An Enhanced Approach of Pso Driven Fa for A Spherical Interacting System

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ABSTRACT:

Storage tanks play a vital role in process industries. Controlling the level in storage tank improves and accelerates the process throughput. PID controllers are pressed into service for control purposes and furthermore to tune the controller PSO driven FA is used here. The system to be analysed is segregated into four sub regions and a dedicated PID controller is employed for each and every region. In the proposed work the PID based PSO driven FA is compared with the conventional method (ZN) with MATLAB and Simulink software. The obtained results are validated in the order of time domain specifications and performance indices such as rise time, peak time, Peak Overshoot, Settling time and ISE, IAE and ITAE respectively. The optimized results are obtained with less number of iterations and with considerably less errors.

Keywords*: Firefly Algorithm, Particle Swarm Optimization Algorithm, Interacting system, Non-linear, Spherical system*

INTRODUCTION

PID structure is the most demanding controller even though there has been many control theories that has been evolved till date. The spherical systems are widely used in Petrochemical industries as storage vessels. One of the benchmark problems of process control industries is controlling the level of interacting spherical system. Due to variation in the radius of the tank and due to the interaction of the two tanks the spherical tank system is considered as an extremely non-linear process. The disorderly and wild liquid level may result in explosions and may lead to imbalance disproportion reactions[1-5]. Therefore it is vital to control the level of the spherical system. The modelling of the interacting spherical tank system is separated into four regions as the radius of the spherical tank varies from top to bottom.

The simplicity, robustness and reliability of PID make the PID the most demanding one. Most of the control loops in the industry are PID control loops. In PID, to improve the production and eliminate the error[5-7] there are a number of methods to deduce the tuning parameters(kp,ki,kd) .In some cases the process operator decides the value for tuning parameters. In either way it is a difficult method as it requires fine mathematical analysis as well as good process knowledge.

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In industries ACO,PSO and BFO algorithms are widely used to obtain the optimal point as they normally require less mathematical analysis and little process knowledge [8-10].PSO has been used by researchers worldwide for computing and organizing purpose. Guoli Song [11] has developed a non-invasive method for the automatic detection of tumour using PSO. Similarly a collision free control has been developed and framed with the aid of FA and Taguchi method [12]. Therefore optimization process helps in obtaining the optimum tuning parameters for stable and unstable models.

Among the optimization algorithms the PSO and FA has been considered. In PSO as there is no mutation or crossover the optimization, often sticks to local optimization[13]. Similarly in FA the optimization always depends on the brightness values [14]. So a hybrid algorithm of two existing algorithms FA and PSO have been proposed to increase the controller performance . In this work, the hybrid algorithm (FAPSO) is been used to optimize the time domain specification and performance indices of the spherical interacting system. The result obtained using FAPSO algorithm is compared with the results of Ziegler-Nichols tuning method.

In Section 2 the methodology/algorithm has been proposed. In Section 3 the processes considered for analysis has been described. In Section 4 results and responses has been discussed and in Section 5 the final conclusions are drawn.

METHODOLOGY

A hybrid of FA and PSO algorithm has been used for obtaining the optimized parameters for PID controller .The algorithm is used to tune the controller for second order systems. In PSO the local and global search defining the position and velocity of swarm that decides a population. Subsequently in FA the updation of the brightness value decides the optimized value. The spherical interacting system model has been used as a test system. The PID parameters for the four regions are found out using FAPSO algorithm and have been compared with Ziegler Nichols results.

A.PSO

Ebenhart and Kenedy[13] in the year 1995 exhibited the social behaviour of fish schooling as PSO . The population is random initially and it has been updated with new velocity and position through eq. (1) . Equilibrium between exploration and exploitation was through inertia weight (w) and and the constraint factors C_1 and C_2.

$$v_{new} = w * v_{old} + C_1(p_{best} - p_{current}) + C_2(g_{best} - p_{current}) -- \ (1)$$

Where

v_{new} is the updated velocity;
p_{best} is the local best position;
g_{best} is the global best position.;
$p_{current}$ is the current position
W is the inertia weight; C_1 and C_2 are constants;

B.FA

Yang in 2008, developed FA based on the behaviour of fireflies[14]. The solutions are regarded as fireflies and each solution is compared with the subsequent one. Eventually the optimized solutions are the brightest one and obviously the other fireflies/solutions get attracted towards the best solution as per eq. (2).

$$X_{it}(n+1) = X_{i_t}(n) + \beta_0 e^{-\gamma r_{ij}^2}\left(X_{jt}\text{-}X_{it}\right) + \alpha\epsilon_i \text{----}(2)$$

Where

β_0 is the maximumm brightness of the firefly; α is the step size of the firefly; γ is the adsorption co- efficient.

Till date tremendous reserach has been done over FA and enormous variants of FA has been developed to reduce the randomness in the solutions. One of the ways in doing so is generatiog a pre optimized populations and finding the optimized solution from it.

DESIGN OF PID CONTROLLER

The K_p , K_i ,K_d of PID are optimized by FAPSO algorithm. The populations/solutions are initialized randomly. The search for optimal solution is optimized by making the constraint factors as adaptive. The factors C_1 and C_2 are self-tuned by considering the deviation of current fitness value from the mean value and the maximum fitness values. This adapted population will be the population of firefly and thus the hybrid algorithm FAPSO has been framed.

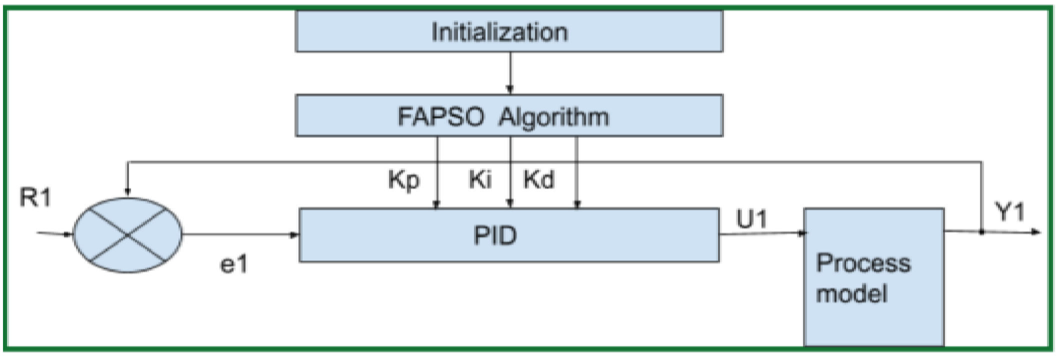

Figure 3.1 FAPSO tuned PID Controller

Step 1: Initialization:
The fireflies and swarms for FA and PSO are randomly made between the proper limits.
Step 2: Gauging objective function:
The objective function of both FA and PSO are evaluated
Step 3: Changing the positions:

$$C_{1_{new}} = \frac{c_{max}}{c_{min}} * \left[\frac{\min(current\ fitness)}{\max(current\ fitness)}\right] + \left[\frac{\min(current\ fitness)}{2*\max(current\ fitness)}\right] + C_{min} \qquad (3)$$

$C_2 = C_{1new}/2$;

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$C_1 = C_{1new/}2$;

The new local and global positions are updated using the above formula

Step 4:Updation:

The location of the swarm is upgraded. The objective functions are calculated for the updated positions. Similarly the C_1 and C_2 values are updated.

Step 5:Positioning

The positions gained by the swarms represented by C_1 are updated as initial positions of the fireflies.

Step 6:Iteration:

Several iteration have been put through for the updation of the firefly's initial position so as to reach the objective functions.

Step 7:Brightness updation :

The brightness of the firefly is modified by updating with the current position value of the swarm Step 8: Final iterations:

The simulation is carried out to find the optimal point.

PROCESS DESCRIPTION

The process that is taken into account is TTSIS (Two Tank Spherical Interacting system. It is highly nonlinear as its cross sectional area varies with the height (level of the liquid in the tank). The interacting nature of the tank aids the non-linearity and increases the complexity. The input is the flow rate to the first tank and the variable that is controlled is the height of the second tank (H_2).The corresponding mass balance equation is

$$F_{in} - F_{out} = \frac{1}{3}\left[A\frac{dh}{dt} + h\frac{dA}{dt}\right] \text{-------} (4)$$

The balance equations for tank 1 and tank 2are given by eq (5) & (6)

$$F_{in1} - \beta_{12}\sqrt{(h_1 - h_2)} = \frac{4}{3}(A_1\frac{dh_1}{dt} + h_1\frac{dA_1}{dt}) \text{ ------ } (5)$$

$$\beta_{12}\sqrt{(h_1 - h_2)} - \beta_2\sqrt{h_2} = \frac{4}{3}(A_2\frac{dh_2}{dt} + h_2\frac{dA_2}{dt}) \text{ ------ } (6)$$

Where

A_1 and A_2 are the areas of a circular cross section of the spherical tank.
H_1 and H_2 is the level of tank 1 and tank 2 respectively.
F_{in1} is the input flow rate.
β_{12} *and* β_2 are the valve coefficient of interacting valve and the outlet valve respectively.

Eq (5) & Eq (6) can be rewritten as eq (7)& (8)

$$\frac{dh_1}{dt} = \frac{F_{in1} - \beta_{12}\sqrt{(h_1 - h_2)} - \frac{4}{3}h_1\frac{dA_1}{dt}}{\frac{4}{3}A_1} \quad (7)$$

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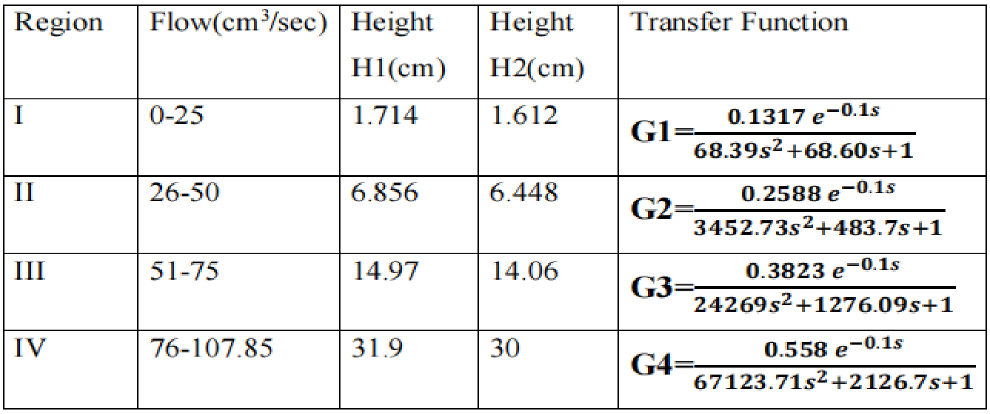
$$\frac{dh_2}{dt} = \frac{\beta_{12}\sqrt{(h_1 - h_2)} - \beta_2\sqrt{h_2} - \frac{4}{3}h_1\frac{dA_1}{dt}}{\frac{4}{3}A_1} \quad (8)$$

The obtained mathematical models (7) & (8) are transformed into S domain and after applying the suggested time constants and radius by Ravi et al [15],the transfer functions of TTSIS for the four different regions has been found out [16-20].They are listed in the following Table 4.1.

TABLE 4.1 TRANSFER FUNCTIONS OF SPHERICAL INTERACTING SYSTEM



Region	Flow(cm^3/sec)	Height H1(cm)	Height H2(cm)	Transfer Function
I	0-25	1.714	1.612	$G1=\frac{0.1317\, e^{-0.1s}}{68.39s^2+68.60s+1}$
II	26-50	6.856	6.448	$G2=\frac{0.2588\, e^{-0.1s}}{3452.73s^2+483.7s+1}$
III	51-75	14.97	14.06	$G3=\frac{0.3823\, e^{-0.1s}}{24269s^2+1276.09s+1}$
IV	76-107.85	31.9	30	$G4=\frac{0.558\, e^{-0.1s}}{67123.71s^2+2126.7s+1}$

RESULTS

The FAPSO is executed for each transfer function for number of iterations in MATLAB and Simulink environment. The values that are considered for the hybrid approach are C_1 =1.2, C2=0.2, W=0.75, α=0.8 and β=0.4. The sampling time period is taken as 0.01. The simulation time varies for all the four regions and they are 100,300,600,600 respectively. The best among the iterations having least ITAE and peak overshoot is taken as the optimal result and compared with the results obtained using ZN tuning. The outcomes of FAPSO and ZN tuning are tabulated and are listed. The figure 5.1-5.4 and tables 5.1-5.4 shows output response of the levels of the spherical interacting system and the corresponding performance indices and time domain specifications respectively. From the table and from the responses it is well known that the FAPSO based PID controller exhibits minimum error and minimum peak overshoot.

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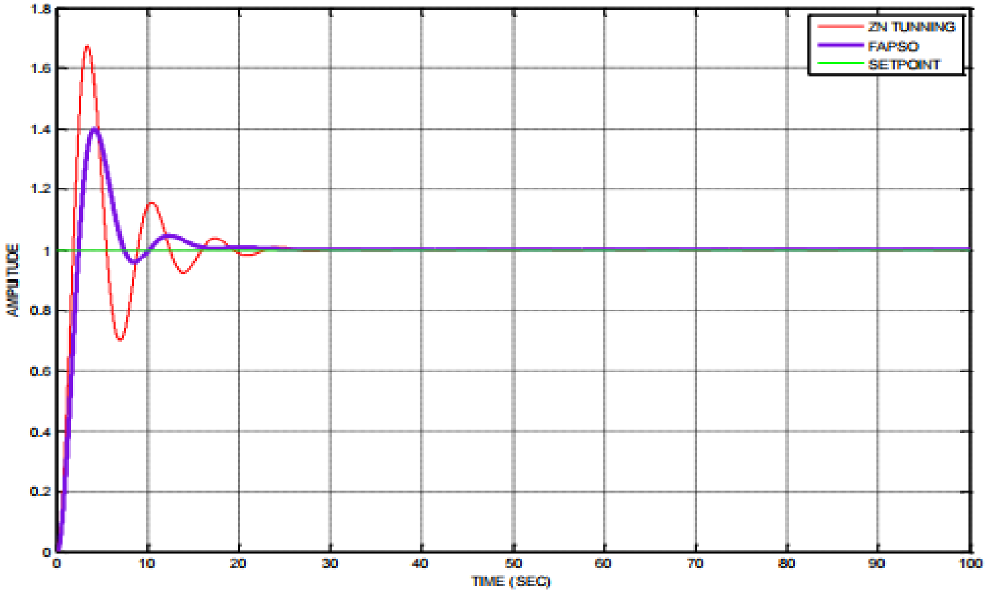
TABLE 5.1 COMPARISON OF FAPSO AND ZN FOR REGION I

$\frac{0.1317\, e^{-0.1s}}{68.39s^2 + 68.60s + 1}$	**FAPSO**	**ZN TUNNING**
$K_{p\,(1/ms)}$	383.2858	539.700
$K_{i\,(ms)}$	52.5319	207.6000
K_d	-704.3504	0
ISE	1.4973	1.9448
ITAE	11.0503	20.3498
IAE	2.9430	4.0890
OVERSHOOT	39.8236	67.4117
RISE TIME(sec)	158.0524	115.615
SETTLING TIME(sec)	14832	1863.7
PEAK TIME(sec)	420	344
PEAK OVERSHOOT%	1.3982	1.6741



. *Figure 5.1.1 Step Response of Spherical interacting system for region I*

TABLE5.2 COMPARISON OF FAPSO AND ZN FOR REGION II

$\frac{0.2588\, e^{-0.1s}}{3452.73s^2 + 483.7s + 1}$	**FAPSO**	**ZN TUNNING**
$K_{p(1/ms)}$	364.1694	262.3000
$K_{i\ (ms)}$	21.2278	14.7008
K_d	0.2066	0
ISE	10.6997	11.886
ITAE	687.61323	787.890
IAE	22.9952	25.018
OVERSHOOT	63.3771	59.7071
RISE TIME(sec)	729.2912	889.8169
SETTLING TIME(sec)	11315.0	11475.0
PEAK TIME(sec)	2073	2510
PEAK OVERSHOOT%	1.6338	1.5971

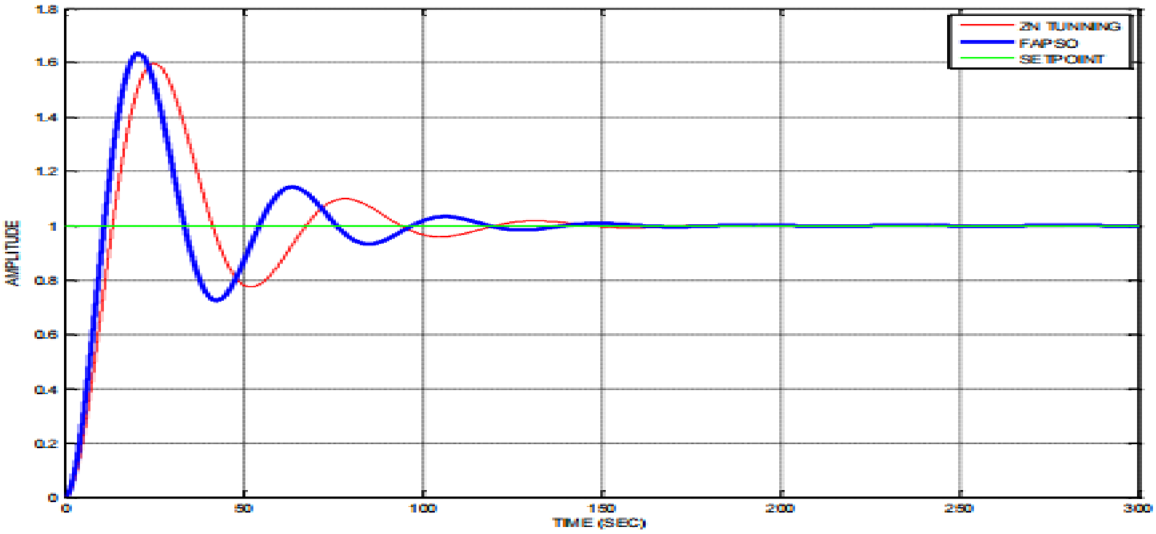


Figure 5.1.2 Step Response of Spherical interacting system for region II with PID controller

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TABLE 5.3 COMPARISON OF FAPSO AND ZN FOR REGION III

$\frac{0.3823\, e^{-0.1s}}{24269s^2 + 1276.09s + 1}$	**FAPSO**	**ZN TUNNING**
$K_{p(1/ms)}$	1245.0	180
$K_{i\ (ms)}$	-0.0003	3.6730
K_d	-0.0006	0
ISE	11.2122	30.1135
ITAE	1315.7	4989.3
IAE	26.9985	63.1787
OVERSHOOT	56.2487	57.9856
RISE TIME(sec)	843.4921	2360.7
SETTLING TIME(sec)	14352.0	29969.0
PEAK TIME(sec)	2289	6601
PEAK OVERSHOOT%	1.5592	1.5800

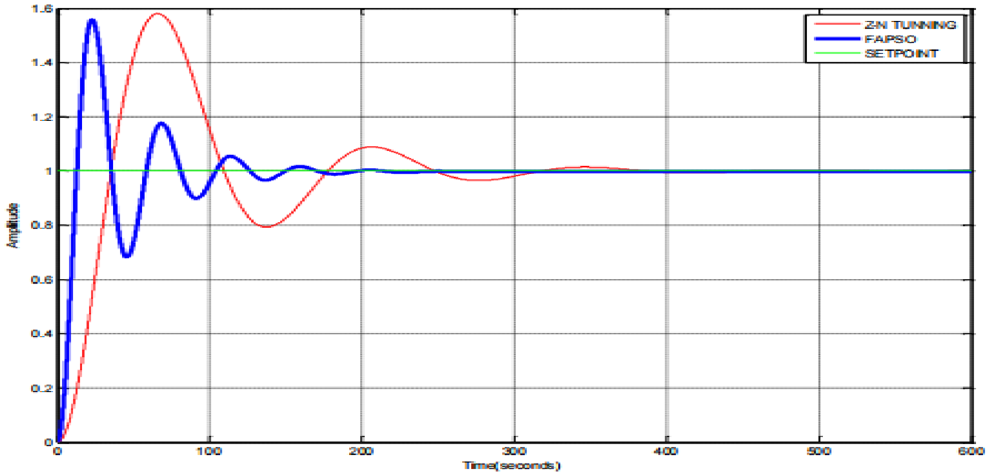

FIGURE 5.3 STEP RESPONSE OF SPHERICAL INTERACTING SYSTEM FOR REGION III

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TABLE 5.4 COMPARISON OF FAPSO AND ZN FOR REGION IV

$\frac{0.558\, e^{-0.1s}}{67123.71s^2 + 2126.7s + 1}$	**FAPSO**	**ZN TUNNING**
$K_{p(1/ms)}$	1294.0	123.2
$K_{i\ (ms)}$	-0.0	1.522
K_d	152030	0
ISE	15.5309	50.0104
ITAE	2434.5	13141.0
IAE	39.1749	104.1122
OVERSHOOT	84.9783	56.1065
RISE TIME(sec)	335.8329	3968.8
SETTLING TIME(sec)	23911.0	51602.0
PEAK TIME(sec)	1006	10981
PEAK OVERSHOOT%	1.8494	1.5794

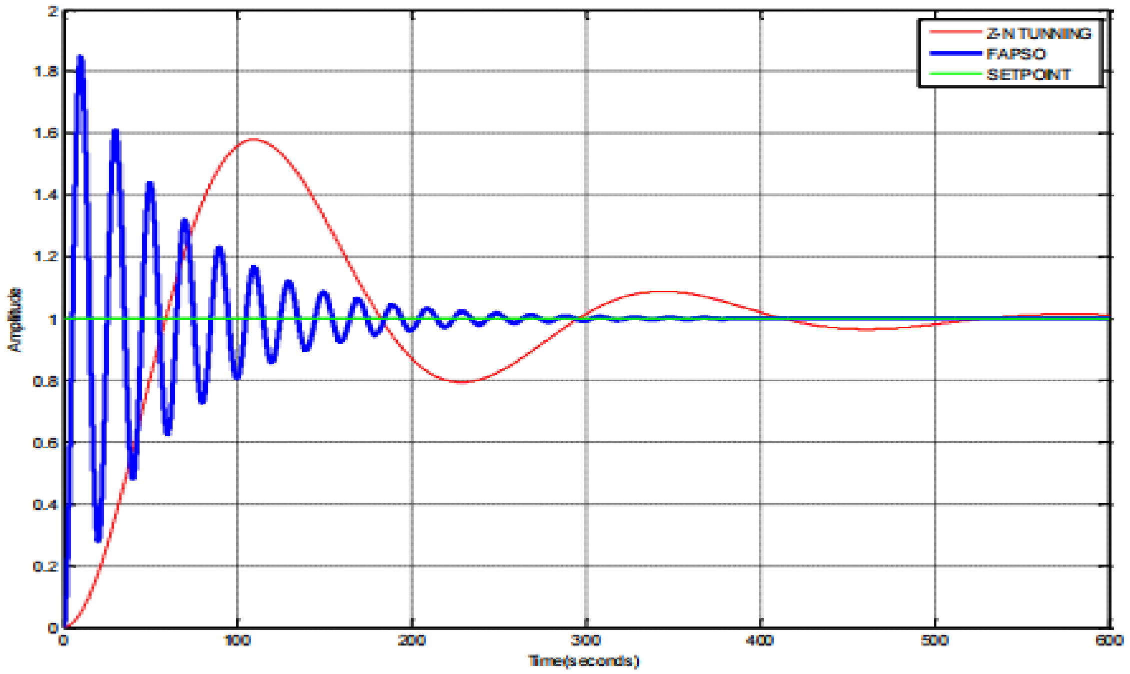

Figure 5.4. Step Response of Spherical interacting system for Region IV

CONCLUSION

The FAPSO algorithm based PID controller has been designed, developed and put into effect on spherical interacting system .The performance indices such as IAE, ITAE and time domain specification such as rising time and settling time has been obtained using FAPSO algorithm for the four levels of spherical interacting system. These parameters are compared with the results of ZN tuning and then it is inferred that FAPSO provided better results with lesser error value.

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