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OPTIMIZATION OF EQUITABLE DISTRIBUTIONS OF TEACHERS BASED ON GEOGRAPHIC LOCATION USING GENERAL SERIES TIME VARIANT PSO

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ABSTRACT

Distribution of teachers is a fundamental problem that still become an issue from central to regional level. This distribution is characterized by teacher shortages in some schools, but overages in the other. These issues can be overcome by making the arrangement and equal distribution of teachers, called displacement. Displacement is transferring teachers from one school to another. This removal must be done with clear criteria so that the arrangement and equitable distribution of teachers can be done right on target. Structuring and equalization which are done on the right target will ensure teachers can work better. According to these, this study creates a system that is able to provide restructurization and optimization of teacher distribution automatically. Optimization aims to produce a more proportional distribution of teachers and better right on target and in accordance with predetermined rules. The optimization technique used is Geometric Time Variant Particle Swarm Optimization (GTVPSO), which is a population-based optimization technique inspired by the social behavior of animals flock movements like ~~a~~ birds or ~~a~~ fishes. PSO combines methods of local search and global search methods using Geometric Series as smoothing of Previous Time Variant, in which each particle will move around the search space and adjust the position of the personal experiences and also experiences of other particles in the surrounding. The test results obtained the most optimal parameters of GTVPSO can improve the fitness value.

Index Terms— *Equitable Distributions of Teachers, Teacher Shortages and Surplus, Geographic Location, Geometric Time Variant Particle Swarm Optimization (GTVPSO).*

1. INTRODUCTION

Structurization and equitable distribution of teachers are some efforts to improve the quality of education by doing by teacher~~s~~ transfer. The term of mutation is the transfer of teachers among educational units within the sub-district, district, or province, so the composition of teachers is accordance with the real needs of each educational unit [5].

However, in reality, efforts of structurization and distribution of teachers by doing the mutation does not yet give results in line with the expectations. Until now, still, unbalanced distribution of teachers in several regions in Indonesia can be found. Many schools lack teachers, but on the other hand there are also schools that surplus teachers. Generally, a school with lack teachers is located in a district inside or suburb area, whereas the surplus teachers are in the small or big town. But, Chairman of Gerakan Indonesia Pintar (GIP) revealed that in urban areas, schools that lack teacher can still be found although not as much as in rural areas, where total lack teacher in urban areas reached 21%, 37% in rural areas and 66% in remote or isolated areas [6].

Ministry of Education and Culture, Muhammad Nuh, asserted that a teacher shortage is not due to the

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unavailability of sufficient teachers, but due more to the uneven distribution of teachers. Recruiting new teachers will only give a solution to the shortage of school teachers but not for schools that excess teachers. In addition, the recruitment of new teachers will require more budget funds. So, it is better to do the optimization of the existing number of teachers to be equitably distributed to the public in the nation [2]. However, to equitable distribute of teachers require setup process and time, which is quite a long time, because there are a lot of things to consider when transferring teachers, so that they can be transferred according to the target. Structurization and equitable distribution of teachers are based on Surat Keputusan Bersama (SKB) from 5 ministers who set the arrangement and equitable distribution of teachers based on the fulfillment of teaching hours, at least 24 hours every week.

One of the considerations of transfering teachers is a factor of the distance and access from the residence of teachers to another school as the transfer destination. Structurization and equitable distribution, if done right, can guarantee teachers to work better because, in addition to providing the advantage of fulfillment shortage of teaching hours, teachers transferred to other schools will have closer access to residence, so the teacher does not feel burdened. To give the structuring and equitable distribution of teachers on right target, it would be helpful if there is a optimization system for the determination of transfer destination school, teachers that will be transferred, as in some previous researches that performed equitable distribution of teachers using genetic algorithm [7]. The researches showed that experiments using best parameters can produce mutations without penalty that means all teachers have been transferred to the correct position. Other research uses Dijkstra methods. This study is also about the equitable distribution of teachers based on the shortest distance by transferring teachers using weighted graph. Thus, excess teachers can be transferred to districts outside or around Batu city which is still in a shortage of teachers [9].

Then there is previous research for the optimization of the allocation of human resources in a company using the Multi-objective Particle Swarm Optimization (MOPSO). The results of this experiment showed that MOPSO is capable of being used for resource allocation optimization problems by find employees with the greatest profitability value and the smallest cost to fill a new position in the company [4]. In this research, computer-based system using Geometric Time Variant Particle Swarm Optimization (GTVPSO) to optimize PSO algorithm is proposed that utilizes to enhance equitable distribution of teachers of subjects In Lumajang District, so that equitable is more proportionate and targeted. The algorithm GTVPSO is used because of the advantages that its process is much simpler compared to other algorithms and is faster to achieve optimal solutions and is able to balance the ability of exploration and exploitation by time variant inertia weight and acceleration coefficients (TVIW and TVAC) based on previous research [3].

2. METHOD

2.1 Time Variant Particle Swarm Optimization (TVPSO)

Time variant is used to control capability of PSO in local search to be efficient and global convergent to the optimum solution [8]. The minimum and maximum values w (TVIW) that are used are 0.4 and 0.9 and this value is proven to increase optimum solution in many problems, while the value range c_1 and c_2 (TVAC) used is [2.5, 0.5] and [0.5, 2.5]. As explained earlier that the PSO is an optimization algorithm which individuals acts as a particle and has d-dimension, position and velocity that is the basis of the TVPSO. Position and velocity of a particle ith are represented as Xi and Vi with Equation (1) and (2), and TVPSO algorithm always update the value of w, c_1 and c_2 for each iteration by the Equation (3)., (4) and (5) [3]:

$$v_{i,j}^{t+1} = w.v_{i,j}^{t} + c_1.r_1\left(Pbest_{i,j}^{t} - x_{i,j}^{t}\right) + c_2.r_2\left(Gbest_{g,j}^{t} - x_{i,j}^{t}\right) \quad (1)$$

$$x_{i,j}^{t+1} = x_{i,j}^{t} + v_{i,j}^{t+1} \quad (2)$$

$$w = w_{\min} + \left(w_{\max} - w_{\min}\right)\frac{\left(t_{\max} - t\right)}{t_{\max}} \quad (3)$$

Equation (3) also referred to as *Time-varying inertia weight* (TVIW). c_1 and c_2 are the coefficient acceleration for a better balance between global exploration and local exploitation, *Time varying acceleration coefficients* (TVAC). The essence of TVAC is c_1 which decreases from the initial value c_{1i} to c_{1f}, and c_2 increases from $c2i$ to c_{2f} based on the equation TVAC mathematically as follows [3]:

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$$c_1 = \left(c_{1f} - c_{1i}\right)\frac{t}{t_{max}} + c_{1i} \tag{4}$$

$$c_2 = \left(c_{2f} - c_{2i}\right)\frac{t}{t_{max}} + c_{2i} \tag{5}$$

where c_{1f}, c_{1i}, c_{2f}, c_{2i} are constant, t is the initial iteration of the algorithm and t_{max} is the maximum value of iterations.

2.2 Modified Arithmetic Time Variant Particle Swarm Optimization (TVPSO)

The basis of the proposed Modified Arithmetic method is from the concept of arithmetic series of the value in the nth term. Time variant that modified from Equation (3), (4) and (5) is a form of the detail of the outlining is made more a precision value from the lower to the upper bound, and vice versa.

$$w = w_{max} + \left[(t-1)\left(\frac{w_{min} - w_{max}}{t_{max} - 1}\right)\right] \tag{6}$$

$$c_1 = c_{1i} + \left[(t-1)\left(\frac{c_{1f} - c_{1i}}{t_{max} - 1}\right)\right] \tag{7}$$

$$c_2 = c_{2i} + \left[(t-1)\left(\frac{c_{2f} - c_{2i}}{t_{max} - 1}\right)\right] \tag{8}$$

In Equation (6), (7) and (8) all raised from the formula nth term of the arithmetic series [1].

2.3 Geometric Time Variant Particle Swarm Optimization (GTVPSO)

The term of geometry and arithmetic series are very different. To form the Geometric Time Variant (non-linear Time Variant), this research proposed adopting from the formula nth term in geometric series. That the Time Variant value, it can be made by general series approach, to a specific series, or against with a specific equation that essentially starts from the first term as lower bound to the last term as upper bound that is already known before. Here General series Time Variant based on the geometric series or it call Geometric Time Variant Particle Swarm Optimization (GTVPSO) that can be seen in (9), (10), and (11) [1].

$$w = w_{max}\left[\left(\frac{w_{min}}{w_{max}}\right)^{\frac{1}{(t_{max}-1)}}\right]^{(t-1)} \tag{9}$$

$$c_1 = c_{1i}\left[\left(\frac{c_{1f}}{c_{1i}}\right)^{\frac{1}{(t_{max}-1)}}\right]^{(t-1)} \tag{10}$$

$$c_2 = c_{2i}\left[\left(\frac{c_{2f}}{c_{2i}}\right)^{\frac{1}{t_{max}-1}}\right]^{(t-1)} \tag{11}$$

When analyzed from the visualization value of the first term to the last term based on the Equation (3-11), it appears that the results of the visualization will form a straight line (linear) and curved (non-linear) as in Fig. 1. Although the value of w, as it does not look curved, but in fact, it forms a curve, because of the lower and upper bound of that influence.

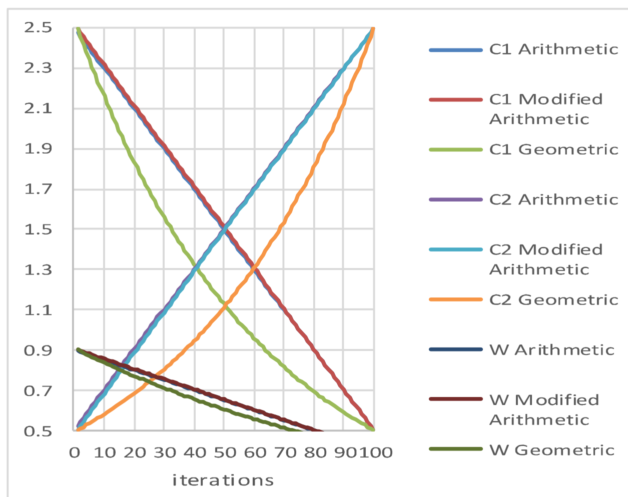

Fig. 1. Visualization of c_1, c_2, and w

If the concept of geometry is applied, it will mean that capability, adaptability and movement change from exploration to exploitation process will run smoothly and become more stable. This is because, when movement changes in a straight line, then the particle it moves to be more visible as like do several jumps from one position to a new position. Thus, this linear change will involve the particles are not able to explore, most areas in the search space to discover the optimal solution. Meanwhile, if geometry changes (non-linear) is used, then the analysis,

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the particles will move to the next position, but when it will move towards to a new position, the particles will be able to control the movements smoothly, as if the particles divide the way into several sub-stages, thus providing a great opportunity that allows the particles to find a better position before going into the new position, more than if using the concept of movement of a straight line (linear change).

Table 1. Formation Requirements Teacher

No	School	Course	-	+	Availability of Teachers
1	SMP 2	IPS	1	0	3
		MTK	0	1	3
		TIK	1	0	0
		BD	1	0	0
2	SMP 5	IPS	0	1	4
		MTK	0	2	4
		TIK	1	0	0
		BD	0	2	4
3	SMP 6	IPS	0	1	4
		MTK	1	0	2
		TIK	0	2	4
		BD	1	0	0

Table 2. Teacher selection (Course: IPS)

ID Choice	Teacher *i*th School	Age	Work Period (years)	Distance (km) SMP 2
1	1 SMP 5	51	5	4
2	2 SMP 5	49	8	6
3	3 SMP 5	34	4	3
4	4 SMP 5	37	8	7
5	1 SMP 6	42	9	7
6	2 SMP 6	32	7	1.5
7	3 SMP 6	53	3	2
8	4 SMP 6	44	5	2

Table 3. Data of choice distribution

Course	Total Shortage	Total Surplus	Total Distribution
IPS	1	2	1
MTK	1	3	1
TIK	2	2	2
BD	2	2	2
Total	*d* = 6	9	6

Table 4. Initialization particles

Particle *i*th	Course	r	Dimension *j*th	Position	Velocity
1	IPS	0.4	1	4	0
	MTK	0.4	2	3	0
	TIK	0.9	3	7	0
	TIK	0.2	4	2	0
	BD	1	5	8	0
	BD	0.1	6	2	0
..	..	..	..	..	..
Swarm Size	IPS	..	..	..	0
	MTK	..	..	..	0
	..	..	..	..	..
	BD	..	..	..	0

Based on Table 4, the position value of 1st dimensions and 1st particle is 4, which 4 shows the position of teachers that are selected for transfer to other schools that is in shortage of teacher, the teacher is 4th teacher SMP 5. The way to calculate the value can be done as follows $x_{11} = 1 + 0.4(8 - 1) \approx 4$. According to Table 1-4, the application of PSO algorithms for optimization of the equitable distribution of teachers using the solution of representation and each particle's position has a value of fitness. In this case, the fitness value is calculated using Equation (12), where, mk (work period), u (age), and j (get distance is using Google Maps APIs based on a map in Fig. 2 and then save to the database). Particles with larger fitness value are considered as a candidate for a better solution.

$$Fitness = mk + \frac{1000}{u + j} \quad (12)$$

Fig. 2. Lumajang district map

```
procedure PSOAlgorithm
begin
    t = 0
    initialization:
     position (xij(t)) and count fitness each particle
     velocity (vij(t)=0)
     Pbestij(t) = xij(t)
     Gbestgj(t)
        do
                t = t + 1
                update velocity (vij(t))
                update position (xij(t))
                count fitness each particle
                update Pbestij(t) and Gbestgj(t)
        while (not a termination condition)
end
```

Fig. 3. PSO Algorithm

3. RESULTS

Experiments were performed to determine the effectiveness of GTVPSO that conducts particle velocity decrease linearly (arithmetic time variant) and non-linear (geometric time variants) towards the optimum solution, on the data that consists of 50 schools, 968 teachers, 12 course. A maximum number of iterations used for the experiment is 100. The iteration increments by 10, starting from 10 to 100. Experiment maximum for each iteration will be repeated 10 times, to get the results each increments by 10 and conclusions to be easy because the PSO algorithm is stochastic. For a combination of the inertia weight, acceleration coefficient and other PSO parameter used can be seen in Table 5.

Table 5. PSO parameters

Swarm Size	25
w_{min}	0.4
w_{max}	0.9
c_{1i}	2.5
c_{1f}	0.5
c_{2i}	0.5
c_{2f}	2.5
r_1,r_2	0.5

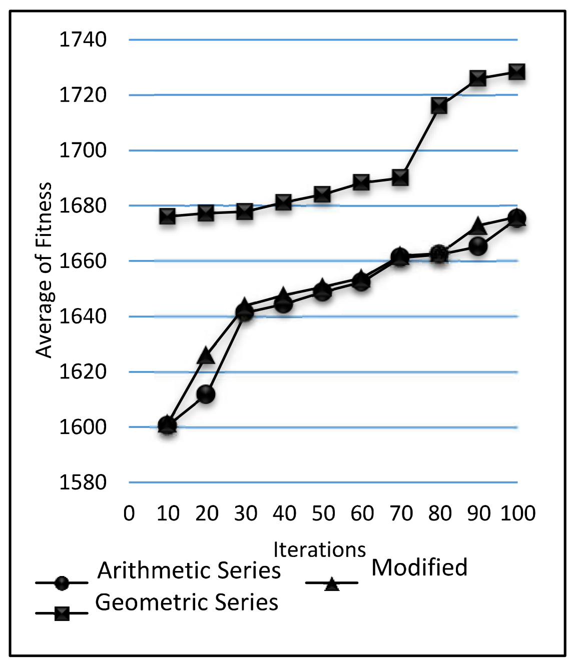

Fig. 4. Comparison of fitness between geometric time variant and arithmetic time-variant

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The experimental results are presented in Table 6. The experimental results indicate that the PSO with geometric time variant capable of giving out a better solution than the PSO with arithmetic time variant, as shown in the graph in Fig. 4 that the value of the average fitness of each experiment the maximum iteration the overall geometry of variant time value is greater than the average fitness generated by arithmetic-time variant. That is because by using time variant-geometry allows slower speed reduction be done. The decrease the slower speed is useful for an optimal solution is not easily missed.

4. CONCLUSIONS

Optimization equitable distribution of teachers has been completed with Geometric Time Variant Particle Swarm Optimization (GTVPSO). The experimental results show that the PSO with Geometric Time Variant is able to produce a better solution. Then for future research, it should use more parameters to 'teacher transfer', so that consideration of the transfer of teachers is not only based on age, work period, and distance. In addition, optimization techniques can be developed for structuring and equitable distributions of teacher's course in other educational levels. And for better GTVPSO result, its algorithm can be hybrid with other meta-heuristics methods.

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Tabel 6. Result testing Time Variant

Time Variant and Series	Iteration	Number of Trials										Average of Fitness
		1	2	3	4	5	6	7	8	9	10	
	10	1669.82	1672.52	1705.95	1677.65	1696.13	1648.01	1669.80	1611.32	1756.40	1654.06	1676.17
	20	1640.73	1648.74	1702.73	1674.76	1679.73	1680.78	1706.72	1652.80	1678.71	1706.72	1677.24
Geometric	30	1694.75	1649.75	1609.76	1714.73	1716.74	1711.72	1667.71	1638.78	1676.77	1697.71	1677.84
	40	1697.75	1640.73	1720.73	1653.75	1667.75	1695.74	1666.78	1651.72	1683.78	1732.73	1681.15
	50	1701.95	1704.81	1691.90	1675.55	1708.77	1732.49	1665.16	1689.95	1660.85	1609.34	1684.08

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	60	1655.74	1640.76	1715.74	1679.74	1658.78	1718.74	1706.76	1718.76	1719.71	1668.70	1688.34
	70	1713.32	1646.11	1680.60	1614.65	1717.16	1648.79	1724.37	1726.69	1739.18	1689.29	1690.02
	80	1671.79	1727.75	1652.71	1741.71	1720.72	1719.75	1725.77	1727.69	1732.72	1739.70	1716.03
	90	1725.54	1731.85	1657.25	1742.39	1774.22	1737.35	1743.61	1686.64	1770.32	1690.66	1725.98
	100	1761.00	1674.63	1747.40	1760.86	1754.79	1754.94	1782.20	1695.85	1694.48	1658.11	1728.43
Modified Arithmetic	10	1690.73	1049.77	1670.74	1615.76	1632.74	1666.78	1641.74	1664.74	1681.76	1699.76	1601.45
	20	1599.23	1661.15	1630.60	1643.05	1592.86	1579.81	1680.53	1561.35	1632.37	1680.30	1626.12
	30	1610.84	1673.59	1642.36	1681.26	1604.62	1670.51	1645.68	1674.88	1614.34	1620.60	1643.87
	40	1673.74	1665.76	1649.75	1618.73	1629.77	1639.76	1682.74	1652.77	1634.73	1628.76	1647.65
	50	1667.20	1695.22	1635.50	1675.93	1649.35	1629.06	1619.45	1621.00	1661.75	1652.64	1650.71
	60	1620.71	1660.71	1655.78	1646.78	1678.75	1686.75	1665.76	1649.75	1644.72	1629.77	1653.95
	70	1640.74	1658.78	1699.76	1606.77	1653.69	1701.75	1656.72	1704.75	1640.71	1655.73	1661.94
	80	1640.77	1700.64	1660.36	1652.16	1673.01	1632.60	1628.42	1687.45	1697.80	1654.04	1662.72
	90	1661.38	1652.85	1686.83	1649.99	1625.58	1708.30	1715.48	1640.18	1697.37	1690.91	1672.89
	100	1694.33	1629.21	1720.31	1634.02	1680.49	1725.46	1731.78	1602.58	1687.74	1654.74	1676.07
Arithmetic	10	1639.79	1683.75	1148.73	1642.74	1617.76	1683.78	1680.74	1618.73	1660.76	1629.77	1600.66
	20	1618.10	1542.06	1650.71	1666.13	1662.84	1593.81	1620.03	1566.10	1640.43	1557.75	1611.80
	30	1614.04	1692.75	1619.34	1666.08	1644.39	1600.04	1594.05	1691.09	1666.34	1624.92	1641.31
	40	1624.68	1658.54	1632.23	1648.29	1622.09	1652.24	1663.06	1686.69	1649.54	1607.74	1644.51
	50	1578.43	1640.29	1655.73	1684.36	1657.01	1614.66	1643.63	1685.89	1648.06	1680.60	1648.87
	60	1666.40	1637.31	1637.11	1675.27	1609.60	1679.82	1622.58	1665.67	1625.97	1704.03	1652.38
	70	1673.55	1623.24	1690.72	1630.86	1636.38	1623.52	1697.20	1706.27	1644.87	1685.82	1661.24
	80	1596.45	1686.42	1652.95	1685.07	1668.61	1678.50	1683.74	1611.12	1685.52	1676.24	1662.46
	90	1687.29	1704.85	1671.32	1617.29	1652.42	1649.63	1701.81	1646.38	1653.47	1668.21	1665.27
	100	1604.08	1662.54	1656.12	1654.89	1655.09	1714.77	1716.38	1654.54	1717.34	1718.33	1675.41