letter indicates the target of manipulation (P: contradictory parameter as the target to resolve problem, O: two objectives as the targets to resolve problem). The third (and the fourth) letters indicate manipulation methods. (V: by using different **V**alue ranges of a parameter, **S**: by Splitting one contradictory parameter into two so as to satisfy two incompatible demands separately, **P**: using contradictory parameters to satisfy one demand, **E**: using exclusive parameters to satisfy one demand, **A**: using non-constituent external **A**dditional parameters which are not any of the constituent parameters from the local system. They are parameters from external components seemingly irrelevant to the problem but can be used as some resources for problem solving. Figure 2 shows the 17-plus strategies thus developed.

Acronyms of the strategies are summarized in Table 2.

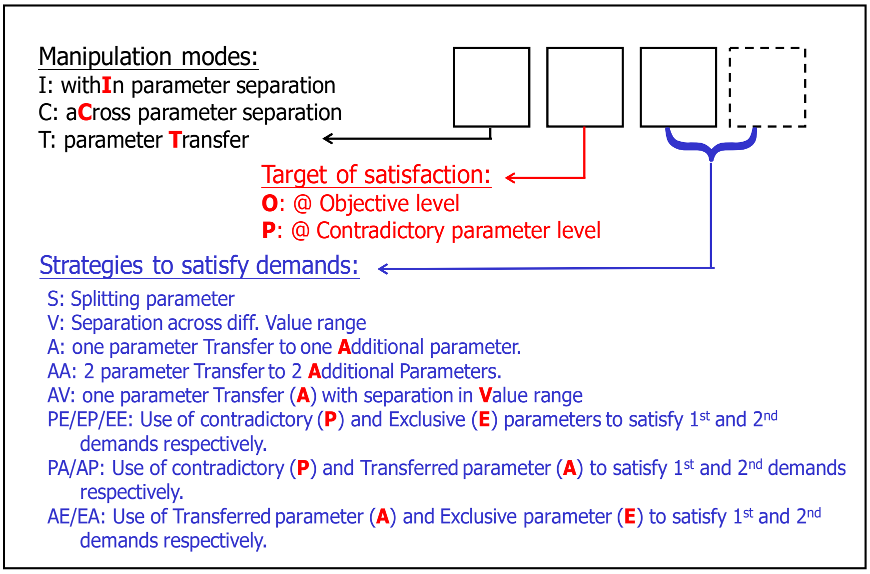

Fig. 1. Strategy Symbols for Parameter Separation and Transfer

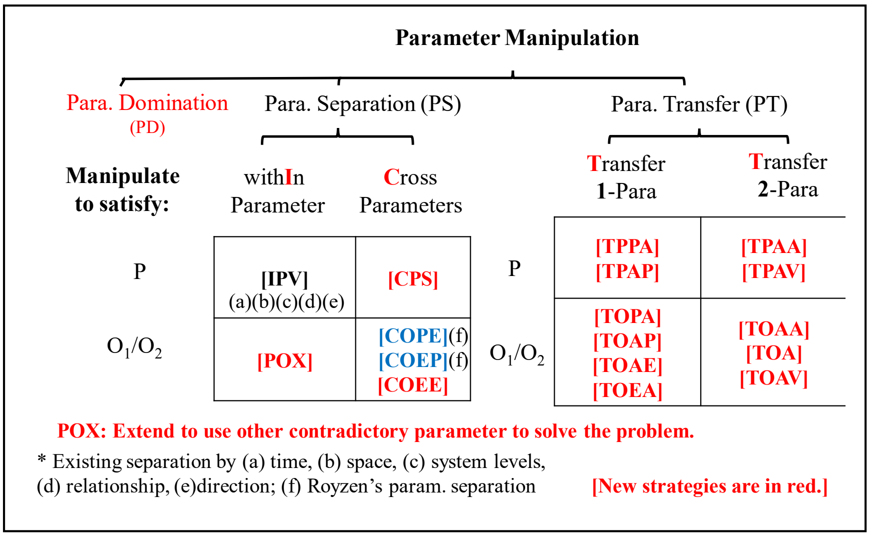

Fig. 2. Overview of strategies of parameter manipulation

Table 2. List of the various strategies

PD	**P**arameter **D**omination. By enhancing one or multiple compatible constituent parameters (Z_k) greatly to the extent that the influence by Z_k dominate the influence of P_j thus O1 and O2 can be achieved simultaneously.
IPV	With**I**n **P**arameter separation by **V**alue range. This includes all existing separation principles and more as indicated by separation at different value range of X_{jm} in Eq. 2.
CPS	**C**ross **P**arameter separation by **S**plitting parameter. Splitting a contradictory parameter into two
COPE/ COPE	**C**ross **P**arameter separation. PE: Use +P to satisfy O1 and Exclusive parameter of O2 to satisfy O2. EP: Use -P to satisfy O2 and Exclusive parameter of O1 to satisfy O1.
COEE	**C**ross parameter separation to satisfy at **O**bjective level. EE: Using **E**xclusive parameter of O1 to satisfy O1, EE: Using **E**xclusive parameter of O2 to satisfy O2,
TPPA/ TPAP	**T**ransfer a parameter to satisfy a contradictory parameter **P**. **PA**: Let P = +P and use an Additional (external) parameter to satisfy –P. AP: Let P = -P and use an Additional (external) parameter to satisfy +P.
TPAA/ TPAV	TRAA: **T**ransfer two contradictory demands at **P** level to two **a**dditional parameters (**AA**) separately. TPAV: **T**ransfer two contradictory demands at **P** level to one **A**dditioal parameter but at two separate **V**alue ranges.
TOPA/ TOAP	TOPA: **T**ransfer satisfaction of **O**2 to an **A**dditional parameter while letting **P = +P** to satisfy O1. TOAP: **T**ransfer satisfaction of **O**1 to an **A**dditional parameter while letting **P = -P** to satisfy O2.
TOAE/ TOEA	TOAE: Using **E**xclusive parameter of **O**2 to satisfy O2 and **T**ransfer satisfaction of O1 to an **A**dditional parameter. TOEA: Using **E**xclusive parameter of **O**1 to satisfy O1 and **T**ransfer satisfaction of O2 to an **A**dditional parameter.

TOAA/ TOA/T OAV	Transfer satisfaction of O1/O2 (TO) to: 1) two distinct Additional parameters (AA), 2) one Additional parameter on which the contradiction disappear or become non-effectual, 3) one **A**dditional parameter but separate them by **V**alue range (AV).
POX	Refer to Figure 2 and Section 2.5. Satisfaction of contradictory demands at **P** or **O** level strategy e**X**tension by using P_j's as the contradictory parameter when *j* is greater than or equal to 2. For each additional P_j , or P', identified there are 3 additional separation strategies (IP'V, COP'E, COEP') and 6 additional transfer strategies(TP'PA/TP'AP/TP'AA/ TP'AV/ TOP'A/TOAP').

2.5 Three Basic Modes of Parameter Manipulation

Refer to Figure 2. The three basic modes of Parameter Manipulations for problem solving are explained below:

1) Parameter Domination (PD): By enforcing a compatible parameter Z_k to the extent that the impact of the contradictory parameter become much less influential and Z_k dominates the results, the two objectives can still be simultaneously satisfied.

   Take eyeglasses as an example.

   For glasses [O1] not slip off, nose-pad normal force [P] should be large [+P]. But,
   to avoid nose discomfort [O2], nose-pad normal force[P] should be small [-P].

   Parameter Deployment:
   [O1] For glasses not slip off = fn(nose-pad friction force↑, nose-pad friction coefficient↑; nose grease ↓; eyeglasses weight ↓, nose-pad area ↑)
   [O2] To avoid nose discomfort = fn(nose-pad friction force↓, nose-pad friction coefficient →; nose-pad softness ↑, air humidity →; eyeglasses weight ↓, nose-pad area ↑)

   Where:

   ↑/↓: Indicates that within the scope of observation in the practical range, the higher/lower the value is the better to satisfy the dependent O or P.

   →: Indicates that within the scope of observation in the practical range, there exists certain optimal value to satisfy the dependent O or P.

   PD Solution: The compatible constituent parameters for this case are "eyeglasses weight" and "nose-pad area". In the parameter observation range and other things being the same, we can lower the weight of the eyeglass frame and/or increase the contact area of nose-pad to achieve O1 and O2 simultaneous. Whether or not a compatible parameter Z_k *is* able to dominate the influence on O1/O2 can be easily tested by enhancing the Z_k *in* the desirable direction and check if the O1/O2 can be achieved simultaneously with certain P value.

2) Parameter Separation (PS):

2a) Solution strategy IPV: Use 2 distinct value ranges of a constituent parameter of the contradictory parameter to satisfy the two contradictory demands. This includes all existing traditional separations by time, space, system levels, relationship, directions, etc. It is possible to have more constituent parameters thus more opportunities for problem solving using other parameters with IPV strategy.

For example, to make a pencil comfortable to hold (O1), the pencil shaft should have no angles (+P: round shape). To keep the pencil from rolling (O2), the pencil shaft should have angles (-P: say, hexagonal cross-section). With [IPV] strategy, using space as the constituent parameter to solve the problem. We can make the pencil shaft to have no angles (+P) on the part where people hold it, and have angles (-P) at the end of the pencil shaft to avoid rolling.

2b) Solution strategy CPS: Split the contradictory parameter P into two parameters so that one P can satisfy +P and the other P can satisfy –P demand thus solving the problem.

Taking outdoor public display panel as an example. Refer to Figure 3. The cover plate for the display is a frame structure covering the glass display on its circumference. The formulation of physical contradiction follows:

- To prevent the panel from rain leakage in (O1), the holes of cover plate should not exist (+P).
- To allow good heat dissipation by ventilation of the hot air (O2), the holes of the cover place should exist (-P).

The CPS strategy suggested splitting the cover plate into two cover plates with a gap between them. The outer plate has no hole to prevent water coming in and opens at the bottom so that the water can not come up into the in-between gap while leaving space for air to vent from below. Make the inner cover plate contains holes so that the hot air can come out of the holes of inner layer and going through the gap down and out. See CPS in Figure 3.

2c) Solution strategy COPE/COEP, COEE: Use 2 distinct constituent parameters of O1/O2 to satisfy O1 and O2 separately. Royzen's Separation by parameter [2] falls into COPE and COPE. But, there is no methods proposed to identify the constituent parameters in Royzen's approach. This paper proposed the parameter deployment to systematically identify all constituent parameters for O1, O2, and P for comprehensive considerations.

With the same outdoor display panel mentioned above, the parameter deployment results in the below constituent parameters.

- Prevent rain leakage (O1) = fn(Holes on cover plateØ, cover plate thickness ↑, sealedness↑; cover plate water resistance↑, water amount↓;)
- Good heat dissipate (O2) = fn(Holes on cover plate∃, cover plate thickness↓, sealedness↓; Cover plate heat dissipation rate↑;)
- Holes on cover plate (P_1) = fn(.., heat generation rate, cover plate specification)
- Cover plate thickness (P_2) = fn(..,heat generation rate, cover plate specification)
- Sealedness (P_3) = fn(.., water amount, sealant specification)

Where Ø means non-existent, ∃ means existent. The "..," signifies the first default set of constituent parameters for traditional separation constituent parameters for the P_j's. They are space, time, system level, relationship, direction, etc.

Refer to Figure 3 for partial solutions generated by parameter separation.

COPE suggest a solution of {no holes on cover plate, cover plate with high heat dissipation rate material/design}

COEP suggests solution of {holes on cover plate, high water resistance (design the hole downward out)}

Note that when there are more than one contradictory parameters, the P_1 in COPE/COEP above refers to the original contradictory parameter, holes on cover plate.

COEE suggest a combination of E_c^1 and E_c^2: such as {water resistant cover plate (hole or no hole), high heat dissipation cover plate}. There are multiple combinatory ways to substantiate the solution model by taking any one from E_c^1 to combine any one from E_c^2 to form a possible solution.

3) Parameter Transfer (PT): Transfer one or both of the two contradictory demands to one or two parameter(s) of seemingly unrelated external component/system not in the local system so that the two demands do not crash on the same parameter. This include as TPPA, TPAP, TOPA, TOAP, TOAE, TOEA, TPAA, TPAV, TOAA, TOA, TOAV in Figure 2. As an example, one TOAA solution is to delegate the task of preventing water leakage to an external rain shield and/or the task of heat dissipation to a heat pipe both of which are external resources, not belonging to the local system, capable of satisfying O1 and O2 respectively.

Due to space limitation, the category of Parameter Transfer and how to systematically identify those external resources will be explained in a subsequent paper. This paper focuses on parameter domination and separation only.

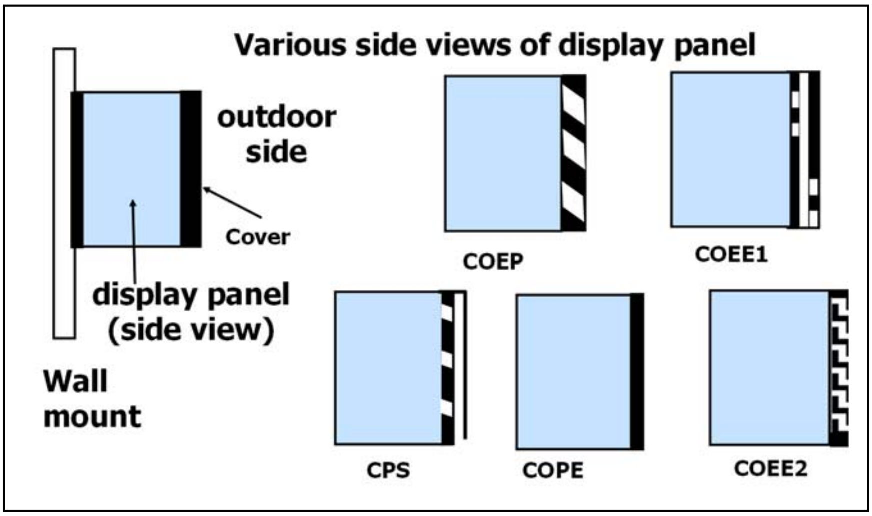

Fig. 3. Partial solutions of display panel

2.6 The POX Extension Strategy

Refer to Figure 4. The strategy of POX is applicable when after parameter deployment, we found additional contradictory parameters P_j exist, j = 2, 3, .., J. With each additional P_j, we can replace the original P_1 in the strategies of IPV/CPS/COPE/COEP or any of the parameter transfer strategies which involve using a contradictory parameter P such as TPPA/TPAP/TOPA/TOAP/TPAA/TPAV strategies for problem solving. With each additional identified $P' = P_j$, j = 2,3,.., J, to replace the original P_1, 10 more strategies can be used which 6 of them belong to Parameter Transfer category and 4 of them from the part of Parameter Separation. Therefore, a total of 5+4 (J-1) strategies can be used to solve the problem using parameter separation. Together with Parameter Domination and Parameter Transfer categories, a total of 17 + 10 (J-1) strategies can be used. Where J is the number of contradictory parameters identified by the parameter deployment.

For example (Fig. 4), if we use the Cover plate thickness (P2) as the subject contradictory parameter, apply the various strategies may generate ideas such as:

- IP_2V strategy: Let the frontal cover plate to be thick (no hole) to protect against rains. Let the lower side of the cover plate to be so thin with high heat dissipation so that the heat can dissipate from below the display.

- CP_2S: split cover plate thickness into 2 partitions. Partition 1 contains upper and side frames. Partition 2 contains lower frame. Make the partition 1 cover thick to prevent rain leakage and the partition 2 thin for heat dissipation.
- COP_2E: To prevent panel from rain leakage, make the cover plate thick (and no hole). However, use high heat conductivity materials for the cover plate to allow good heat dissipation.
- $COEP_2$: Make cover plate thickness thin (P_2) to dissipate heat better, but with water resistant design (E1) to prevent water leakage.

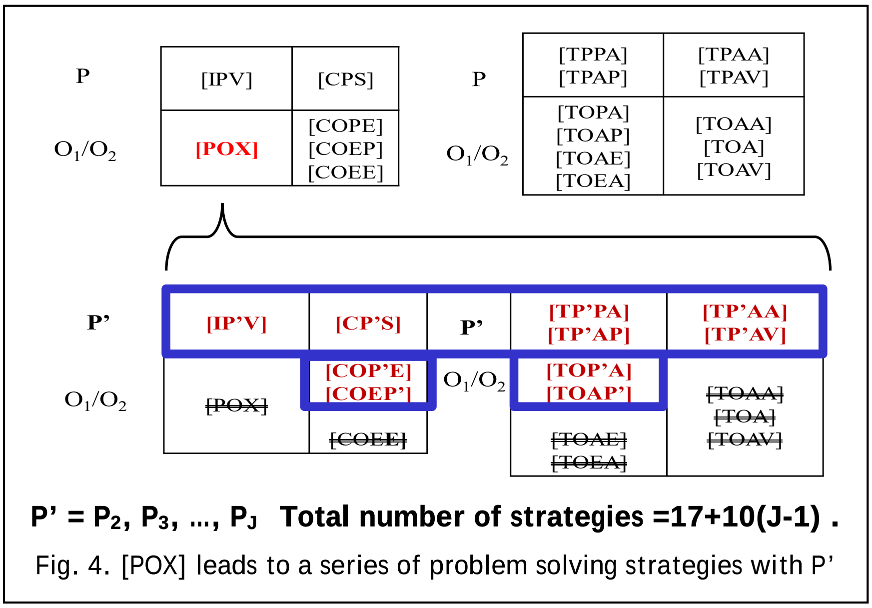

Fig. 4. Cover plate thickness various strategies summary

3 Method of Parameter Deployment

3.1 Component Identification and Parameter Deployment

In order to identify all immediate causal parameters contributing to the physical contradiction for parameter deployment, a set of forms are designed. By filling out the designed tables step-by-step, the user is prompted to consider all necessary aspects of the parameter deployment procedurally and systematically. Table 3 is the Parameter Identification Table in which the users identify the center components, the representative parameters of O1, O2, and P. Then, and all the contacting components of the center components are identified. The set of center components and contacting components constitute the local system of the contradiction. All immediate causal factors must be coming from the parameters of the local system components.

To identify constituent parameters as complete as possible, two steps were taken:

1) On each component of the local system, we ask Thought Provoking Question: What attributes/parameters of this component can cause or influence O1/O2/P? Those are the causing constituent parameters for deployment.
2) Then, we quickly go through a list of some 83 collected parameters as a secondary check list to see if any of the parameters on the list of this component can cause/influence the O1/O2/P.

In Table 4, Parameter Deployment Table, users can determine the category of each parameters by perturbing each potentially relevant parameter around the current observed value to see if increasing/decreasing or optimizing the parameter can move the respective dependent O1, O2 in the desirable direction thus determining the direction of movement for the constituent parameter as the desirable direction in Table 4. If perturbation of a parameter does not affect the O1/ O2/P, the parameter is not a constituent parameter of the respective O1/O2/P, it can be dropped. If the desired direction for O1 and O2 upon the constituent are incompatible, a contradictory parameter P is identified. Using this method, it is possible to identify more than one contradictory parameter for O1/O2, as $P_{i.}$ If both O1 and O2 require the constituent parameter to move the same direction, the constituent parameter is a compatible parameter, Z_k. If the constituent parameter only affect either O1 or O2, it is an exclusive parameter E_c^a. In this way, preliminary formula of the deployment can be obtained. In case there is some known scientific formula for O1/O2/P, the constituent factors of the scientific parameter can be added to its corresponding set of constituent parameters. This concludes the parameter deployment.

Table 3. Parameter Identification Table

System：{fill in system name}

For [O_1]{fill in O1}, [P] {fill in contradictory parameter} should be [+P]{fill in the requirement for contradictory parameter of O1}. But, For [O_2]{fill in O2}, [P] {fill in contradictory parameter} should be [-P]{fill in the requirement for contradictory parameter of O2}.				
O_1	{fill in representative parameter of O1 }	Central component：{fill in the central parameter of O1}	P	{fill in Central component of P}
O_2	{fill in representative parameter of O2 }	Central component：{fill in the central parameter of O2}		
Component Contact Diagram				
{Use the central elements of O1 / O2 / P as center components respectively, to identify components that directly contact those center components. Then, identify parameters of those central and contacting components for possible causing factors of the problem. Lines connecting cells below indicate the contact status.}				

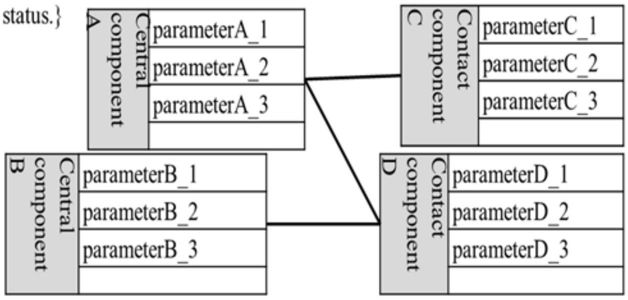

Table 4. Parameter Deployment Table

System：{ fill in system name}					+P	{fill in +P state}		-P	{fill in –P state}		
O_1	{fill in O1}				O_2	{fill in O2}					
Center/Contact components											
{Fill in component A}			{Fill in component B}			{Fill in component C}			{Fill in component D}		
Param.	O_1	O_2	Param.	O_1	O_2	Param.	O_1	O_2	Param.	O_1	O_2
{parameter name of component A}	{fill in required direction}	{fill in required direction}									
Parameter Deployment	[O1] {fill in the O1} = fn (P, ...; E, ...; Z, ...) {construct the deployment parameters of O1} [O2] {fill in the O2} = fn (P, ...; E, ...; Z, ...) {construct the deployment parameters of O2} [Pi] {the conflict parameter i} = fn(.., X1, X2, ...) {construct the deployment parameters of Pi} …										

4 Test Results

25 cases of physical contradictions (PC) were tested with the parameter manipulation strategies. The results are given in Table 5 in which columns are explained below.

PD: number of solution ideas generated by Parameter Domination;

PS: Parameter Separation;

Para.: Parameter

Total net incr.: Total net increase of the number of solution ideas generated.

With the combination of various parameter manipulations, the number of net increase in solution ideas is 149% from an average of 5.08 ideas by all existing methods of PC problem solving to 12.28 ideas by the proposed 6-plus PD+PS strategies. With the additions of parameter transfer strategies, the number of solution ideas can be as many as 10 times more than the ideas generated from all existing methods.

Table 5. Comparison of Numbers of Solutions Generated

Problem Title	PD	Existing separation principles	COPE/COEP	all existing methods	PD + PS	Net incr. PD+PS	# of solutions by Para. Transfer	total # of Sol.
Public display	0	2	6	8	26	225%	161	187
projector	1	0	4	4	14	250%	117	131
smart phone	0	2	2	4	5	25%	70	75
PCB welding	0	3	4	7	11	57%	21	32
Bike glove	1	3	4	7	20	186%	166	186
needle hole	1	2	5	7	16	129%	122	138
ball valve	0	1	3	4	12	200%	41	53
glasses	2	0	3	3	10	233%	52	62
bike brake	4	1	2	3	10	233%	18	28
probe stain	0	3	5	8	24	200%	48	72
car tire	1	0	3	3	13	333%	32	45
PCB flux cleaning	0	1	2	3	7	133%	38	45
pencil	0	2	1	3	8	167%	20	28
metal plating	1	2	1	3	5	67%	23	28
probe stuck	0	1	3	4	6	50%	14	20

Bicycle Seat	0	1	2	3	5	67%	31	36
mold Preheating	1	2	5	7	15	114%	42	57
mold injection curing	0	1	4	5	14	180%	9	23
Mold ejection	0	2	4	6	10	67%	20	30
test tube machine	1	4	3	7	19	171%	16	35
Wind Turbines	0	2	5	7	13	86%	18	31
bottle valve	3	1	2	3	12	300%	9	21
Bus wheel differential	0	0	4	4	8	100%	17	25
CMP Conditioner	0	3	4	7	10	43%	26	36
F-Connector	0	2	5	7	14	100%	11	25
Average	0.64	1.64	3.44	5.08	12.28	149%	45.68	57.96

5 Conclusion and Contributions

This paper established methods of parameter deployment and parameter separation/domination as part one of the full set of parameter manipulation for solving physical contradictions. The main contributions of this paper include:

1) Proposing a systematic parameter identification, deployment, domination, separation, and transfer methods under a unified set of theory of parameter manipulation. Problem solving can be achieved by manipulating all the parameters for systematic problem solving at either contradictory parameter level or objective level.
2) Proposing 6-plus problem solving strategies within a unified theory of parameter separation to achieve many more solutions beyond current approaches. All current solution methods fall only within three out of the 6-plus strategies developed thus capable of generating many more solution ideas which includes all solution ideas that can be generated by existing methods. As such, the quality of solutions using the proposed methods will be better or at least the same compared to using existing methods. In all the cases we have tested, the proposed strategies identified many good solutions which otherwise are not identified by existing methods.
3) Providing a set of operational forms to facilitate convenient systematic problem solving.

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