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SYNTHESIS OF PLANAR MECHANISMS SIMULTANEOUSLY FOR BOTH TYPE AND DIMENSIONALITY USING EVOLUTIONARY SEARCH AND CONVERTIBLE AGENTS

By

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ABSTRACT

SYNTHESIS OF PLANAR MECHANISMS SIMULTANEOUSLY FOR BOTH TYPE AND DIMENSIONALITY USING EVOLUTIONARY SEARCH AND CONVERTIBLE AGENTS

By

John C. Oliva

In the field of mechanical engineering, synthesizing a mechanism to perform an intended task is deceptively complex. In this dissertation, a novel approach to automated mechanism synthesis is described which uses an evolutionary search algorithm and a technique called "convertible agents" to simultaneously find the most appropriate mechanism type for a given problem, while finding an optimum set of dimensions for that mechanism to realize a specified behavior. The convertible agent technique has been developed in response to the unique design challenges encountered when synthesizing a mechanism for both type and dimensionality. Several case studies are presented which demonstrate the approach's effectiveness over earlier solution strategies. In these studies, six different planar single-degree-of-freedom mechanism types are considered: a four-bar mechanism, Stephenson's six-bar-mechanisms (types I, II, and III), and Watt's six-bar-mechanisms (types I and II). The method is readily scalable to account for any number of different mechanism types and complexities. The developed convertible agent approach is well suited for evolutionary design applications outside of mechanism synthesis in which there are a small number of distinct topological design possibilities each with parametric variables to be optimized.

DEDICATION

This dissertation is dedicated to my wife Lisa. Without her constant support and encouragement, this work would have never been completed.

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I would like to thank Dr. Erik Goodman for his willingness to accommodate my non-traditional degree trajectory throughout my tenure at Michigan State University. When I was originally seeking a research advisor, he was unfeigned by the prospect of working with a PhD candidate that intended to have a full-time job outside of the university.

During my time at Michigan State University, I have held two professional positions that allowed me both the flexibility and the financial support to pursue my degree while gaining valuable career experience. This opportunity came first at Grand Valley State University's School of Engineering under the direction of Paul Plotkowski and Jeff Ray (now with Southern Polytechnic University). Later, a similar opportunity was provided by the National Superconducting Cyclotron Laboratory thanks to the consideration of Thomas Glasmacher and Don Lawton.

I would like to thank all of the students that I had the privilege of teaching at both Kettering University and Grand Valley State University. It was those students that made me fall in love with engineering education and inspired me to pursue my doctoral degree.

Finally, I would like to thank my parents, John and Eleanor, my sister Jenni, and my Aunt Toni for their guidance and support throughout my education. The initial direction that they provided from my early childhood set my course for this achievement.

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1.0 Introduction - A Historical Perspective

To appreciate the concept of evolutionary mechanism synthesis, one must first understand the evolution of machine design itself. The story of man's most recent evolutionary steps cannot be separated from the evolution of his basic understanding of the physical world around him.

Not long after man first discovered the wheel, he attached some form of pivoting axle to this wheel and the first mechanism had been invented [1]. Archeologists and historians believe that the proverbial invention of the wheel happened very early in modern man's history, dating to around 3500 to 3000 B.C. By some definitions, it was an invention of this sort that first distinguished man from the primate world [2]. Harnessing the potential of what had been discovered was something entirely different, though. It took thousands of years for man to truly realize the potential of the mechanical curiosities he had stumbled upon. Although the existence of mechanisms dates back to antiquity, the formal study of their behavior and design is a rather recent practice.

For millennia after the invention of the wheel, most mechanical innovations continued to be based on the wheel. The earliest chapters of recorded history note widespread use of early wheeled machines like water wheels and potter's wheels. Beyond that, though, there was not much interest in machines and mechanisms. During the time periods of the Greek and Roman Empires, many mechanical contrivances were intended more as amusements and curiosities rather than as means of doing productive work [2]. The one enduring exception was in the tools of warfare.

An early field of machine design that did captivate the interest of primitive machine designers was the search for the design of a perpetual motion machine. Given modern perspectives, the very notion of a machine that could run forever without any outside sources of power or motion seems absurd. But dating back to the fifth century and continuing forward to the great minds of the likes of Leonardo da Vinci (1452-1519), man sought this elusive self-propelled machinery [1]. Of course, none of these experimenters were ever successful in their efforts, and as a result, much of their time that could have advanced the study of machines ended up being less productive.

Although the true scientific philosophers of early time periods did not want to be bothered by the practical applications of science to the physical world, some advances were still made. Early machines and mechanisms were often created by untrained inventors who sought to alleviate the burdens of their everyday manual labor. These early machines were typically powered by natural means, making use of windmills, animal power, or perhaps water wheels located in nearby rivers [2]. It was not until the industrial revolution of the nineteenth century that mechanisms as we know them today first emerged and flourished. Two forces came together during this time period to open the door to a resurgence of interest in all things mechanical. First, this time period saw the initial widespread use of sources of rotational motion such as steam engines, internal combustion engines, and eventually the electric motor, that were so critical for reliably powering mechanisms. Furthermore, the increasing mechanization of many agricultural, manufacturing, and other previously laborintensive processes made the study of mechanisms essential. Coupled with these societal trends was the then budding profession of engineering, setting the ground to establish the nineteenth and twentieth centuries as the glory days of mechanisms. Many historians have even gone so far as to label the last 250 years of our civilization as "The Machine Age" [3].

Early investigations into the behavior of mechanisms approached the topic from an analysis point of view. Engineers of the day studied existing machines with the intent of being able to quantify their performance. This built upon the scientific foundations laid before them by Galileo, Newton, and Lagrange to be able to calculate the trajectories, velocities, and accelerations of machine components they witnessed in operation before them.

The problem remained, though, not only to study an existing machine, but also to be able to design a mechanism to perform an intended task without having to employ the time-consuming method of trial and error so often used to arrive at the earliest machine configurations. This process of mechanism synthesis was a deceptively complex task that has continued to elude designers through to modern times.

Throughout the last one hundred years, a plethora of schemes has been proposed and implemented to synthesize a mechanism to perform an intended task. Techniques have ranged from exhausting cataloging efforts whereby it was intended to record all possible linkage configurations [4], to intricate graphical procedures that could be followed to design a machine to meet certain input parameters [5]. As engineering evolved into the applied scientific field it is today, analytical mathematical methods emerged [6]. Mechanism synthesis techniques have continued to receive attention even into the computer age. Countless computerized engineering optimization schemes have been adapted to solve the mechanism synthesis problem.

Although such attention has been paid to mechanism synthesis throughout the years, there still exists tremendous potential for improvement of the synthesis tools available to modern practicing engineers. Many commercial software packages are available to today's engineer for the purposes of analyzing mechanisms. But, just as their counterparts one hundred years earlier, engineers are often "left to their own devices" when faced with the task of synthesizing a mechanism. At present time, there are few commercially available mechanism synthesis programs, and those that do exist have seen rather limited usage. One might cite different reasons for these observations, such as the lack of versatility of these programs, or a missing user friendliness that professional engineers have come to expect. Others have even gone so far as to say that using a computer program to arrive at a design is counterintuitive to an engineer's normal mode of operation [7]. Whatever the reasons may be, the field of mechanism synthesis continues to be one that could benefit from the development of better synthesis tools that could effectively design a mechanism like those that have captivated man's curiosity from the dawn of time.

2.0 Mechanism Synthesis Overview

From a mechanical engineering point of view, the term "mechanism" refers to a collection of mechanical components that are connected to each other via some type of mechanical joints. The term "linkage" is often used interchangeably with "mechanism". By driving such a mechanism with a motor, engine, or hydraulics, the mechanism is used to perform useful work. Although in reality any value of load acting on a mechanism will cause the individual links to deform from their unloaded shape, when designing and analyzing a mechanism, these structures are typically considered to be completely rigid. With the rigid body assumption, much of mechanism analysis becomes a practice in applied geometry. The study of the changing geometry of a mechanism as it passes through its operational configurations is termed "kinematics".

Mechanisms can be classified in several ways. If all elements that make up a mechanism and all of its resulting movements are confined to a single plane of motion, then the mechanism is considered a "planar" mechanism. Any motions that take the links of a mechanism into a third dimension of action render it a "spatial" mechanism. A mechanism can also be classified by the number of links that it consists of. The simplest possible configuration is a four-bar mechanism. Note that it is customary to consider in this count the stationary ground link that all of the moving links are attached to. Thus, to look at a four-bar mechanism, one may observe that it has only three moving parts, but the fourth bar is the immovable base or structure that the other three links are mounted to. A schematic view of a generic four-bar mechanism configuration is shown here as Figure 1. More complex mechanisms can be devised then by simply adding to the link count, totaling five, six, or even more members within the mechanism. With each additional component added to the linkage, it becomes more complex to design and control, but the resulting motions can become that much more complex as well.

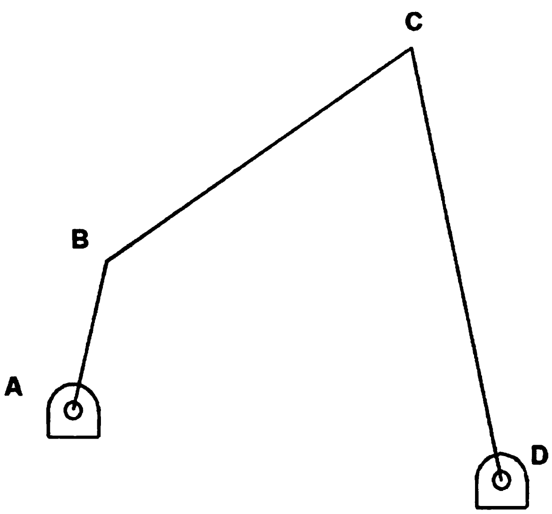

Figure 1. Typical Four-Bar Mechanism Configuration.

Designing a mechanism to meet a particular set of design constraints involves two distinct activities. The first is the mechanism synthesis component of the process. Mechanism synthesis involves the specification of the geometry of the mechanism. Determining what type of mechanism to use (planar, spatial, five-bar, etc.), what type of joints to use, the size of the links, and the arrangement of the pivot points are all parameters defined during the mechanism synthesis stage of the design process. Once a candidate design has been synthesized, then the designer moves on to the analysis stage whereby the techniques of kinematics are applied to quantify such critical design characteristics as the velocities and accelerations of points of interest on the machine, and simply the trajectories of the various points on the mechanism as it passes through its range of motion.

The goals of mechanism design will of course vary depending on the intended end use of the machine. Most authors, though, cite three distinct classifications of mechanism synthesis. The first is path generation, where the goal is to have a point on the machine follow some specified trajectory. In the second, motion generation, the position and orientation of one of the actual member links is to be specified. The third classification, function generation, is where the mechanism is thought of as a conversion device, such that, for example, the input force or angular movement is converted to a different output force or movement [8].

Of the two tasks within mechanism design, the more complex portion is the synthesis stage. As mentioned earlier, many tools are available to the engineer when analyzing an existing mechanism. The geometric model of the machine will provide "exact" determinations of the mechanism's kinematic properties. Commercially available software packages are also in wide use to aid in this activity, regardless of how complex a given linkage may become.

Synthesizing a mechanism to meet intended specifications is a far more complex activity. For synthesis, the mechanism designer is left without a well-defined algorithm. Although many methods of mechanism synthesis have been proposed throughout the years, most offer only approximate results to varying degrees of accuracy. Many of these techniques are tedious and laborious, sometimes resulting in very poor designs. When this occurs, the entire process must be repeated either with different inputs throughout the process, or using an entirely different technique.

Some of the earliest methods of mechanism synthesis were graphical in nature. These techniques rely on drafting tools to physically sketch out the synthesized mechanism through a series of geometric construction operations. Graphical methods are readily available for three- and four-precision-point requirements, where a point on the resulting mechanism will pass through the specified number of points [6]. Although initially developed for hand-drawn constructions, these techniques are now equally adaptable to computer-aided design (CAD) tools. Variations on these same techniques exist for both motion and function generation objectives. Analytical methods are also options for these same purposes. Some of the purely math-based tools are directly based on their graphical counterparts whereas others were developed independently. Chebyshev's, Bloch's, and Freudenstein's methods are all examples of analytical mechanism synthesis schemes [5, 6].

Another method of mechanism synthesis attempted in the mid-twentieth century was the development of coupler curve atlases. The concept here was that if an exhaustive collection of mechanisms' behaviors could be cataloged, then it would be a simple matter for the mechanism designer to flip through the pages of such an atlas and find a mechanism that met the constraints specified. The most enduring of these efforts is Hrones and Nelson's 1951 *Analysis of the Four Bar Linkage* in which some seven thousand linkages were documented [4].

The computer age ushered in a resurgence of interest in mechanism synthesis research. Problems previously too complicated or with a vast number of constraints were now within reach using computational methods. It seems that practically every computer-based optimization algorithm has been applied to the mechanism synthesis problem. Traditional gradient-based methods, pattern matching, neural networks, and goal programming, are just a sampling of the computer tools that have been used in the attempt to be able to find the perfect linkage for a given problem [9, 10, 11, 12].

3.0 Evolutionary Computing Overview

Within the last couple of decades, another wave of interest has hit the mechanism synthesis community with the introduction of evolutionary computing techniques. Evolutionary computing is a field of computer science that uses various models of natural biological evolution as optimization strategies. This class of techniques first emerged in the late 1950's [13]. But, as with preceding advances in other disciplines, it would take many years for the new strategies to be applied to mechanism synthesis.

The most basic form of evolutionary computing, as first proposed by John Holland, is a genetic algorithm (GA) [13]. The GA framework is a generalized model for adaptive systems that has found applications in fields as diverse as engineering, business, social science, and ironically, biological modeling. As the GA optimization strategy strives to mimic biological evolution, the terminology between the two paradigms also shares a lot of similarities. The fundamental technique and the pertinent terminology will be illustrated here using a simple mechanism application. Consider again the basic four-bar mechanism that appears as Figure 1. The physical mechanism can be represented genetically as a chromosome of genes. Programmatically, this may be an array of real numbers. Here, the mechanism can be represented using a chromosome of seven genes; two corresponding to each of the mechanism's two pivot point locations in X and Y Cartesian coordinates, and a length dimension for each link of the mechanism. This chromosome is shown as Figure 2.

Pivot A, X-Coordinate
Pivot A, Y-Coordinate
Pivot D, X-Coordinate
Pivot D, Y-Coordinate
Link Length AB
Link Length BC
Link Length CD

Figure 2. Example Mechanism Chromosome.

At the beginning of the evolutionary process, an initial population of candidates is generated. A common initialization technique is to have the value of each gene randomly generated by the evolution algorithm. (Ranges of acceptable values for these parameters would be specified while defining the problem so that only meaningful candidates are created.) The next step is to evaluate the fitness of each member of the population. For the mechanism in Figure 1, its fitness may be measured by how well its motion matches an intended motion. The techniques used to evaluate mechanism fitness for this work will be detailed in section 4.2.

Three characteristic elements of a genetic algorithm are selection, crossover, and mutation. Selection is the process by which two members of the population are chosen to act as parents to generate offspring members for the next generation. A multitude of different approaches exists for making this selection, but most are probabilistic, giving those members with greater fitnesses a greater chance of being selected to act as a parent. This is in accordance with the often-cited Darwinian theory of "survival of the fittest".

Once two candidates are selected as parents, crossover is the process through which the genetic definitions of the two parents are recombined such that the resulting offspring design contains some genetic resemblance to each parent. Again, any number of crossover methods may be used, but the most basic is that termed "one-point crossover" in which a random point is chosen along the chromosome. The offspring inherits the genes from one parent up to that point, and then crosses over to the other parent's chromosome for the remainder of its genetic definition [14]. Thus, in the four-bar mechanism example here, an offspring design may inherit its pivot point data from one parent, and then its link length definitions from the other parent. The selection and crossover processes then continue until an entire new population of designs has been generated.

Finally, in order to preserve genetic diversity, a small chance of mutation is also introduced into the algorithm. As with selection and crossover, myriad different mutation techniques have been suggested in the evolutionary computing literature. But, the basic premise is that each gene of every design in the population is given a small probability that it will be mutated. If the gene is selected to be mutated, then it may be multiplied by a random multiplication factor such that it experiences an increase or decrease in its original value [14].

With the newly defined offspring population defined, one may proceed to the next generation in different manners. One technique is to blindly use the new population, completely replacing the previous generation. Another method is to compare each offspring to one of its parents, and the individual with the greatest fitness is carried forward to the next generation. "Elitism" is the strategy whereby the best individual in the current generation is carried forth into the next generation unchanged so as not to risk taking a step backwards in evolutionary progress [14].

During the last ten to fifteen years, many researchers have applied some variant of a genetic algorithm to the mechanism synthesis problem. Similar to previous introductions of new technology to the discipline, the mechanisms synthesized with GA's were taken back to their simplest forms for early studies, and then slowly more complex mechanisms and objectives were strived for [15, 16, 17, 18, 19, 20, 21].

Thus far, several references have been made in regard to making the mechanism synthesis task more challenging. This can be done in several different ways such as by expanding the search to include more complex mechanisms like six- or eight-bar linkages, or accommodating mechanisms with non-planar behavior. However, another increase in difficulty comes with synthesizing both the type and dimensionality of the mechanism *simultaneously*. The GA mechanism synthesis studies already mentioned have all focused only on optimizing the dimensionality of a mechanism for a given task; the type of mechanism was chosen *a priori* [15, 16, 17, 18, 19, 20, 21]. In recent years, Liu has enhanced this effort and documented several studies demonstrating the simultaneous type and dimensional synthesis of planar mechanisms using GA's [22, 23].

In all of these cases, the researchers have used a fairly standard GA. Although Holland originally conceived of GA's as being defined with strictly binary data [13], and these mechanism studies have used real number representations, beyond that, the mechanism synthesis studies using GA's to date have not gone far beyond Holland's original framework. The research presented in this dissertation expands upon (although completely independently) the direction that Liu was taking in simultaneously synthesizing both the type and dimensionality of planar mechanisms, primarily by employing a more sophisticated evolutionary computing architecture and advanced optimization methods to obtain far greater efficiency in the synthesis process.

3.1 Parallel Genetic Algorithms

The term "parallel genetic algorithm" (PGA) can take on different meanings based on context. One interpretation can be in terms of how the GA is functionally implemented when being executed. As described in the preceding section, once an entire population of candidate designs has been defined, the fitness of each member of the population must be evaluated. In many instances, the computing time devoted to function evaluations far outweighs that consumed by the overhead of the GA itself. One method of speeding computation time is to run the function evaluations in parallel either on multiple processors, or physically on different computers [14].

Another form of PGA is one in which the evolution itself is carried out in a parallel fashion, which may or may not be on different processors. This methodology is inspired by Darwin's observations on the Galapagos Islands.

Because the islands are geographically isolated, many endemic species were able to evolve independent of evolution taking place in other parts of the world. It is thought that some of these species may have not survived had they been competing for the same resources as more powerful species on other continents. From an optimization point of view then, the concept is to have multiple separate populations ("islands") of designs evolving independently so that a very strong-performing design found early in a run in one population does not immediately overpower the entire computation domain, which may still find other fruitful designs, albeit in a slower manner. This method enables a GA to overcome the tendency to prematurely converge to locally optimal rather than globally optimal solutions. The islands may also be allowed to pass good designs to each other ("migration") on a periodic basis [14].

Lin et al. expanded upon this type of parallel genetic algorithm with their model that they termed an "Injection Island Genetic Algorithm (iiGA)". In this approach, the optimization scheme utilizes multiple parallel populations of candidate designs as just described. The added search efficiency comes from the fact that each island can be searching using a different representation of the problem. For example, suppose that the optimization problem at hand involves the structural optimization of a mechanical component. As each design is generated, it may be analyzed using a finite element model which is then solved, and the resulting calculated mechanical strength is then used to determine its fitness. Using an iiGA, one population of designs could be using a rather coarse mesh of elements to represent the geometry, while a second island of designs uses a much finer mesh. The coarse population will be able to evaluate designs faster but with less accuracy than the refined mesh representation. The iiGA thus exploits the speed of the coarse mesh models by using that population to quickly explore the design domain. As that population finds designs that perform well, it periodically passes that design information to the population running in parallel which then refines those designs and further optimizes the geometry with a narrower search space and its finer mesh of elements. One can see how this model could be used to encompass any number of islands searching at varying resolutions of a problem to quickly hone in on optimal solutions [24].

3.2 Multi-Agent Optimization Tool

Many researchers have developed parallel evolutionary search algorithms allowing search within multiple populations and occasional interchange of solutions among them. Because the emphasis of the mechanism synthesis research presented here was not on the particular evolutionary operators to be used, but rather on the organization of the search agents and of the simultaneous search of the mechanism topology and dimensionality spaces, it was decided to use an available commercial software tool rather than writing another such search package. Red Cedar Technology offers a commercially available general purpose optimization software called HEEDS (for Hierarchical Evolutionary Engineering Design System). This software is the backbone of the mechanism synthesis described herein. The user provides the function evaluation portion of the design analysis while HEEDS takes care of the core evolutionary optimization. Furthermore, a user defines how each design will be represented as it is passed between HEEDS and the function evaluation program, as well as how the fitness of each design will be reported back to HEEDS. HEEDS provides the user with a range of optimization strategies from traditional optimization schemes like quadratic programming to evolutionary-based methods like genetic algorithms. HEEDS also offers Red Cedar Technology's own proprietary search method, termed "SHERPA". This technique uses a combination of different search algorithms and has demonstrated its effectiveness on several parametric optimization problems [25]. All of the mechanism synthesis studies presented later in this paper employed the SHERPA search strategy within HEEDS.

Similar to the iiGA model, HEEDS allows the user to define multiple search "agents" to perform an optimization task. These agents are analogous to the parallel islands in the iiGA model. Likewise, as in the iiGA approach, HEEDS then provides the option of "linking" the defined agents together so that they can share design information on a periodic basis during the optimization run. Just as with an iiGA, the agents can use different representations of the problem definition, and the user merely needs to define how one representation "maps" into the other [25].

4.0 Mechanism Synthesis Using Parallel Search Agents

Parallel evolutionary search agents were used within HEEDS in conjunction with custom-written mechanism evaluation programs to synthesize planar single-degree-of-freedom mechanisms. Six different mechanism types were taken into consideration for a series of different synthesis case studies. The six types included a four-bar mechanism, Stephenson's six-bar-mechanisms (types I, II, and III), and Watt's six-bar-mechanisms (types I and II). These mechanism types will be referred to as "4B", "S1", "S2", "S3", "W1", and "W2", respectively. The six mechanism types are illustrated schematically in Figure 3.

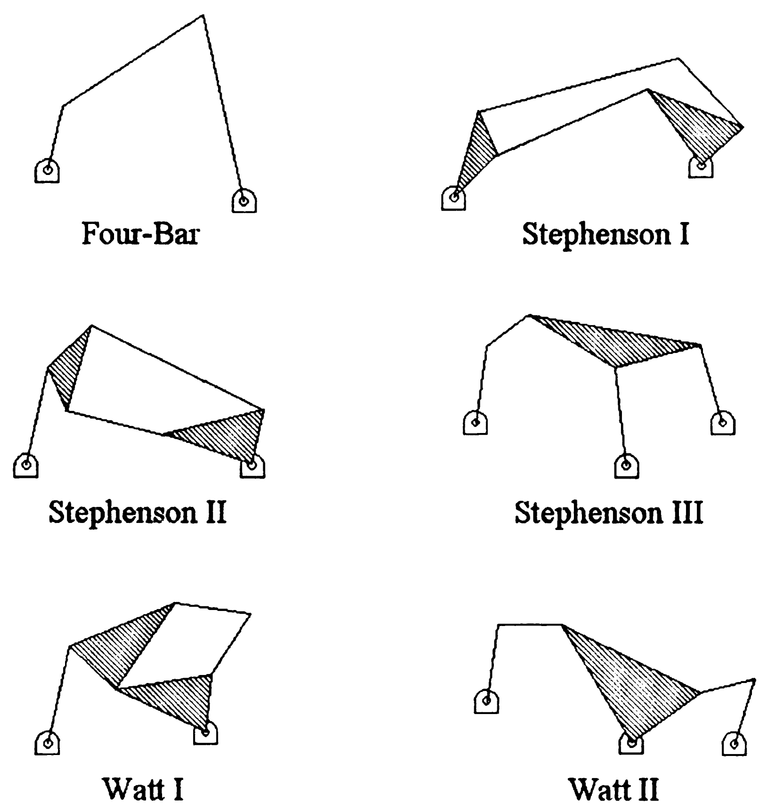

Figure 3. Mechanism Types Considered in This Study.

As will be described, the techniques used here are directly scalable to account for any number of different mechanism types; these six were chosen in this study merely to demonstrate the effectiveness of the techniques.

Three different approaches were used when synthesizing the mechanisms. The first was to establish six independent search agents; one for each mechanism type. This approach was comparable to that taken by many of the earlier researchers who used conventional GA's to synthesize a single type of mechanism as discussed in section 3.1. Although all six types were being evolved simultaneously within HEEDS, the agents themselves had no interaction with each other, so the results would not be any different than if six independent runs were conducted, each searching for a single mechanism type. The six independent search agents are illustrated in Figure 4.

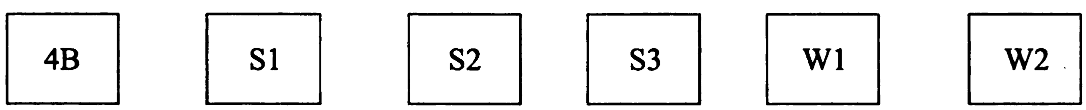

Figure 4. Schematic of Six Independent, Parallel Mechanism Search Agents.

The second evolutionary approach was to take these same six agents, but to link them together so that they could periodically exchange design information regarding the best designs that each had found thus far during the evolutionary process. This linking is shown in Figure 5. Notice that a link is created from every agent to every other agent to enable them to exchange information directly.

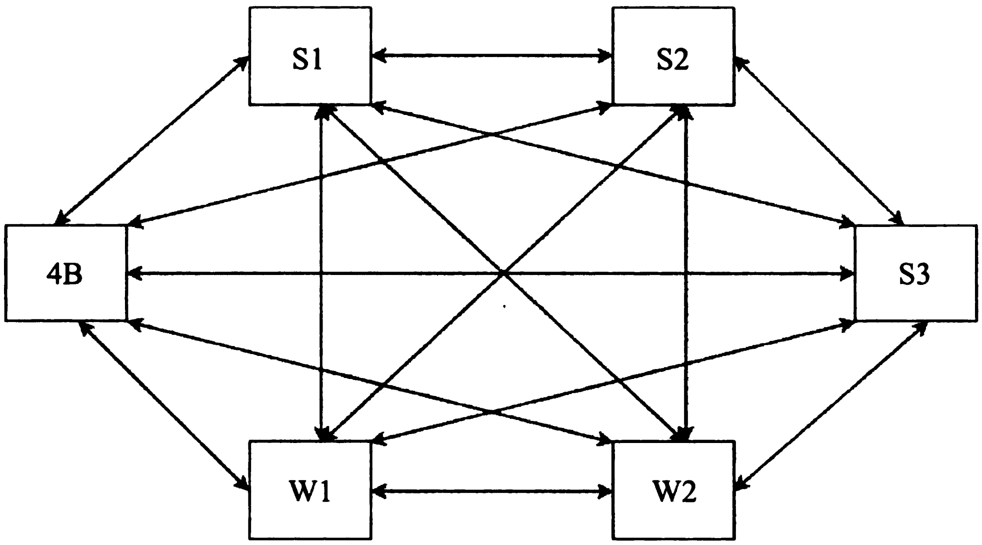

Figure 5. Schematic of Six Linked Mechanism Search Agents.

Later in this dissertation, detailed results from the case studies investigated will be presented to demonstrate the relative effectiveness of the different evolutionary methods discussed here. However, it is instructive to preemptively discuss the results of the first two methods in general terms because those results provide the motivation for the third evolutionary method that was developed.

Three broad observations can be made when examining the mechanism synthesis results obtained when using independent parallel agents and those found using linked agents. First, the independent agents serve as a baseline population with which to compare the subsequent methods. As mentioned, evolving the mechanism types completely independently is essentially a reproduction of the efforts performed by prior researchers using genetic algorithms for their optimization. However, instead of a canonical GA, the more efficient SHERPA search algorithm in HEEDS was used. In the case studies performed in this research, the independent agents always arrived at acceptable solutions, demonstrating the functionality of the fitness evaluation codes developed here.

A second observation comes from the comparison of the results obtained using the independent agents versus those from the linked agents. In general, there was not a change in quality between the two result sets. Thus, the mechanism agents do not appear to gain any meaningful design information when exchanging data with each other. The author speculates that this is analogous to phenomena witnessed in the natural world. For example, two species may share many topological features (as do, for example, dogs and cats), yet the two are not compatible enough to enable reproduction between the species. In the case of mechanisms, referring to Figure 3, it can be seen that S2 and W1 mechanisms share a lot of topological features; they both have two ground pivot points, they both have three binary links, and two ternary links. Yet, the linked agent evolution method results indicate that typically the parameters that yield a good performing S2 mechanism for a particular problem do not translate into a W1 mechanism that performs well on that problem.

Finally, it can be observed that for all of the case studies, and for both of the evolutionary methods, certain design problems tend to converge to the same mechanism type consistently as the optimum solution. That is to say that certain mechanism types emerge that are particularly well suited for specific applications compared to other mechanism types. Conversely, this same mechanism type may be the worst-performing type for a different application. This demonstrates the need to consider a range of possible solutions for any given problem because the top performing type is usually not obvious to the designer.

4.1 Convertible Agents

The synthesis approaches described thus far, although developed independently and contemporaneously with the work by Liu, differ only insofar as the performance of the SHERPA search algorithm differs from the traditional genetic algorithm approach followed by Liu [22, 23]. In light of the observations made in the preceding section, it was desirable to seek a multi-agent architecture that would enable the agents to interact in such a way as to provide a more effective search for the particular problem domain being investigated here. Although developed within HEEDS, the methods developed below could also be used within the framework of a conventional parallel genetic algorithm, and could be reproduced independent of the HEEDS context.

It was clear that for any given problem, particular mechanism types were never arriving at good designs compared to their better performing counterparts because those types were ill-suited for the particular design objective. As a result, the available computing resources were not being used as effectively as they could be, since, inevitably, computing time was being consumed in every run on mechanism types that were destined to be underperforming from the beginning.

The strategy for structuring the evolution that was developed to overcome these shortcomings was termed "convertible agents". In this scenario, the evolution begins just as it did before, with six search agents running in parallel, each looking for a specific type of mechanism to meet the common design objectives. After a subset of evaluations has taken place, however, the best results that each agent has found are compared. At this point, the agent that has found the worst-performing mechanism to date is converted to become another agent searching for the type of mechanism that has thus far found the best performing mechanism type. This agent conversion event is illustrated below as Figure 6. Even though all of the agents are always linked together in this strategy, this figure emphasizes the added power that comes with the linking of like agents in the search.

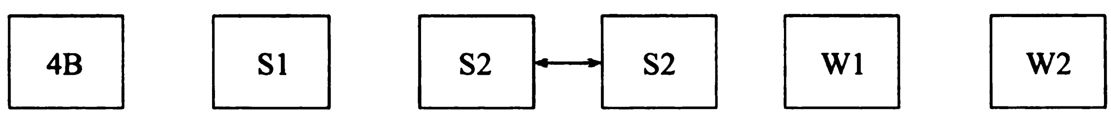

Figure 6. Illustration of an S3 Agent Having Been Converted to an S2 Agent.

Thus, the computing resources that were being invested in a mechanism that would likely be underperforming for the entire optimization run have now been reallocated to searching the design space that has proven thus far to be the most promising. Furthermore, throughout this process, all of the agents are linked together and are intermittently exchanging design information with each other. As noted earlier, dissimilar agents do not gain much from this exchange; however, when two agents of the same type are linked, they progress with their search faster than either agent can do alone.

This process of “converting” search agents continues as the search progresses. Thus, after another subset of evaluations has been performed, the new worst-performing mechanism agent is converted to be an agent of the type that has performed the best. Eventually, as more agents of the same type emerge, the linking of the like agents becomes more like that shown in Figure 5, so that there are a number of agents all seeking mechanisms of the same type that are all exchanging design information with each other.

HEEDS does not provide a means of changing the objective function of an agent after an optimization run has begun. Therefore, the convertible agent concept was implemented by the author by developing a program that runs in parallel to the HEEDS internal optimization algorithm. This program essentially monitors the progress of the evolution as it is happening. The monitoring program maintains a list of which mechanism type each of the six agents is currently evolving. Then, the mechanism evaluation code in any agent evaluates each candidate design as any of the six mechanism types based on the type definition it receives from the monitoring program. The monitoring program is added to the HEEDS project as an additional analysis definition, just as the analyses for the six mechanism agents are defined. However, the monitoring program does not have any inputs or outputs defined within HEEDS. So, HEEDS runs the monitoring program during every evolutionary cycle sequentially after each of the mechanism agents, but all of its activities are hidden from the HEEDS point of view.

The convertible agent approach has some similarities to a model proposed recently by Gustafson that he has called "The Speciating Island Model" [26]. In this work, as a new topology is discovered through an evolutionary approach, its species is allowed to evolve independently so as not to be overpowered by better performing species that have already been developed. Similar to what has been witnessed in the mechanism analysis described herein, the species are kept independent because they do not in general produce meaningful results via reproduction with other species. The key difference between the convertible agent concept and that of the speciating island model is knowledge of the species possibilities. For the mechanism synthesis problem, the number of possible topologies is known *a priori*; there are only a distinct number of combinations of links that create a single-degree-of-freedom mechanism. This is in contrast to the speciating island model which is in effect being used to discover possible species. In this respect, the two models contrast sharply.

The case studies described later in this paper show that for mechanism synthesis problems that tended to arrive consistently at a particular mechanism type using independent search agents, the convertible agent approach not only tends to converge to this same type, but also for the same amount of computing resources, a substantially better solution is found. Similarly, for problems that had more than one of the six mechanism types that consistently performed well, the convertible agents converge to those solutions proportionately as well.

It is instructive to compare the amount of search performed with the convertible agent approach on each of the six topologies. For illustration, let us assume one of the cases studied in which one of the topologies consistently outperformed all others. For a run totaling 2,500 evaluations per agent (so 15,000 total evaluations), after each of the six 417-evaluation periods, an additional agent would be converted to evaluating that topology, so the total number of 417-evaluation periods spent on that topology is the sixth Fibonacci number, 21. That equates to 8,757 evaluations in the agent using the best topology (21 x 417). Let us contrast that with the effort it would take to do that number of evaluations on each of the six topologies, which is 6 x 8,757 or 52,542. The savings in computational effort over that scenario is 37,542; the convertible agent approach uses less than a third as many total evaluations to find a solution of the same quality. The convertible agent run also benefits from the island-parallel organization further increasing its search effectiveness.

Note also that the proposed convertible agent approach for mechanism synthesis is directly scalable to consider any number of different mechanism types. Six agents were used in this study to demonstrate the effectiveness of the technique; however, one could envision how other agents seeking mechanisms of different topologies could easily be added to the model. Any number of possibilities, including non-revolute pin joints, more rigid links, or non-planar behavior, could be included with the specification of additional agents and their associated evaluation tools.

4.2 Mechanism Evaluation

A subtle element that makes the convertible agent technique possible is the way that the mechanisms themselves are represented. A novel approach has been taken whereby every mechanism type uses an identical chromosome. Even though the different mechanisms have different numbers of defining geometric parameters, a chromosome of eighteen genes was chosen such that it can accommodate all six types, and certain genes go unused depending on the specific mechanism being represented. Furthermore, the convertible agent monitoring program maintains a list of what mechanism type each agent is evolving. Then, a single mechanism evaluation code is used that can evaluate the chromosome as any of the six mechanism types based on the type definition it receives from the monitoring program. A schematic of the convertible mechanism representation is depicted as Figure 7. Notice that the eighteen possible design parameters included in this chromosome are all simple geometric dimensions of the mechanisms.

Pivot 1, X-Coordinate
Pivot 1, Y-Coordinate
Pivot 2, X-Coordinate
Pivot 2, Y-Coordinate
Pivot 3, X-Coordinate
Pivot 3, Y-Coordinate
Link Length 1
Link Length 2
Link Length 3
Link Length 4
Link Length 5
Link Length 6
Link Length 7
Link Length 8
Link Length 9
Link Length 10
Link Length 11
Angle of Target Link

Figure 7. Mechanism Chromosome for Convertible Agents.

Regardless of the specific evolution method implemented, all of the techniques described rely on an evaluation of each design's fitness for guidance. Any one of the commercially available, general purpose kinematic solvers could be implemented to perform the fitness calculation. However, in this study, since only relatively simple, planar, single-degree–of-freedom mechanisms are considered, a custom program was written to process just the mechanism types considered, for speed and simplicity. In general, the algorithm cycles a mechanism's input link through its full range of motion, and calculates the distance from the target link on the mechanism to each of the individual targets at each step of the motion. Although the different mechanism types have defining geometric characteristics that make them each unique, the fitness calculation for the six types follows the same basic approach. For the sake of illustration, a general Watt I mechanism will be used to demonstrate this fitness evaluation.

Appendix A contains illustrations that map the generalized variables listed in Figure 7 to the actual geometric interpretation of those variables for each mechanism type. Consider the W1 mechanism depicted in Figure 8. As shown in the appendix, the genetic information maps to this mechanism type as shown via equations 1 through 16.

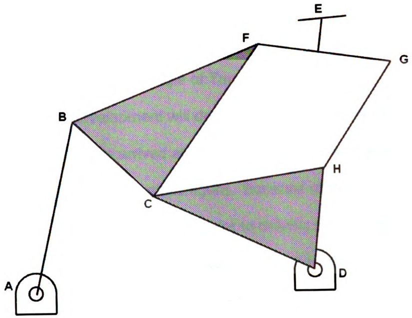

Figure 8. Representative Watt I Mechanism.

Ax = Pivot 1, X-Coordinate (1)

Ay = Pivot 1, Y-Coordinate (2)

Dx = Pivot 2, X-Coordinate (3)

Dy = Pivot 2, Y-Coordinate (4)

AB = Link Length 1 (5)

BC = Link Length 2 (6)

BF = Link Length 3 (7)

CF = Link Length 4 (8)

CD = Link Length 5 (9)

CH = Link Length 6 (10)

DH = Link Length 7 (11)

FG = Link Length 8 (12)

GH = Link Length 9 (13)

Ex = Link Length 10 (14)

Ey = Link Length 11 (15)

φ = Angle of Target Link (16)

The following development will demonstrate how the mechanism configuration of Figure 8 is arrived at. However, mechanism kinematics are not easily visualized using solely a static figure. Because of this, it is helpful to describe the motion of this mechanism prior to delving into the geometric construction of it. In the figure, link *AB* can rotate a full 360° about the pivot point at *A*. This is the mechanism's input or driven link. Links *BCF*, *CDH*, *EFG*, and *GH* are connected to link *AB* through a series of revolute joints. Hence, as *AB* rotates through its range of motion, *CDH* tends to oscillate back and forth about pivot point *D*, while the other links move accordingly. Recall that this is a single-degree-of-freedom mechanism as are all of the linkages considered in this study. Thus, for any specified input angle of link *AB*, the rest of the mechanism's configuration is uniquely defined. (It should be reemphasized that link *EFG* is taken here as a single rigid body whereas the other points in the illustration are revolute joints.)

When the evaluation code receives the mechanism definition from HEEDS, it can directly plot points *A* and *D*. Furthermore, the evaluation code specifies an angle for the input link. This angle θ, along with the link length *AB* enables the calculation of the coordinates of point *B* via equations 17 and 18.

$$B_x = A_x + AB \cdot \cos(\theta) \quad (17)$$

$$B_y = A_y + AB \cdot \sin(\theta) \quad (18)$$

At this point, the mechanism construction appears as Figure 9.

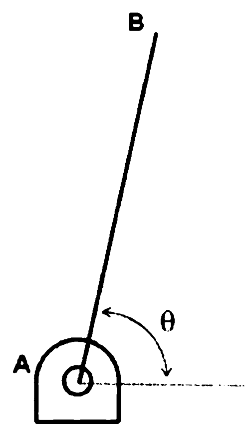

Figure 9. First Step of Mechanism Construction.

Making use of the Law of Cosines, and link lengths *BC*, *CD*, and *BD*, the coordinates of point *C* can be calculated. First, an intermediate step is required to calculate the length of the third side of the triangle that will be used in this operation, in this case *BD*. This is a "virtual length" in the sense that the dimension is actual, but there is no physical mechanism link that corresponds to this direct connection. The geometric constructions developed via equations 19 through 23 are illustrated in Figure 10.

$$BD = \sqrt{(D_x - B_x)^2 + (D_y - B_y)^2} \qquad (19)$$

$$\alpha = \cos^{-1}\left(\frac{BC^2 + BD^2 - CD^2}{2 \cdot BC \cdot BD}\right) \qquad (20)$$

$$\beta = \sin^{-1}\left(\frac{D_y - B_y}{BD}\right) \qquad (21)$$

$$C_x = B_x + BC \cdot \cos(\alpha + \beta) \qquad (22)$$

$$C_y = B_y + BC \cdot \sin(\alpha + \beta) \quad (23)$$

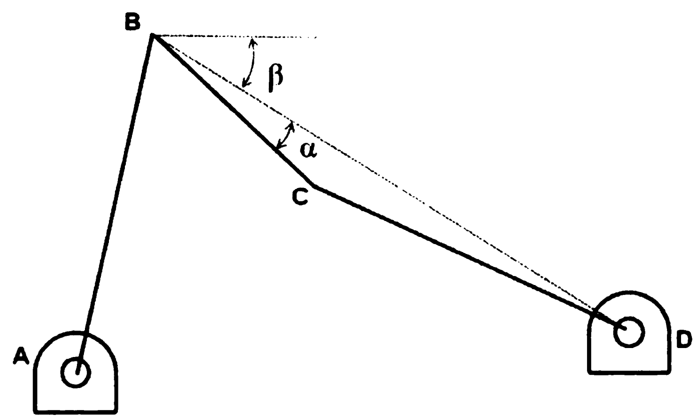

Figure 10. Second Step of Mechanism Construction.

The same approach taken to locate *C* with respect to points *B* and *D* can be utilized to construct the two ternary links of the W1 mechanism as well. Thus, point *F* can be positioned with respect to points *B* and *C*, and point *H* can be located with respect to points *C* and *D*. (Note however that in these cases, because these are ternary links, the intermediate step comparable to calculating the virtual length *BD* is not needed, because all of the link lengths for the ternary links are specified in the mechanism definition.) Once these calculations have been performed, the mechanism construction appears as shown in Figure 11.

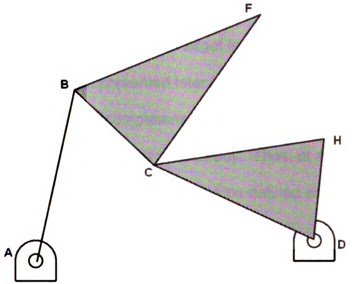

Figure 11. Third Step of Mechanism Construction.

The remaining pivot point of the mechanism, point *G*, can be located with one more iteration of the trigonometric approach taken before, and again calculating a new virtual length, this time length *FH*.

The remainder of the geometric development is rather straightforward. The location of target link *E* is defined via one dimension measured along link *FG*, and a second dimension measured perpendicular to link *FG* (see equations 14 and 15). Finally, the angle φ specifies the angle of the target link with respect to link *FG*. Thus, the complete position of the mechanism has been determined as was shown in Figure 8.

In the motion generation (or "rigid body guidance") mechanism synthesis problems considered in this study, the objective is to have the target link *E* pass through a series of prescribed positions specified to complete a given task [8].

Thus, a pair of X,Y point coordinates is also specified for each target position. The program developed for this study can account for any *N* targets. The length of target link *E* is taken to be equal to the target lengths themselves.

To arrive at the results presented later in this work, a step size of 1° for the input angle θ was used for completeness, although a larger step size could have been used with a negligible loss of accuracy. Thus, at any given angular step θ, the distance *d* from link *E* to target *i* can be defined simply as:

$$d_{i,\theta} = \sqrt{(E_x - i_x)^2 + (E_y - i_y)^2} \quad (24)$$

This is actually done for the points defining each end of the target and target link respectively, and the total distance is taken as the sum of the two. Throughout the range of motion, the distances are monitored, and the minimum distance at which the target link approaches each target is recorded.

$$d_i = \min_{\theta = 0° \rightarrow 359°} (d_{i,\theta}) \quad (25)$$

The mechanism's total objective function then is taken as the sum of these minimum distances for each of the *N* targets.

$$ObjectiveFunction = \sum_{i=1 \rightarrow N} d_i \quad (26)$$

Additional code is included to allow for mechanisms that do not have a full range of motion yet still produce meaningful results, and to eliminate mechanisms that have only very limited ranges of motion by assigning arbitrarily high objective function values.

5.0 Case Studies

To demonstrate the relative effectiveness of the three different evolution methods as applied to mechanism synthesis, a series of case studies was investigated. These case studies were inspired by mechanism synthesis projects carried out by earlier researchers and documented in the engineering literature. It should be emphasized that it was not the intent of this effort to find "better" solutions than those originally presented in each work. Instead, these cases were chosen because they represented real-world design tasks taken from a variety of different fields, and they were all cases that posed some challenges to the original investigators. In all of the cases though, the original work involved design considerations that went beyond the scope of the current research. Thus, only the kinematic motion generating properties of the cases were used as the basis for the studies presented here. In some cases, however, the convertible agent approach does demonstrate its power in the quality of solutions found, and the fact that it proceeds with the push of a button as compared to the often elaborate methods originally employed by the initial investigators.

Certain parameters were the same for all three case studies. In each case, the problem at hand was solved using each of the three different evolution methods: independent agents, linked agents, and convertible agents. Each strategy was performed 25 times to gain confidence in the consistency of the results produced. (Since the evolution process involves a multitude of random numbers, there is always the possibility that very good or very bad results could be found as an anomaly during any particular run.) HEEDS was configured to evolve the mechanisms using 2500 calls to the objective function under the SHERPA method. In the case of the converging agents, the monitoring program was set to convert an agent every 417 iterations (one sixth of 2500) so that at the conclusion of the synthesis, there was the possibility of having all of the agents converge to a single type.

5.1 Hinge Mechanism Case Study

The first case study comes from the field of furniture / cabinet design. A quick glance at any office or home furnishings with doors shows that a lot of effort has gone into the design of the hinges. The objective of the designers is to have a hinge that provides a smooth range of motion while taking up as little space as possible.

Chen presented a formal engineering approach to this design objective whereby a mechanism was synthesized to act as a furniture hinge. The synthesis goal was to arrive at a hinge that would initially have the door move perpendicular to the door opening and then swing wide open to reveal the contents behind the door. Furthermore, it was desired to have hinge components that required as little mounting space as possible, and that would allow them to be surface mounted to both the door and the main support structure [27]. (Many modern hinges require elaborate mounting features to be cut into the cabinet itself to allow proper functionality.)

During the original synthesis process described for the hinge design study, a series of target positions was not explicitly defined as is the approach in the current research method. Thus, a series of five target positions were selected for this study to replicate the motion as described by Chen. Other details such as allowable link lengths, permissible pivot locations, and sizes in general were chosen here to be consistent with Chen's work, although such specifics were not provided in the original publication. The geometry of this design space is shown in Figure 12.

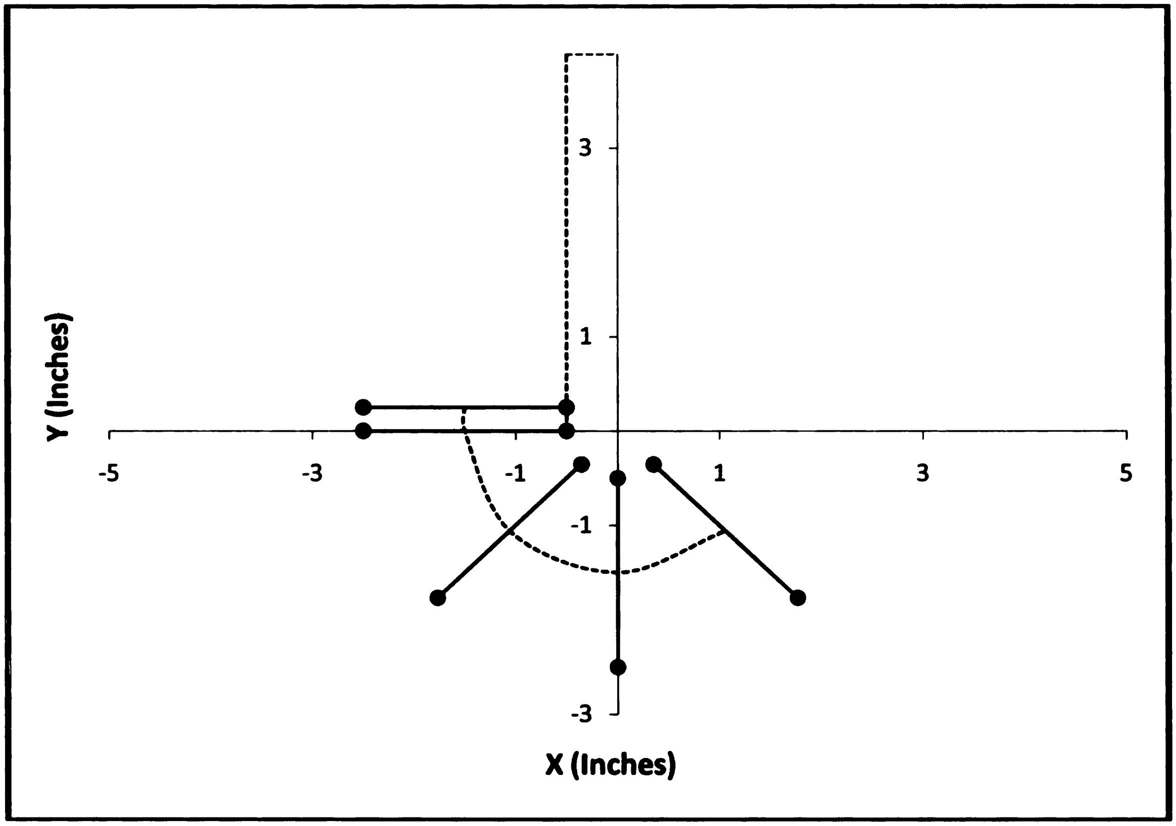

Figure 12. Design Space and Target Locations for Furniture Hinge Mechanism.

In Figure 12, the origin is taken as the contact point between the cabinet door and the cabinet structure. The cabinet would extend up along the +Y axis, and the door would extend back along the -X axis, in its closed position. The five lines plotted in the figure are the five target positions for the hinge through its range of motion. They are connected with a dotted line to indicate the expected path between them. Notice how the two targets closest to the cabinet are exactly parallel with each other, yielding the opening motion as described earlier. Also note that the first target is inset from the door when it is in its closed position. This is to meet the criteria that the hinge can be surface mounted. Finally, the box in the figure extending from the origin to the point (-0.5, 4.0) represents the allowable range that was specified for the location of the fixed ground points.

Appendix B contains a complete reproduction of all of the evolution results found for this first case study. A summary of these results appears here as Table 1. The first three columns show the average objective function results obtained when using independent agents, linked agents, and convertible agents, respectively. The next two columns compare the effectiveness of the three approaches using the independent agents as a baseline for comparison. Notice the sign convention adopted for this comparison. A mechanism that passes through the targets more exactly is indicated by a lower objective function value. However, when comparing the average objective function values in this paper, better results are indicated with a positive percentage comparison. The final column of Table 1 indicates the number of times the convertible agents converged to each mechanism type during the 25 runs.

Table 1. Result Compilation for Furniture Hinge Mechanism Case Study.

Mech. Type	Ind. Agents	Linked Agents	Conv. Agents	Ind. vs. Linked	Ind. vs. Conv.	Conv. Agent Solutions
4B	1.40	1.71	1.21	-22.1%	13.6%	2
S1	2.58	1.66	0.99	35.7%	61.6%	8
S2	1.81	1.81	0.61	0.0%	66.3%	9
S3	2.54	2.10	0.99	17.3%	61.0%	3
W1	3.97	3.03	-	23.7%	-	0
W2	2.35	2.06	1.15	12.3%	51.1%	3

With the presentation of the remaining two case studies, it will be shown that this first case study is the only one investigated for which significant gains in performance were achieved using linked agents over independent agents. As shown in Table 1, four of the mechanism types saw respectable gains, while only the S2 mechanism type remained constant, and the 4B mechanism type was worse. The convertible agents found much better results for all of the mechanism types with the exception of W1. The W1 type performed very poorly as a furniture hinge mechanism using all of the synthesis methods attempted - so poorly, in fact, that the convertible agents never converged to a solution that used the W1 topology, hence its entry for the convertible agents is left blank in Table 1, and it has a zero entry in the right most column.

It is also interesting to note once again that the W1 mechanism type was found to be the worst type for this particular synthesis case by all three evolutionary methods. This is notable because in the original work, Chen concluded that the W1 type was the "most feasible" for the hinge design [27]. However, Chen approached the problem from a different perspective, using the Creative Mechanism Design Method to first select the mechanism type, and then optimizing the dimensions of that type. Chen did take into consideration design aspects that went beyond the kinematic behavior sought here, but those considerations were made *after* the mechanism type had already been chosen. Here, by synthesizing the type and dimensionality of the mechanism simultaneously, a very different conclusion is drawn.

5.2 Walking Leg Mechanism Case Study

The second case study is taken from the robotics literature. Shieh et al. describe an effort in which they synthesized a mechanism to act as a leg for a walking robot. The desired path of the mechanism's foot is to follow a delta-shaped trajectory so that it can climb up stairs [28]. As with the first case study, specific details about the objectives and limits for variables needed in the current synthesis approach were not originally specified, so reasonable values were specified here for the permissible lengths and bounding regions.

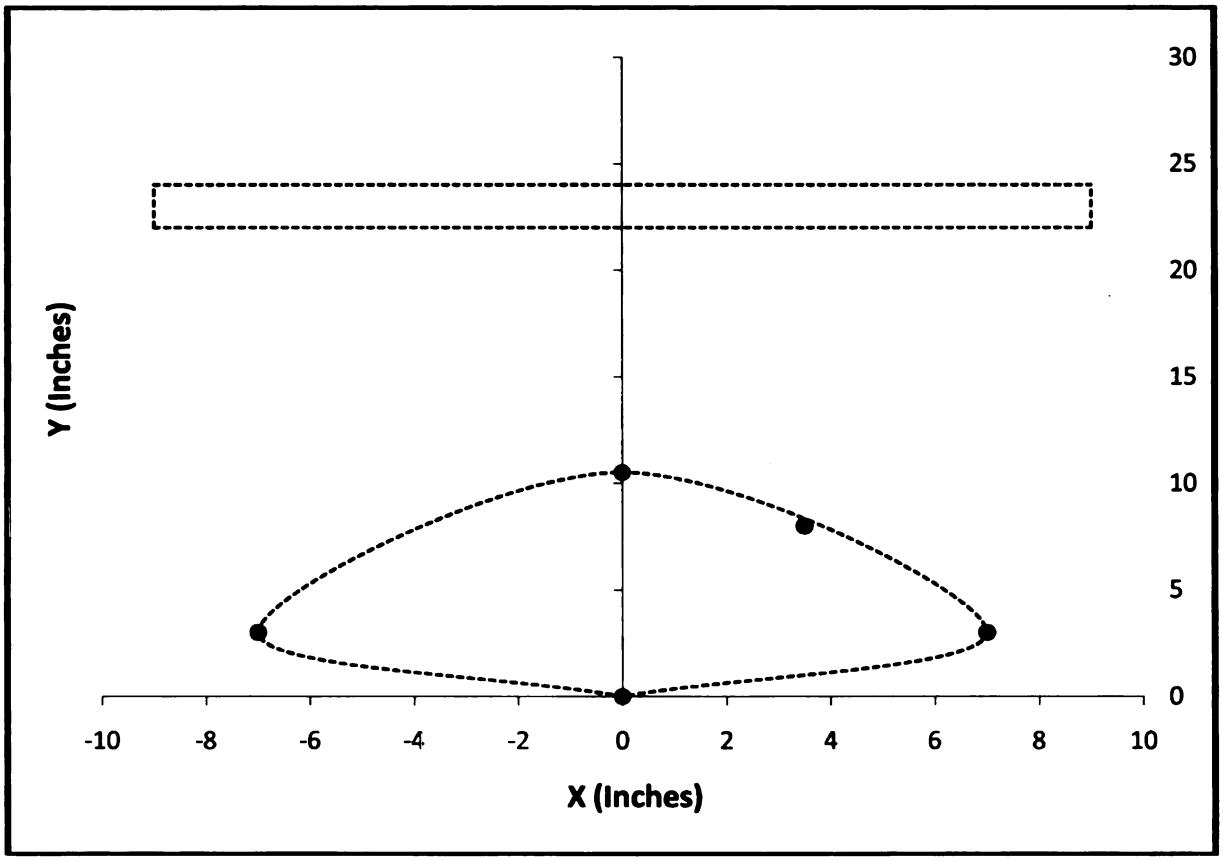

Figure 13. Design Space and Target Locations for Leg Mechanism.

Figure 13 shows the targets selected to trace out the delta-shaped foot path. Notice that in this case, the robot's foot could be effective if it were a sharp point, thus for this work, an arbitrarily short target length was chosen, leaving a series of target positions that appear to be points instead of lines. The dotted box at the top of Figure 13 represents the region within which the mechanism pivots can be located, which would correspond to where the leg would be mounted to the robot. From a kinematic perspective, this complicates the synthesis task by having the mechanism's fixed ground located remotely with respect to the desired path of action.

When synthesized using HEEDS and the three different evolutionary methods, the results shown in Table 2 were found. A complete listing of the raw data for this case study can be found in Appendix C. In this case, only the W1 mechanism type yielded considerable improvements when linked agents were used instead of independent agents. However, once again, the convertible agents produced much better mechanisms than either of the other two evolutionary approaches, given comparable computing resources.

As witnessed in the first case study, the search agents for this particular synthesis study found one mechanism type to be consistently ill-suited for the task. Here it was the S2 mechanism type for which the independent and linked agents found the poorest results, and consequently then, the convertible agents never found a solution of this type.

Table 2. Result Compilation for Leg Mechanism Case Study.

Mech. Type	Ind. Agents	Linked Agents	Conv. Agents	Ind. vs. Linked	Ind. vs. Conv.	Conv. Agent Solutions
4B	8.68	8.41	4.48	3.1%	48.4%	8
S1	11.62	12.06	3.08	-3.8%	73.5%	4
S2	24.09	27.19	-	-12.9%	-	0
S3	8.67	7.89	4.49	9.0%	48.2%	7
W1	11.52	8.94	6.57	22.4%	43.0%	3
W2	12.17	12.44	3.29	-2.2%	73.0%	3

5.3 Challenge Mechanism Case Study

The final case study considered was originally proposed for the sake of acting as a challenging case for mechanism synthesis approaches. Professor Michael McCarthy of the University of California - Irvine challenged software vendors to devise a mechanism synthesis tool that could design a mechanism that would pass through eleven specified targets along an irregularly shaped path [29]. A re-creation of this design space is shown in Figure 14.

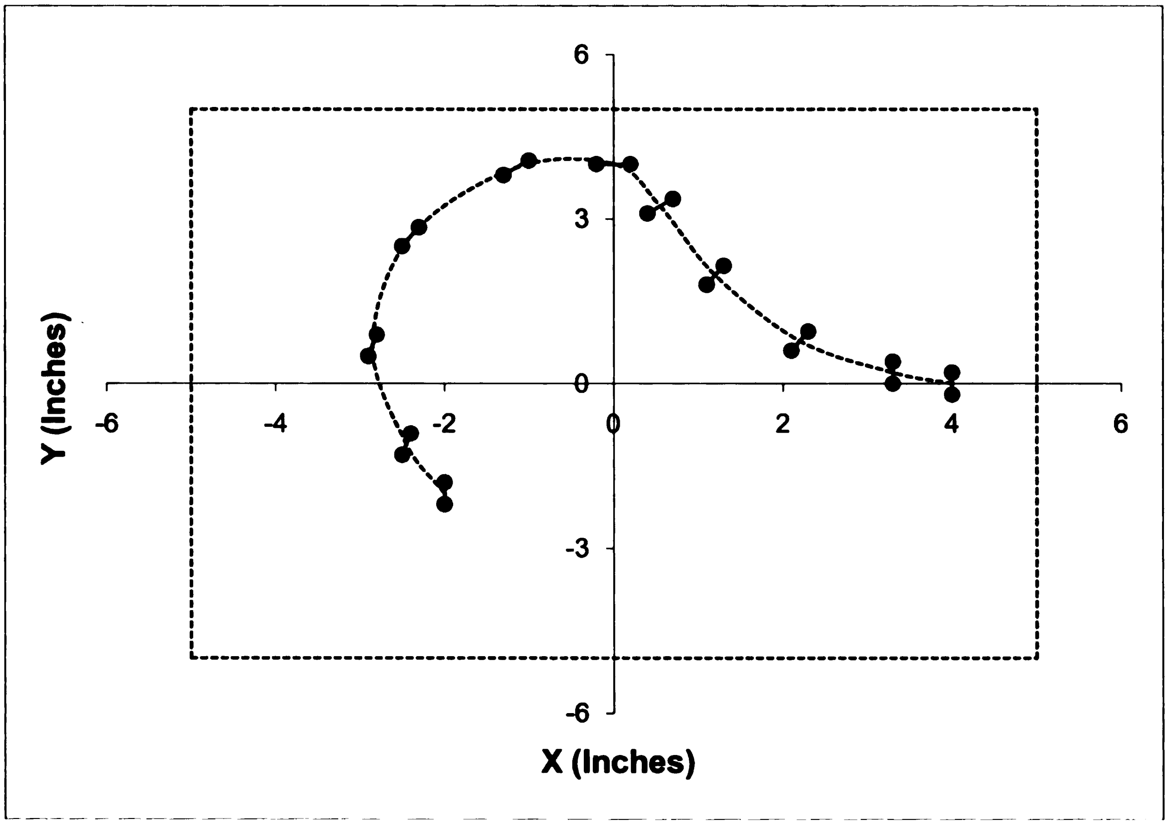

Figure 14. Design Space and Target Locations for Challenge Mechanism.

Although the targets were distinctly specified in the original challenge, the remaining constraints (pivot location range, allowable link lengths, etc.) were less specific, and were thus chosen here by the author. Compared to the earlier two case studies, the complexity of this present study comes from the sheer number of targets, and the path that they lie along.

As with the other case studies, HEEDS was used to synthesize mechanisms to pass through the eleven specified targets using the three different evolutionary methods. The complete data set from this case study appears as Appendix D. The average results obtained from these efforts are recorded in Table 3.

Table 3. Result Compilation for Challenge Mechanism Case Study.

Mech. Type	Ind. Agents	Linked Agents	Conv. Agents	Ind. vs. Linked	Ind. vs. Conv.	Conv. Agent Solutions
4B	9.33	8.91	5.26	4.5%	43.6%	9
S1	8.91	10.51	5.23	-18.0%	41.3%	2
S2	9.13	11.39	7.34	-24.8%	19.6%	5
S3	9.36	10.25	5.88	-9.5%	37.2%	4
W1	10.98	10.83	-	1.4%	-	0
W2	10.62	10.80	5.56	-1.7%	47.6%	5

Here, more-so than with either of the preceding case studies, the convertible agent approach demonstrates its superior effectiveness compared to the other evolutionary methods. That is to say, for the same amount of computing resources (i.e. an equal number of function evaluations), the convertible agents consistently arrived at solutions that better met the specified targets. Once again, linking the agents in this case caused the solutions to have worse average objective function values than when the agents were allowed to evolve independently, for every type except the 4B and W1 mechanism types, which only achieved negligible gains with the linked agents.

5.4 Case Study Summary

As was hypothesized, the convertible agent evolutionary method developed here for the synthesis of mechanisms has demonstrated through the preceding case studies to be a robust method that consistently arrives at better solutions than the other evolutionary methods investigated. Further insight comes from a comparison of the results arrived at using the convertible agent method for each of the three case studies. For convenience, these result sets are summarized in Table 4.

Table 4. Summary of Convertible Agent Average Objective Function Values for the Three Case Studies (data repeated from earlier tables).

Mech. Type	Case Study 1	Case Study 2	Case Study 3
4B	1.21	4.48	5.26
S1	0.99	3.08	5.23
S2	0.61	-	7.34
S3	0.99	4.49	5.88
W1	-	6.57	-
W2	1.15	3.29	5.56

The three case studies were intentionally presented in an order in this dissertation indicative of their relative synthesis complexity. The relative magnitudes of the average objective function values for each case illustrate these differences. For example, in the first case study, the furniture hinge, there were only five targets arranged in a relatively simple path. Thus, the evolved mechanisms very easily match those targets, and the average objective function values are consequently rather low. Compare this to the eleven targets arranged in an irregular path for the third case study, the challenge mechanism, where the best mechanisms tended to have comparatively higher objective function values.

Even if all of the values in Table 4 are normalized on the basis of objective function value per number of targets, the results for the third case study are still three to four times larger than for the first case study, owing to the complexity of the target path.

Recognize also the variety of results obtained among the three cases in terms of the mechanism types found to be best and worst. For example, in the first case study, the S2 mechanism was found to be the top-performing mechanism type, on average. However, in the second case study, this same mechanism type performed so poorly, on average, that the convertible agents never arrived at a solution containing the S2 type. And, although there are such differences among the results sets, there are also some notable similarities. For example, the W1 type performed poorly for all three of the case studies considered in this research. In the first and third cases, the convertible agents never arrived at a W1 solution. In the second case study, even though some W1 solutions were found, on average, they were still the worst solutions arrived at for that study. The author speculates that given enough characteristically different synthesis cases, situations would emerge where each mechanism type is found to be the best solution for the task, while other cases would be found where that type is the worst solution. All of these characteristics serve to further demonstrate the benefits of being able to consider automatically a number of different mechanism topologies for any given synthesis task.

6.0 Further Convertible Agent Studies

The preceding two chapters have sought to demonstrate the motivation leading up to the convertible agent approach, the specifics of that methodology, and the performance of the approach as applied to actual mechanism synthesis problems. As with any system, after studying its behavior, one can propose variations to further enhance its performance. This chapter seeks to discuss such efforts. First, several enhancements to the evolution approach are proposed. Then, using this enhanced convertible agent strategy, the results from a case-study synthesis problem for which there is a known solution are presented to illustrate that elements of the original strategy have been improved.

6.1 Enhanced Convertible Agent Approach

A key characteristic of the convertible agent method is its ability to reallocate underutilized computing resources being wasted on underperforming solution types to those types that are demonstrating the most promising convergence performance. However, in the approach as demonstrated thus far, this reallocation is done decidedly unintelligently. That is to say that as the six convertible agents progress through a given optimization run, the worst performing type gets converted to an agent type like that which is performing the best. But, this "best" and "worst" comparison is done blindly in regards to the relative magnitudes of the agent's objective function values. So, at the point in time of comparison, if all six of the agents are performing relatively equally, the "best" and "worst" could differ by a finite yet trivial amount. Because the convertible agent approach as illustrated thus far does not take this in to consideration, the "worst" agent will still get converted (and thus eliminated) from the population.

In a similar vein, the timing of the conversion event in the convertible agent approach discussed thus far has been chosen rather arbitrarily. As described in the case studies of chapter 5, the conversion interval was set to be one sixth of the total number of evaluations performed during the full optimization run. This was selected simply because there were six agents corresponding to the six mechanism types considered, and it was desired to have the possibility of having all of the agents converge to a single type at the conclusion of any particular solution. Again, one can argue that this conversion decision is being made based upon very little information. It could be that a particular agent may have a relatively high objective function value compared to the other agents, but it is making greater strides in improving itself compared to its peers. If that is the case, it would be beneficial to provide that agent with additional time to converge to an optimized solution rather than eliminating it solely based on its objective function value. In recognition of this phenomenon, a more rational approach would be to decide agent conversion not on an arbitrary number of performed evaluations, but rather on a measure of an agent's historical performance such that agents that have stagnated become more likely to get converted.

To address the deficiencies just described, several enhancements were made to the convertible agent approach to improve the criteria on when agent conversions take place, and which agents get converted. First, to take into consideration the relative values of all of the agents' best objective function values, at every iteration of the enhanced convertible agent method, the objective function for each agent is recorded. With these values, the average objective function value of the agents, and the standard deviation of this data set is calculated. Agent convergence is then determined on an "as needed" basis based on the relative range of objective function values. Convergence can occur if the "best" agent has an objective function that is a specified number of standard deviations less than the average of the population, while the "worst" agent's objective function value is that number of standard deviations greater than the average of the population. In this sense, now the "best" and "worst" are not deemed to be so by trivial amounts, but because they are true outliers of the overall population.

A series of experimental runs was performed to determine what measure of standard deviation disparity would lead to productive agent convergence. If the measure is too high, such that the "best" and "worst" agents need to be a large number of standard deviations away from the average, then the agents never get converted, and the search progresses as though the agents were merely running in parallel. If the threshold is too low, then the agents are constantly getting converted, and the search progression becomes undirected and does not converge effectively. Through this trial and error process, it was found that a value of 0.75 standard deviations yielded a search with fruitful agent conversions.

Another element added to this enhanced convertible agent method is a monitoring of the evolution progression of the different agents. Even with the value comparisons as just described, one can imagine that in a given iteration of the method, one particular agent may get converted. During the next round of comparisons, this agent will have had only a mere fraction of the function evaluations to shape its design that the other agents have had, so it is likely to still have the worst objective function value of the population. If the convergence criteria were limited to just objective function values, then this same agent would get converted again and again throughout the search. To avoid this, the enhanced convertible agent method also takes into consideration the iteration-based gradient of each agent's objective function value. In the scenario just proposed, even though the newly converted agent has the highest (i.e., worst) objective function value, in general, at the beginning of any evolutionary process, that agent will also likely be making the greatest strides in improving its performance. Thus, during each iteration of the enhanced convertible agent method, the objective function gradient with respect to number of iterations is calculated for each agent based on its previous 100 reported objective function values. Added to the convergence criteria already described then is a constraint that the agent getting converted must have either the lowest convergence gradient of the population (i.e., it is making the least progress) or its gradient has to be zero, which could be the case in the event that all of the agents have stagnated.

To summarize the convergence criteria in the enhanced convertible agent method, consider the pseudo code below appearing as equations 27 through 29. An agent gets converted if the following three criteria are simultaneously met:

$$ObjFunc_{\max} > ObjFunc_{avg} + 0.75 \cdot \sigma \qquad (27)$$

$$ObjFunc_{\min} < ObjFunc_{avg} - 0.75 \cdot \sigma \qquad (28)$$

$$\nabla ObjFunc_{\max} < 0.00001 \text{ OR } \nabla ObjFunc_{\max} = \min(\nabla ObjFunc) \qquad (29)$$

In these equations, $ObjFunc_{max}$, $ObjFunc_{min}$, and $ObjFunc_{avg}$ are the maximum, minimum, and average objective function values of the set of all agents in the population, respectively. The standard deviation of the set of agent objective function values is denoted as σ. The gradient of the agent with the highest objective function value is shown as $\nabla ObjFunc_{max}$ and the minimum agent gradient of the set of all agents is $min(\nabla ObjFunc)$. Note that this minimum agent gradient is determined regardless of that particular agent's objective function value, whereas $\nabla ObjFunc_{max}$ is determined specifically as the gradient of the agent with the worst objective function value.

Notice that in equation 29, instead of determining a stagnated agent as having a gradient of zero, a small yet finite objective function value is used in practice so as to avoid numerical rounding issues. Furthermore, it should also be mentioned that in the actual implementation of the enhanced convertible agent method, no agent conversions are allowed during the initial start up period of a particular run, or for a set number of iterations after an agent conversion occurs. These periods were set at 1667 iterations, and 100 iterations, respectively. This allows the agent behavior to settle a bit after the disruption that the agent conversion causes. Again, these values were chosen based on experimentation with different threshold values.

A final enhancement to the convertible agent approach is in regards to the number of agents employed. Much like some of the other parameters described in this section, the number of agents was chosen in the original convertible agent method to be six simply because that was the number of mechanism types being considered. The error in this selection is due to the probabilistic nature of any evolutionary approach. As illustrated in the case study results of chapter 5, although any particular synthesis problem tends to have one or two mechanism types that appear to be particularly well suited for that intended motion based on the frequency of finding solutions of those types, the fact remains that during any given run a particularly good or particularly bad design for any of the types may emerge that can steer the results in a different direction. The logical way to avoid this inevitable pitfall is to increase the population size such that anomalous outliers tend to have less of an effect on the overall progress of the domain search. For example, given the results of Case Study 1 shown in Table 1, one can see that the Stephenson II mechanism was the most often found solution by the convertible agents. For the 25 solution runs performed, 9 times (or 36% of the trials), the convertible agents arrived at a Stephenson II type. If one subscribes to the hypothesis that the Stephenson II type is the best suited for this particular mechanism synthesis problem, this data also indicates that more than half of the time (64% of the trials) the convertible agents converged to a less than ideal solution type. In light of this, by expanding the agent population to 24 agents such that there are initially 4 agents searching for each of the 6 mechanism types, then the probabilities indicate that any particular run is more likely to arrive consistently at the optimum type rather than when there were only 6 agents. The subsequent section of this chapter exhibits results from a new case study that utilized the enhanced convertible agent conversion strategy as well as this increased agent population size.

6.2 "Known Solution" Case Study

In the previous chapter of this dissertation, the results of three different case studies were presented to demonstrate the effectiveness of the convertible agent evolution method for mechanism synthesis. In each of these studies, the convertible agents arrived at effective solutions for complex synthesis problems inspired by real-world design studies taken from the mechanical engineering literature. Although "good" solutions were found to each problem, one cannot conclude that a true optimum solution was found without undertaking an exhaustive search of the design space at hand. For the case studies presented thus far, a mechanism with a perfect objective function of zero was never found. Instead, solutions very close to the objective were always arrived at. But, at the same time, without undertaking the aforementioned exhaustive search, one cannot even say with certainty that there is an ideal solution to be found within the space being searched.

To overcome this ambiguity in the performance evaluation of the convertible agent method, a fourth case study has been considered. This problem was fashioned in the inverse sense to the preceding case studies, such that the problem begins with a solution generated perfectly by a known mechanism. In other words, the problem definition began with a known mechanism design that was selected at random. The motion of this mechanism was then characterized, and a series of target positions that it passed through were recorded. With those targets now acting as the mechanism synthesis objective, the problem was presented to the convertible agents just as before. However, in this case, regardless of the quality of solutions found, it is known that a perfect solution does indeed exist.

One additional element was added to this case study problem definition to bolster its credibility. As mentioned in section 5.4, a trend recognized in comparing the results from the three case studies was that the Watt I mechanism type did not perform well for any of the case studies considered. The hypothesis proposed was that any given synthesis problem has a particular mechanism type that is well suited for the required motion, and then conversely, other types will be particularly ill-suited for the problem at hand. Seemingly, just by chance, the three case studies chosen all happened to share some characteristics that led the Watt I type to be unsuited for those applications. To put this theory to the test, this fourth case study began with a Watt I mechanism type that defined the perfect target locations. If the convertible agents were to arrive at consistent solutions utilizing the Watt I configuration, not only does it demonstrate the effectiveness of the solution strategy, but it also strengthens the arguments regarding the concepts that different mechanism types are better for certain problems than others.

The desired target positions for the fourth case study are shown here as Figure 15. Notice that there are a total of 33 targets. This is a large number of targets compared to the preceding studies that had a maximum of 11 target positions.

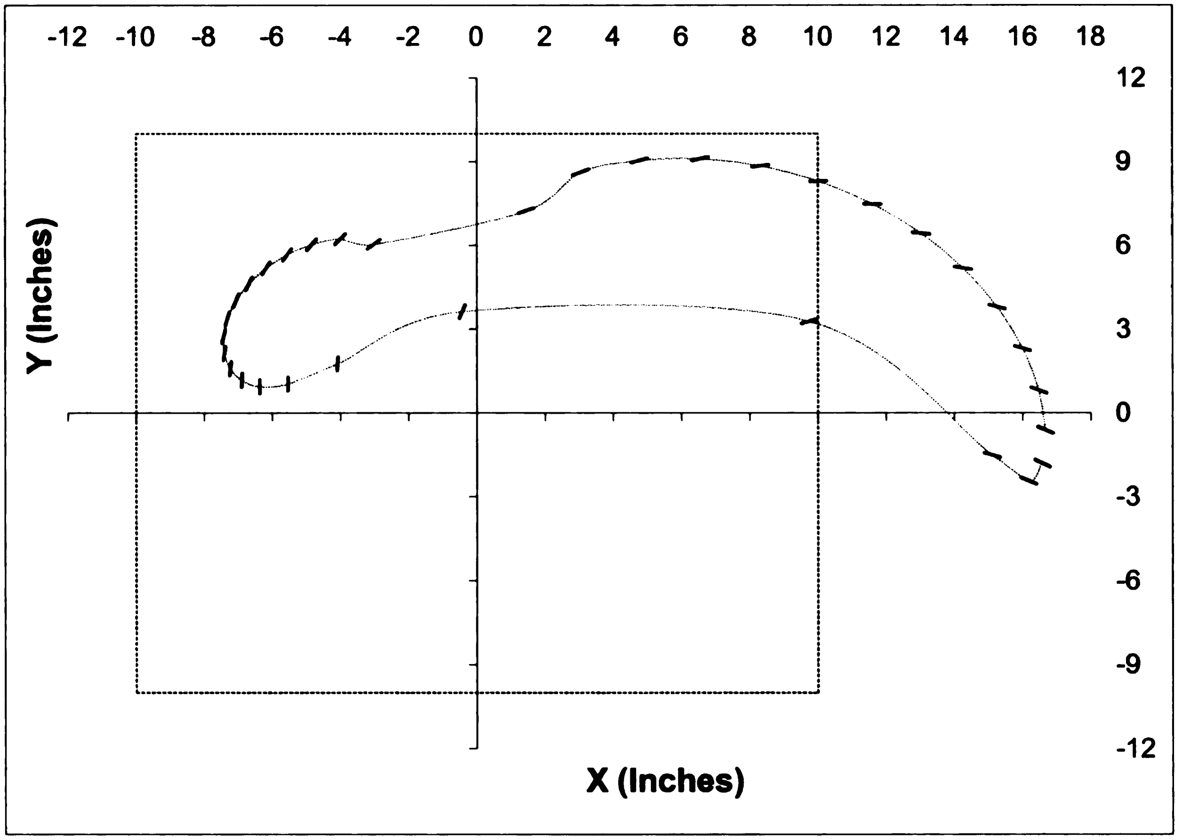

Figure 15. Design Space and Target Locations for "Known Solution" Mechanism.

This case study was attempted with two different evolutionary strategies; the 6-agent architecture like used for the first three case studies, and the 24-agent approach described in the foregoing section that employs the more sophisticated convergence algorithm. Each of these two methods was run 25 times and the results compiled. Note also that for the sake of comparison, the total number of function evaluations was kept equal between the two methods, at a total of 60,000 evaluations. (That is, in the 6-agent case, each of the agents completed 10,000 evaluations, and in the 24-agent case, each of the agents performed 2,500 evaluations.) The compiled results from this effort are shown here as Table 5. The complete raw data from these runs are contained in Appendix E.

Table 5. Result Compilation for the "Known Solution" Mechanism Case Study.

Mech. Type	Average Objective Function Values			Number of Convergences	
	6 Agents	24 Agents	6 vs. 24	6 Agents	24 Agents
4B	-	28.69	-	0	3
S1	39.87	-	-	2	0
S2	37.26	32.88	11.8%	2	4
S3	27.26	28.92	-6.1%	14	7
W1	25.10	27.35	-9.0%	6	8
W2	36.10	26.40	26.9%	1	3

The results of this latest case study exhibit a combination of different features. First, in terms of the solutions found, recall that the known perfect solution for this demonstration was a Watt I type. The original 6-agent architecture did indeed find on average solutions of the Watt I type to have the best performance. With the enhanced convertible agent methodology and 24 search agents, the Watt I type ranks second, lagging only behind the Watt II type. In consideration of the fact that the earlier case studies never converged to Watt I mechanisms, the argument that these strategies can converge to the best type for a given synthesis problem has been bolstered.

In comparing for each mechanism type the average objective function values found by the two different methods (the fourth column of Table 5), one sees inconclusive results. For a third of the mechanism types (Stephenson II and Watt II), the enhanced convertible agent methodology did arrive at better results than the original implementation as proposed. For another third of the types (Stephenson III and Watt I), the enhanced method actually arrived at worse results than the original method (albeit, by a smaller margin than the previous agents were improved by). Finally, for the remaining two mechanism types (Four Bar and Stephenson I), one method or the other did not converge to a mechanism of one of those types, and thus there is no basis for comparison.

The last two columns of Table 5 illustrate the frequency with which each mechanism type was converged to. It is evident that for this particular case study, the code often converged to both Stephenson III and Watt I types. With the original convertible agent method and just 6 agents, the search converged to a Stephenson III type a majority of the time (56% of the trials). The supposition was that by adding additional agents to the search effort along with the enhanced convergence strategy, the agents would have more of a tendency to consistently arrive at the known optimum solution. Strictly speaking, the 24-agent case did demonstrate that the most often found solution was a Watt I type as expected, but the Stephenson III mechanism type still performed consistently well.

It should also be pointed out that neither method ever arrived at the true optimum solution. The 6-agent implementation did arrive at a single Watt I solution with an objective function value of 8.89, and upon inspection of the variable values, there is some resemblance between that design and the known perfect design. Thus, one can conclude that these techniques produce usable designs that for practical applications come close to a designer's intended motion, but one cannot claim that the techniques are able to find a globally optimum mechanism design for a specific problem.

Recall that the number of function evaluations for each trial was selected such that all runs used an equal amount of computing resources so as to maintain an even basis for comparison. However, it should also be emphasized that in a majority of the runs (approximately 85%), the top performing design was found at the end of the maximum number of allowed iterations. There is no reason to believe then that if given additional iterations, the agents would not have continued to refine and improve the optimum solutions even further.

As the discussion leading up to this case study explained, there are many contributing factors to the behavior of the enhanced convertible agent methodology. An overriding dynamic is the problem dependence of the method. It seems that the case study here, which as noted, was specified somewhat randomly, just happens to lend itself to a perfect solution of a Watt I type, but apparently simpler to find (although less than ideal) solutions of the Stephenson III type. So, as with the previous case studies, without performing an exhaustive search of the design space, one cannot characterize the number of solutions that truly exist. It may be that the one known perfect Watt I solution for this synthesis problem is somewhat at a point of instability such that none of its close relatives have a performance that resembles its own. Conversely, the Stephenson III type might have a lot of variations that come close to matching the intended behavior, but none exist that meet it perfectly.

All other control parameters of the enhanced convertible agent method could be further optimized to produce better results. The values chosen for standard deviation weighting, initial convergence interval, intermediate convergence intervals, *et cetera*, could all be studied at length to find what combination yields the most productive search. However, one may also find that this, too, is problem dependent.

In the end, it appears that the slight performance gains achieved are not worth the added computational expense of the enhanced convertible agent method along with the expanded population of search agents. But, this is not to say that further refinement of the enhanced method would not lead to greater efficiency gains. It is likely that some hybrid between the original convertible agent method and the enhanced approach may be the preferred strategy. One could envision using the enhanced convergence strategy with the simpler 6-agent implementation to improve convergence behavior while not incurring additional overhead. Another element that could benefit further investigation is the degree to which the search agents are linked together to exchange information so that the network promotes collaboration, but not immediate homogenization of the population.

7.0 Conclusions

In 1995, renowned mechanisms expert Arthur Erdman wrote a commentary on the current status of computer-aided mechanism design as part of the American Society of Mechanical Engineering's 50th anniversary commemoration. After presenting an overview of what was then considered to be the state-of-the-art in terms of mechanism design software, he concluded that "The great majority of software addresses kinematic and dynamic analysis needs...Software for kinematic synthesis is less available and less mature." Furthermore, he proposed that "In the future one can hope for either a general-purpose mechanical system dimensional synthesis package or a series of separate but connected software tools that are optimized for each class of mechanical systems" [7]. Today, a decade and a half after Erdman made these assessments, one can argue that the state of the computer-aided mechanism design world of the practitioner has not advanced far from where it was in 1995. Although research in mechanism synthesis techniques has remained vibrant, and strides have been made in all manner of computing capabilities, mechanism synthesis tools have remained elusive to the practicing engineer. Newly developed tools seemingly remain confined within the research facilities of academia. Perhaps it is a consequence of the techniques being out of reach for the professional mechanism designer, whether that be for reasons of complexity, computing overhead, or mathematical abstraction. Maybe it is simply a matter of the mechanism synthesis community not posing a great enough need to garner the attention of major software developers.

The point remains that synthesizing mechanisms is an engineering design problem that has both captivated and frustrated generations of engineers. The work presented in this dissertation demonstrates that one can now build upon the efforts of earlier mechanism synthesis researchers to devise fully automated synthesis strategies that simultaneously optimize both the type and dimensionality of a mechanism.

The studies presented in this dissertation have illustrated two key guidelines that mechanism designers can benefit from regardless of specific solution strategy. First and foremost, the results presented demonstrate the value in considering a variety of solution topologies; often times the best mechanism type is not obvious. In that same vein, this research has challenged the commonly held belief in the mechanism synthesis world that more complex mechanism types will always yield better performance than simpler types. In some of the case study results presented, it was shown that the best type also happened to be the simplest. Thus, the convertible agents approach each problem without any predisposed biases; much like a human designer should.

Additionally, the convertible agent approach developed herein is readily scalable to consider any number of different mechanism types that go beyond those considered in this initial study. Mechanisms with different joint types, increased numbers of links, or non-planar behavior can be directly added with the specification of the respective search agents. With each additional type considered, the designer will gain confidence in knowing that they are using the mechanism type best suited for a particular application.

From an evolutionary computing point of view, the convertible agent approach lends itself to be applied to problems outside of the mechanism synthesis task for which it was developed. The technique is well suited for evolutionary design applications in which there are a small number of distinct topological possibilities, each with parametric variables to be optimized. This is in contrast with genetic programming, which has often been applied to synthesis of open-ended system topologies and associated parameters. The convertible agent approach is dramatically more efficient, as the space of topologies (or mechanism types, in this case) that must be searched is small enough to be searched, at least preliminarily, in an exhaustive manner. As with any evolutionary approach, the convertible agents and enhanced convertible agents have many control variables (conversion rates, comparison thresholds, stagnation gradients, and the like) that need to be optimized or "tuned" to improve performance for a general class of problems.

The convertible agent evolutionary approach developed in this research has been shown to be a more robust and efficient evolutionary synthesis strategy for mechanisms than any of the methods that have come before it. It represents a methodology that could be put into service for real-world mechanism design applications with relative simplicity, providing flexible capabilities to deliver a variety of useful results. To this end, the synthesis community can benefit from the further advancement of such tools to fill a void that has been apparent for generations.

Appendices

Appendix A - Mechanism Variable Maps

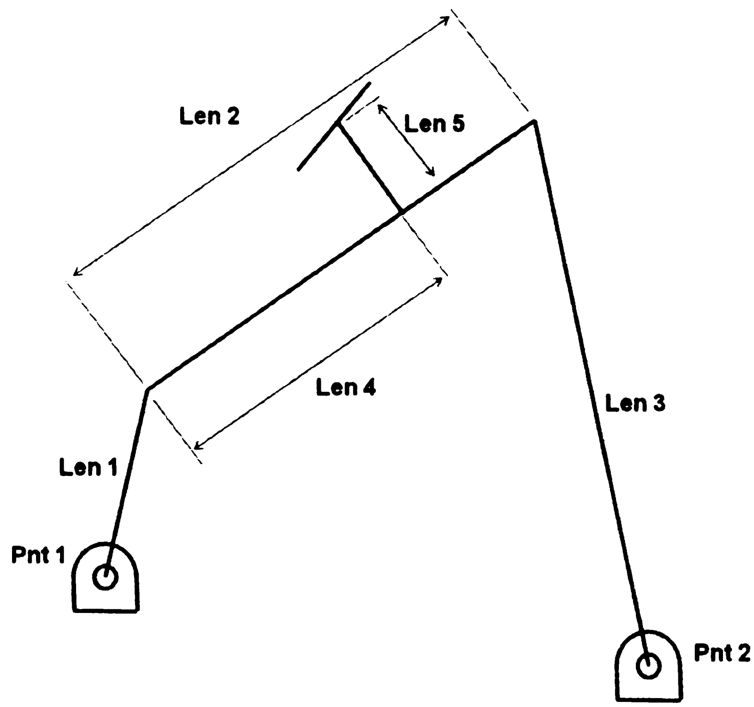

Figure 16. Four-Bar Mechanism Variable Map.

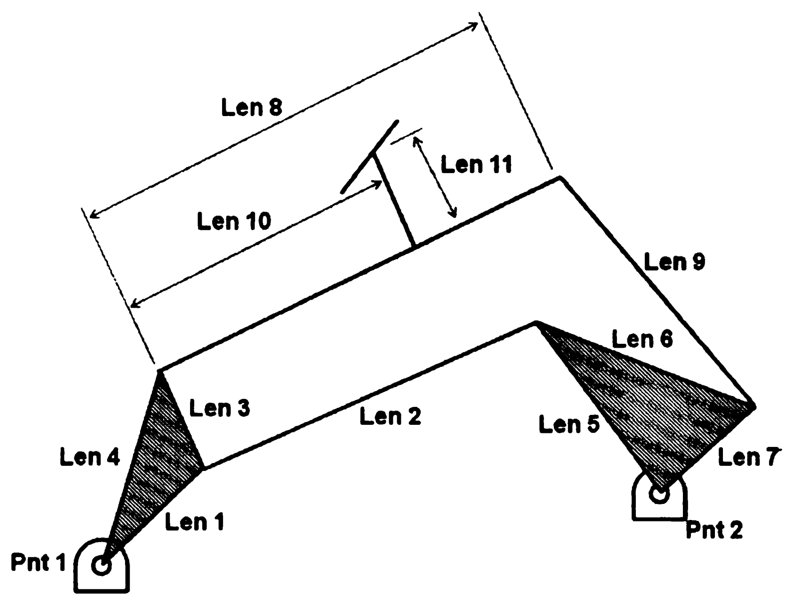

Figure 17. Stephenson I Mechanism Variable Map.

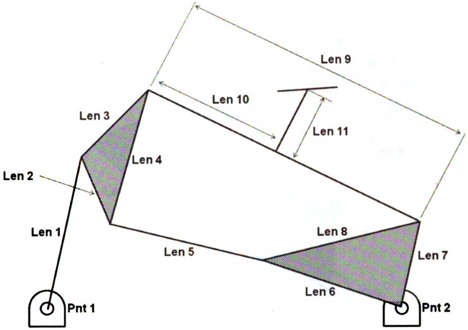

Figure 18. Stephenson II Mechanism Variable Map.

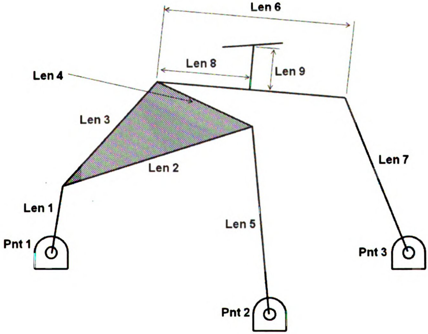

Figure 19. Stephenson III Mechanism Variable Map.

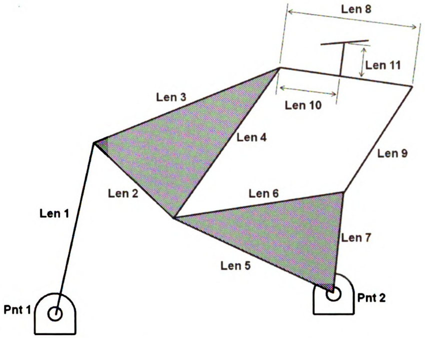

Figure 20. Watt I Mechanism Variable Map.

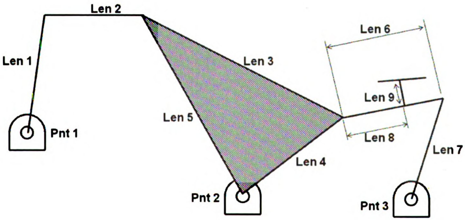

Figure 21. Watt II Mechanism Variable Map.

Appendix B - Hinge Mechanism Case Study - Raw Data

Table 6. Hinge Mechanism - Independant Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	1.07	-0.50	1.08	0.00	0.00	1.62	0.50	0.50	0.50	1.00	1.57
2	0.98	-0.37	0.36	-0.08	0.00	3.93	3.90	0.57	3.69	1.00	1.54
3	1.96	-0.05	0.24	-0.04	3.64	4.00	4.00	3.27	4.00	1.99	1.57
4	1.98	-0.30	0.60	-0.20	3.16	3.16	2.95	2.60	2.85	1.99	1.54
5	1.80	0.00	3.48	-0.11	0.00	4.00	3.16	2.71	0.50	1.00	1.57
6	2.34	-0.01	2.56	-0.36	0.48	3.83	2.99	1.27	1.27	1.00	1.38
7	2.06	-0.31	1.60	-0.01	0.16	2.50	1.48	0.54	0.64	1.00	1.23
8	1.38	-0.42	0.36	0.00	2.64	4.00	3.30	3.02	3.69	1.00	1.57
9	1.68	-0.21	0.28	-0.04	1.76	2.32	1.87	1.97	2.25	1.00	1.57
10	1.38	-0.31	0.44	-0.32	0.00	1.55	4.00	2.88	0.89	1.00	1.41
11	2.28	-0.50	3.08	0.00	0.08	3.62	4.00	3.44	0.68	1.00	1.51
12	1.88	0.00	0.00	-0.01	3.40	4.00	3.72	3.69	4.00	1.00	1.57
13	0.45	0.00	0.00	-0.02	0.00	1.31	3.51	2.25	0.50	1.00	1.04
14	0.43	-0.13	0.04	-0.01	0.00	3.02	2.92	0.50	2.88	1.00	1.57
15	0.25	-0.01	0.00	0.00	0.00	4.00	4.00	0.50	3.97	1.00	1.57
16	0.93	-0.01	0.32	-0.01	0.16	1.80	3.90	2.39	1.41	1.00	1.51
17	0.26	-0.01	0.00	0.00	0.00	4.00	4.00	0.50	3.97	1.00	1.57
18	1.78	-0.44	2.88	-0.13	0.00	3.37	1.62	1.17	0.50	1.00	1.57
19	1.89	-0.50	1.00	-0.13	3.72	1.90	0.68	3.97	0.85	1.00	1.41
20	2.22	-0.21	0.04	-0.50	3.76	3.09	2.81	4.00	3.27	1.00	1.57
21	1.99	-0.17	3.56	0.00	0.00	4.00	1.48	1.17	0.68	1.00	1.57
22	1.76	-0.01	3.04	-0.12	0.00	3.55	2.74	2.29	0.50	1.00	1.57
23	0.38	0.00	0.08	0.00	0.00	0.75	0.54	0.50	0.50	1.00	1.57
24	1.64	-0.46	0.00	-0.05	4.00	1.13	0.50	3.55	0.50	1.99	1.57
25	0.25	-0.01	0.00	0.00	0.00	4.00	3.97	0.50	3.97	1.00	1.57

Table 7. Hinge Mechanism - Independent Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	0.96	-0.44	0.36	-0.49	0.00	1.38	4.00	2.53	1.76	3.41	3.93	1.59	1.94	2.04	1.38	1.00	1.54
2	5.56	-0.26	3.16	-0.11	1.36	2.71	3.69	1.87	3.51	3.37	3.97	2.39	3.51	3.23	1.03	1.99	1.54
3	3.10	-0.50	0.00	-0.50	0.00	4.00	3.83	3.90	4.00	4.00	4.00	0.50	4.00	0.54	4.00	1.00	1.57
4	1.75	-0.46	0.96	-0.25	0.00	4.00	3.65	2.15	3.51	2.29	4.00	1.73	4.00	2.04	2.78	1.00	1.57
5	1.88	-0.01	1.36	0.00	0.00	3.79	4.00	1.31	2.53	3.58	4.00	1.34	3.23	1.06	0.99	1.00	1.23
6	1.82	-0.27	0.12	-0.36	0.04	1.55	2.64	1.52	2.29	2.15	3.69	2.32	3.93	1.24	0.92	1.00	0.50
7	3.70	-0.01	3.92	-0.42	1.44	2.88	4.00	1.45	3.97	3.83	4.00	0.78	3.55	1.48	0.64	1.99	1.57
8	0.44	-0.02	0.00	-0.13	0.12	1.97	1.83	1.69	0.96	1.10	3.58	3.97	3.41	2.74	0.78	1.00	1.54
9	4.68	-0.02	3.92	-0.38	0.16	3.55	2.99	4.00	3.34	3.23	2.22	1.48	3.62	3.55	0.96	1.99	1.57
10	1.36	-0.18	0.00	0.00	0.28	3.58	2.15	3.62	1.52	3.76	2.67	1.20	2.39	0.89	1.20	1.00	1.45
11	2.29	-0.26	3.56	-0.06	1.52	1.38	3.02	2.67	4.00	2.39	2.36	1.06	3.55	2.64	0.50	1.00	1.57
12	0.41	-0.02	0.00	0.00	0.00	4.00	3.90	3.97	1.87	2.50	3.27	1.94	4.00	2.81	1.52	1.00	1.35
13	3.40	-0.03	2.12	0.00	0.04	3.83	3.69	0.78	3.62	2.60	3.97	2.32	3.65	1.59	0.82	1.00	0.63
14	1.18	-0.03	0.00	-0.50	0.00	2.67	3.27	2.78	0.50	2.64	1.94	2.60	3.97	4.00	0.50	1.00	1.57
15	1.08	-0.42	0.88	0.00	0.04	2.39	3.65	0.50	2.50	4.00	4.00	2.43	3.97	0.54	1.59	1.00	1.51
16	0.66	0.00	0.16	-0.06	0.08	2.18	4.00	3.37	2.01	3.79	4.00	0.96	4.00	2.29	0.68	1.00	0.60
17	2.57	0.00	3.16	-0.49	0.00	3.72	2.99	3.86	3.55	3.48	4.00	0.75	3.62	3.44	0.71	1.00	1.54
18	2.01	-0.08	0.56	-0.13	2.56	2.95	1.87	3.34	2.50	3.51	3.34	2.57	3.41	3.37	2.29	1.00	1.57
19	2.82	-0.50	0.92	-0.37	1.76	1.76	3.09	2.74	1.94	2.74	2.08	2.04	1.73	2.95	1.38	1.99	1.57
20	9.72	-0.31	0.16	-0.45	3.68	4.00	3.90	3.76	3.48	3.23	3.37	2.15	0.54	1.17	3.62	1.00	-1.57
21	4.88	-0.43	3.84	-0.28	0.40	4.00	3.90	2.60	3.83	3.97	3.62	0.96	3.86	4.00	0.78	1.00	1.57
22	4.73	0.00	1.52	0.00	3.20	3.97	2.15	4.00	3.97	3.93	3.51	2.11	3.90	3.62	3.27	1.00	1.57
23	1.11	-0.22	0.52	-0.47	0.04	1.52	2.71	2.99	1.48	3.90	3.41	1.06	2.43	2.11	0.50	1.00	1.13
24	0.90	-0.16	0.20	-0.10	0.00	2.88	3.16	2.43	2.29	1.38	3.97	2.99	3.97	2.60	2.08	1.99	1.57
25	1.42	-0.02	0.00	-0.50	3.44	4.00	3.93	3.93	0.71	3.69	4.00	4.00	3.97	4.00	0.54	1.00	1.57

Table 8. Hinge Mechanism - Independent Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	0.52	-0.16	0.36	0.00	0.00	3.30	3.44	3.86	2.04	2.74	3.79	0.75	3.27	3.83	3.72	1.00	0.97
2	2.01	-0.46	0.00	-0.24	0.00	2.46	1.13	2.32	2.50	2.99	3.13	3.58	4.00	1.80	0.50	4.96	1.32
3	2.65	-0.27	2.28	-0.05	0.84	2.50	2.32	3.90	1.90	0.82	3.83	3.06	3.97	3.20	2.71	1.00	-1.07
4	0.70	-0.10	1.44	0.00	0.12	2.64	3.23	2.71	0.54	0.78	3.37	3.58	3.83	3.83	0.64	1.00	-1.16
5	2.52	-0.13	1.64	0.00	0.76	1.90	0.99	3.69	2.95	2.53	2.53	3.34	2.39	1.66	0.64	1.00	-1.51
6	1.00	-0.35	1.00	-0.19	0.00	2.85	3.65	2.11	2.71	2.74	3.41	1.76	3.76	2.81	1.76	2.98	1.13
7	3.02	-0.41	1.16	-0.04	1.16	2.88	1.90	1.17	2.67	0.96	0.75	1.87	1.52	1.87	2.71	1.00	1.48
8	0.83	-0.40	0.84	-0.44	0.04	2.78	3.83	3.27	1.24	2.04	2.18	1.48	2.04	3.69	2.81	1.99	0.63
9	0.56	-0.21	1.48	-0.10	0.04	2.08	3.06	3.34	0.71	3.23	1.38	2.11	2.99	2.95	2.32	2.98	0.69
10	2.54	-0.42	1.96	-0.23	0.44	1.17	0.50	2.92	2.99	1.41	1.24	0.75	0.50	2.71	0.61	1.00	0.28
11	1.23	-0.16	0.00	0.00	0.28	1.13	4.00	4.00	4.00	4.00	4.00	2.95	4.00	3.97	2.92	1.00	-1.57
12	1.40	-0.23	0.68	-0.44	0.36	3.69	3.76	1.24	3.72	1.24	2.81	3.27	4.00	2.29	1.94	2.98	0.09
13	2.71	-0.05	2.56	-0.01	2.00	2.57	3.58	3.09	0.50	3.06	3.34	2.36	3.93	3.09	1.31	3.97	1.51
14	2.79	-0.16	2.68	-0.24	3.40	1.97	2.95	3.86	3.97	1.73	3.83	4.00	3.72	2.04	1.90	1.00	0.44
15	0.59	-0.21	0.84	-0.04	0.08	0.99	3.23	3.93	1.20	2.64	2.08	2.57	3.76	2.60	1.52	2.98	0.25
16	1.00	-0.07	0.08	-0.09	0.04	0.57	1.27	3.48	3.83	3.16	3.48	3.02	1.97	1.62	1.41	1.99	-0.69
17	2.87	-0.48	2.04	-0.02	2.64	2.78	2.60	3.97	2.74	3.72	2.29	2.25	3.37	1.20	0.54	1.99	1.29
18	0.83	-0.30	1.76	-0.13	0.08	3.72	0.71	3.48	3.55	3.34	3.76	3.13	1.69	1.52	1.10	3.97	0.69
19	3.93	-0.36	2.56	-0.42	2.92	3.30	2.67	3.20	3.34	1.48	1.97	2.78	3.27	3.06	1.06	3.97	1.45
20	1.87	-0.35	0.76	-0.09	0.72	1.31	1.38	2.22	2.43	2.46	3.65	2.15	1.62	0.85	1.69	1.99	1.04
21	2.81	-0.50	0.12	-0.43	0.00	4.00	3.51	2.08	2.01	1.45	2.74	3.90	1.83	0.99	4.00	1.00	-1.57
22	1.96	-0.50	0.60	-0.11	0.20	3.48	1.48	3.93	3.37	2.15	2.22	1.94	3.97	2.95	0.61	1.00	-0.41
23	3.00	-0.27	1.36	0.00	0.00	4.00	3.16	3.27	3.06	4.00	0.50	2.32	2.29	2.36	0.50	1.00	1.57
24	1.17	-0.06	0.00	-0.12	0.92	3.79	3.02	0.54	2.71	1.20	3.93	3.65	1.52	3.69	1.87	1.00	-1.35
25	0.79	-0.19	1.68	-0.23	0.16	3.90	2.53	2.46	0.64	2.85	1.52	2.78	2.18	3.20	3.16	3.97	1.13

Table 9. Hinge Mechanism - Independent Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	2.75	-0.02	0.00	-0.28	0.00	-0.18	0.00	1.90	0.99	1.41	1.03	2.22	0.92	2.22	2.39	1.00	0.97
2	3.03	-0.45	0.88	-0.19	1.36	-0.25	2.40	2.46	2.92	2.01	3.51	1.20	2.88	1.97	2.85	1.99	1.57
3	3.51	-0.20	0.00	-0.46	3.48	-0.05	3.64	3.93	2.39	1.52	2.15	3.69	3.83	1.94	3.23	2.98	1.57
4	1.22	-0.02	0.00	-0.15	4.00	0.00	0.00	0.54	0.50	3.90	3.97	4.00	4.00	0.54	3.79	1.00	1.48
5	1.88	-0.23	2.00	-0.20	3.16	-0.02	0.04	2.81	3.72	0.54	3.69	3.90	1.87	0.75	1.34	1.00	1.48
6	5.31	-0.05	1.04	-0.21	0.04	-0.04	4.00	2.64	3.86	1.83	2.74	1.69	1.34	1.83	2.11	3.97	1.54
7	2.83	0.00	0.00	-0.01	0.00	-0.12	3.56	4.00	4.00	2.67	3.97	0.50	3.97	3.83	4.00	1.00	1.57
8	2.26	-0.06	0.44	-0.11	3.68	-0.01	1.84	2.36	2.46	2.60	3.90	3.34	3.90	1.38	3.83	1.99	1.54
9	2.47	-0.50	0.68	-0.50	1.08	-0.34	3.24	0.50	0.50	2.01	2.39	0.57	1.34	3.72	1.52	1.00	1.41
10	3.22	-0.46	1.40	-0.36	3.96	-0.21	2.04	1.87	2.15	2.04	2.36	2.43	1.13	1.48	1.10	1.99	1.41
11	2.43	-0.03	3.68	-0.46	3.56	-0.05	0.00	3.93	3.51	3.83	3.86	0.99	1.97	0.82	1.38	1.00	1.57
12	2.90	-0.40	0.64	0.00	3.52	-0.06	4.00	3.62	2.46	0.85	3.06	2.88	3.93	2.46	3.62	2.98	1.57
13	3.39	-0.12	2.24	-0.07	2.04	-0.49	0.44	1.27	3.97	3.90	1.27	3.20	2.57	0.71	1.45	1.00	1.13
14	1.98	-0.09	3.00	-0.26	3.16	-0.30	0.20	3.97	3.97	2.67	2.11	2.50	1.87	0.96	0.92	1.00	1.57
15	1.61	-0.20	3.88	-0.43	3.12	-0.46	0.08	3.02	0.78	1.90	1.55	2.18	2.46	1.83	0.50	1.00	1.54
16	1.87	-0.50	1.20	-0.50	1.12	-0.24	1.76	2.81	4.00	2.67	3.93	4.00	2.88	2.85	4.00	1.00	1.51
17	2.24	-0.50	0.48	-0.48	0.16	-0.50	3.96	0.75	0.71	1.03	0.50	0.61	0.61	3.48	0.92	1.99	1.57
18	1.92	-0.14	3.96	-0.03	3.40	0.00	0.00	1.97	2.50	2.46	4.00	2.15	3.72	3.34	0.50	1.00	1.57
19	1.98	-0.50	4.00	-0.04	4.00	-0.03	0.00	3.86	3.48	1.52	2.99	3.06	4.00	3.62	0.54	1.00	1.57
20	1.71	-0.45	0.00	-0.24	0.00	-0.06	1.52	2.25	4.00	3.62	1.31	2.67	2.64	1.90	2.74	1.00	1.57
21	1.76	-0.50	1.12	-0.33	1.80	-0.45	0.08	2.29	3.23	2.71	2.46	2.36	2.81	0.57	1.90	1.00	1.35
22	3.30	-0.29	1.28	-0.04	2.48	-0.09	4.00	2.25	3.16	3.16	2.74	2.57	2.64	3.30	2.43	1.99	1.38
23	2.76	-0.50	0.64	0.00	1.88	-0.41	2.76	2.15	1.80	1.62	1.31	3.41	1.66	3.51	2.95	1.00	1.57
24	3.97	-0.50	3.08	0.00	3.40	-0.19	0.96	2.81	2.64	1.69	3.93	4.00	3.48	1.38	1.87	1.00	1.57
25	1.26	0.00	0.00	-0.43	2.96	0.00	1.56	0.92	0.89	2.53	2.85	3.44	3.06	1.90	3.30	1.00	1.51

Table 10. Hinge Mechanism - Independent Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	7.98	0.00	3.60	-0.02	3.48	3.97	3.83	3.97	0.71	3.20	3.97	2.99	3.83	1.97	0.50	1.00	1.38
2	2.74	0.00	3.96	0.00	0.04	4.00	4.00	0.50	3.97	3.97	4.00	4.00	4.00	4.00	0.50	1.00	1.57
3	2.71	0.00	2.64	-0.45	0.60	2.81	3.58	1.34	3.27	2.57	3.65	1.17	3.86	1.20	1.31	1.00	1.45
4	3.05	-0.50	0.44	-0.39	3.72	2.71	2.46	1.06	3.13	2.64	2.18	0.50	2.36	3.30	2.95	1.99	1.57
5	2.31	-0.14	1.00	-0.21	0.52	2.99	3.02	0.71	2.46	1.13	2.74	1.76	4.00	0.54	1.03	1.00	0.72
6	1.99	-0.50	0.00	0.00	0.20	0.50	1.45	0.96	2.39	1.48	1.31	1.10	3.93	4.00	0.50	1.00	1.54
7	4.02	0.00	0.00	-0.01	4.00	4.00	4.00	2.74	4.00	4.00	4.00	0.50	4.00	4.00	4.00	1.00	1.57
8	1.00	-0.50	0.32	-0.05	0.48	4.00	0.50	0.50	0.50	4.00	3.79	0.50	4.00	0.50	4.00	1.00	1.57
9	4.77	-0.01	1.60	-0.50	3.44	3.41	4.00	0.50	3.97	4.00	3.58	0.50	1.90	4.00	3.20	1.99	1.57
10	3.22	-0.24	2.16	-0.20	0.60	2.60	2.78	0.50	3.16	1.73	3.86	2.64	2.60	4.00	0.78	1.00	1.45
11	6.91	-0.50	3.76	-0.04	2.88	3.97	3.97	3.48	0.50	4.00	3.48	2.25	4.00	0.50	0.85	1.00	1.45
12	6.65	0.00	2.64	-0.07	2.24	3.55	4.00	3.93	0.92	3.97	3.44	0.71	4.00	0.96	2.29	1.00	1.26
13	3.85	-0.50	2.16	-0.19	3.36	2.57	1.34	3.23	2.95	1.41	1.59	1.87	4.00	2.67	0.50	1.00	1.57
14	5.88	-0.46	0.76	-0.11	2.00	1.17	2.57	2.36	3.55	3.79	4.00	0.85	3.83	2.11	2.95	1.00	1.57
15	3.71	-0.50	3.88	-0.15	1.68	4.00	3.86	4.00	2.01	0.68	2.78	2.64	3.97	1.59	1.17	1.00	1.57
16	0.52	0.00	0.04	-0.02	0.16	0.50	3.44	0.54	3.90	3.72	3.72	4.00	3.97	1.94	0.50	1.00	1.54
17	4.19	-0.02	0.04	-0.06	4.00	3.44	3.23	3.02	1.48	3.34	3.30	2.25	0.50	3.97	0.54	1.00	1.57
18	3.83	-0.35	0.80	-0.31	3.72	3.16	3.65	3.79	3.97	4.00	4.00	0.54	4.00	3.90	4.00	1.00	1.57
19	2.27	-0.23	3.88	0.00	0.24	3.83	1.80	0.99	2.18	1.87	3.83	2.53	3.27	2.08	0.57	1.00	1.32
20	3.29	-0.50	0.52	-0.11	3.36	1.41	4.00	0.50	3.55	1.41	1.66	0.64	0.50	3.97	0.50	1.00	1.51
21	6.81	-0.49	3.96	0.00	2.80	1.76	3.09	3.93	2.60	2.39	3.55	1.27	3.37	2.25	0.68	1.00	1.35
22	5.91	-0.50	0.64	-0.10	3.72	4.00	0.61	3.97	3.37	3.02	3.51	2.08	3.83	2.39	0.50	1.00	1.57
23	3.95	-0.49	1.44	-0.24	2.44	3.34	3.51	0.50	3.93	3.79	2.78	1.69	2.11	3.58	3.13	1.00	1.57
24	4.31	-0.15	3.36	0.00	1.80	3.93	3.76	3.06	3.09	0.99	3.90	2.92	4.00	3.86	1.13	1.00	1.41
25	3.40	-0.33	1.12	-0.50	0.84	1.10	1.80	1.55	2.88	0.89	2.43	2.08	4.00	2.43	1.20	1.00	1.57

Table 11. Hinge Mechanism - Independent Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	0.81	-0.50	0.44	-0.15	0.00	0.00	0.00	4.00	4.00	2.46	0.71	3.13	0.50	0.50	0.50	1.00	1.57
2	1.96	-0.50	2.64	-0.47	0.60	-0.15	0.28	3.20	2.46	1.20	3.69	3.37	2.64	0.92	2.64	1.00	1.29
3	1.93	-0.15	4.00	0.00	3.52	-0.44	0.16	3.97	0.50	1.76	4.00	3.44	4.00	3.41	0.50	1.00	1.57
4	0.99	-0.39	3.12	-0.41	0.48	-0.04	0.00	3.93	2.29	3.72	3.79	2.88	3.48	0.50	3.44	1.00	1.54
5	0.99	-0.16	0.76	-0.38	0.28	-0.13	0.56	3.97	3.41	2.50	2.60	2.18	1.97	0.99	2.01	1.00	1.38
6	1.59	-0.50	0.08	-0.15	2.72	-0.48	0.32	1.34	2.46	3.55	3.13	3.62	3.97	3.27	0.50	1.00	1.57
7	2.29	-0.49	3.56	0.00	3.76	-0.01	0.08	3.93	0.50	3.51	3.97	3.97	4.00	3.86	0.50	1.00	1.57
8	1.80	-0.46	0.04	-0.02	0.56	-0.03	2.80	1.94	1.97	1.80	2.01	3.30	2.01	2.18	1.76	1.99	1.54
9	1.97	-0.16	0.20	-0.06	0.04	-0.18	3.52	2.85	2.78	3.51	3.97	0.54	3.55	3.90	3.97	1.00	1.54
10	3.07	-0.32	1.12	-0.50	1.92	0.00	4.00	3.06	2.29	1.17	2.39	2.01	0.50	4.00	0.50	1.00	1.45
11	5.86	-0.38	0.40	-0.38	2.48	-0.08	3.76	1.69	2.43	3.20	3.90	3.37	2.08	3.13	0.89	1.00	0.91
12	3.19	-0.34	3.80	-0.22	1.00	-0.50	3.84	3.97	3.86	2.18	3.16	2.57	2.64	3.30	2.53	1.99	1.38
13	3.34	-0.50	0.92	-0.24	0.00	-0.17	3.96	3.48	4.00	3.13	4.00	2.53	3.97	4.00	4.00	1.00	1.57
14	2.16	-0.01	1.68	-0.04	3.24	-0.45	0.64	1.97	2.01	1.45	3.97	3.79	3.69	2.36	0.89	1.00	1.54
15	2.58	-0.17	0.48	-0.44	0.36	-0.40	2.60	2.01	4.00	3.93	1.62	2.95	1.34	2.04	1.20	1.99	1.57
16	1.03	-0.01	0.00	-0.06	0.52	-0.35	0.28	3.48	3.02	2.57	1.59	3.69	2.08	0.82	0.85	1.00	1.45
17	1.26	-0.15	0.68	-0.28	0.80	-0.24	0.24	2.67	3.51	2.11	2.29	3.13	3.62	1.94	1.59	1.00	1.57
18	3.27	-0.01	1.76	-0.35	2.08	0.00	0.20	3.51	4.00	4.00	3.69	0.85	4.00	2.32	1.87	1.00	1.57
19	1.57	-0.25	1.20	-0.50	1.80	-0.06	0.00	1.55	0.89	0.61	2.15	2.71	0.57	0.50	0.50	1.00	1.54
20	6.00	-0.26	0.28	-0.30	3.24	0.00	1.60	2.81	3.62	3.76	4.00	3.27	3.93	2.53	0.50	1.00	1.38
21	2.24	-0.43	0.00	-0.01	0.00	-0.49	3.72	4.00	3.97	3.34	3.48	0.50	3.23	3.97	3.69	1.00	1.57
22	1.33	-0.49	0.00	-0.26	0.36	-0.15	1.12	4.00	2.04	2.22	4.00	2.78	2.95	1.83	3.62	1.00	1.54
23	1.92	-0.12	0.28	-0.36	0.48	-0.45	0.84	0.50	3.79	2.92	3.90	3.83	1.76	2.50	3.48	1.00	1.57
24	1.87	-0.15	0.00	-0.21	0.68	-0.07	3.72	2.57	3.90	2.88	2.64	3.93	2.46	3.06	2.36	1.99	1.57
25	3.79	-0.01	0.00	0.00	0.00	-0.50	3.96	0.50	2.71	3.76	4.00	2.78	3.97	4.00	4.00	1.00	1.57

Table 12. Hinge Mechanism - Linked Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	2.19	-0.26	0.84	-0.01	3.28	2.81	1.83	3.44	2.22	1.24	1.57
2	1.48	-0.13	0.28	-0.48	0.00	1.59	4.00	3.09	0.89	0.50	1.57
3	0.53	-0.01	0.20	-0.11	0.00	1.59	1.69	1.03	1.06	0.57	1.51
4	2.10	-0.08	3.36	-0.13	0.04	4.00	3.79	3.16	0.61	0.89	1.51
5	2.52	-0.50	2.92	-0.01	1.80	3.97	0.50	2.53	0.82	0.64	1.32
6	2.99	-0.30	0.68	-0.06	2.00	3.58	3.02	1.87	2.74	1.59	1.57
7	1.60	-0.01	0.08	-0.12	1.36	2.88	2.74	1.41	2.85	1.52	1.57
8	0.42	-0.03	0.08	-0.03	0.00	1.94	3.51	2.04	1.13	0.50	1.19
9	1.15	-0.04	0.44	-0.17	0.12	2.71	2.92	0.78	1.41	0.54	0.82
10	1.57	-0.02	1.24	-0.29	0.16	2.57	3.06	1.80	1.03	0.57	1.35
11	0.85	-0.02	0.48	-0.19	0.04	1.59	1.97	1.27	0.96	0.64	1.54
12	2.78	-0.36	0.72	-0.15	3.68	1.90	1.52	2.43	1.52	2.67	1.57
13	2.24	-0.05	3.36	-0.22	0.00	3.97	2.39	2.08	0.50	0.50	1.57
14	0.69	0.00	0.00	-0.02	0.12	1.59	1.48	1.10	0.99	0.50	1.41
15	2.33	-0.49	1.80	-0.03	2.52	3.62	1.38	2.99	2.01	1.17	1.45
16	1.48	-0.34	0.60	-0.04	2.28	2.64	2.18	2.11	2.15	1.52	1.48
17	1.11	-0.45	0.76	-0.15	0.76	3.30	1.52	1.90	2.50	0.68	1.57
18	1.15	-0.11	0.80	-0.42	0.48	2.53	3.72	1.62	1.38	0.82	1.23
19	2.07	-0.39	0.20	-0.14	1.68	3.13	2.11	2.53	2.71	0.64	1.54
20	2.74	-0.02	2.20	-0.19	0.60	2.99	3.23	1.90	0.68	0.99	1.51
21	0.72	0.00	0.00	-0.01	0.00	0.54	3.90	3.58	0.50	1.06	1.57
22	4.13	-0.38	2.08	-0.08	2.92	2.29	0.92	2.08	0.61	2.18	1.38
23	1.71	-0.30	1.80	-0.15	0.12	3.41	2.74	1.34	1.76	0.57	1.57
24	0.43	-0.02	0.08	-0.11	0.00	2.15	2.46	0.82	1.45	0.68	1.23
25	1.74	-0.16	1.32	-0.15	0.24	3.23	3.90	1.97	2.01	0.61	1.51

Table 13. Hinge Mechanism - Linked Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	0.97	-0.07	0.40	-0.26	1.68	2.46	3.02	2.88	1.73	1.06	3.16	3.76	4.00	3.41	1.03	0.96	1.32
2	1.63	-0.35	1.84	-0.32	0.08	2.60	3.16	0.78	3.06	2.88	3.41	2.99	3.27	2.43	1.27	0.75	1.54
3	1.74	-0.17	1.60	-0.06	0.12	3.76	2.92	2.08	2.85	1.55	3.65	2.32	1.48	2.60	0.92	1.13	1.16
4	2.84	-0.09	1.36	-0.42	0.64	1.06	1.13	0.61	1.17	0.89	0.85	0.99	2.46	1.38	0.54	1.59	1.48
5	1.45	-0.06	1.12	-0.42	0.08	3.27	1.34	3.30	3.30	2.25	2.36	0.50	3.58	1.17	2.39	0.71	1.54
6	0.66	-0.04	0.24	-0.47	0.08	3.62	3.20	4.00	2.88	1.20	2.71	2.11	3.76	2.32	1.76	0.75	0.88
7	0.86	-0.14	0.04	-0.03	1.44	2.92	3.20	2.46	3.09	1.97	3.72	2.46	3.34	3.55	2.71	1.38	1.35
8	1.34	-0.03	0.72	-0.35	0.56	2.95	3.69	3.23	1.17	1.41	1.80	0.89	2.29	1.87	0.68	1.69	1.48
9	2.72	-0.48	0.24	-0.01	1.44	0.96	0.57	3.90	3.93	2.25	2.67	1.73	3.90	2.64	4.00	1.17	1.57
10	2.39	-0.36	1.20	-0.11	2.24	2.01	3.72	1.41	2.85	2.92	3.41	0.99	1.97	2.81	1.87	1.80	1.54
11	1.73	-0.01	0.76	-0.48	0.48	2.85	2.67	3.44	1.94	1.52	3.09	1.90	3.48	2.50	0.57	1.55	0.85
12	3.05	-0.49	3.84	-0.48	0.16	4.00	4.00	0.50	4.00	3.93	3.93	1.13	3.83	3.20	0.75	1.06	1.54
13	0.59	-0.06	0.16	-0.01	0.08	3.13	2.29	3.37	1.52	2.67	4.00	2.81	1.41	2.71	0.82	1.62	1.13
14	1.75	-0.21	1.32	-0.42	0.04	2.67	3.44	3.79	3.62	2.43	3.51	2.92	3.30	3.55	2.43	0.78	1.51
15	1.68	-0.50	0.20	0.00	0.00	3.83	4.00	2.39	4.00	1.80	4.00	3.37	3.86	3.23	3.69	1.45	1.57
16	0.56	-0.01	0.20	-0.28	0.04	3.02	2.74	2.11	1.66	0.50	1.34	0.85	1.97	1.48	0.78	0.71	1.19
17	3.79	-0.43	0.72	-0.10	2.96	1.66	0.92	2.78	1.17	3.23	3.79	2.64	1.59	3.83	0.82	2.36	1.54
18	0.30	-0.01	0.00	-0.01	0.04	2.92	3.83	3.97	2.64	2.11	2.85	1.97	2.78	1.66	1.13	0.50	0.13
19	0.44	-0.01	0.08	0.00	0.00	3.23	2.78	2.57	1.27	2.32	3.76	2.53	3.20	2.85	0.75	0.85	1.35
20	1.29	-0.15	0.28	-0.09	0.00	3.02	3.97	3.93	3.72	3.79	3.97	3.72	3.97	3.93	2.88	0.54	1.16
21	1.75	-0.30	1.80	-0.07	0.20	3.90	3.51	2.81	3.69	2.74	3.93	1.41	1.73	2.36	1.62	0.54	1.29
22	0.37	-0.01	0.08	-0.03	0.00	3.72	3.69	3.41	2.71	2.71	3.86	1.97	3.58	2.04	1.87	0.92	1.04
23	2.52	-0.33	1.84	-0.40	0.08	2.78	2.78	2.64	3.16	2.25	2.95	1.24	3.23	2.25	1.59	1.17	1.51
24	0.84	-0.04	0.12	-0.29	0.00	0.71	3.69	0.50	0.85	3.76	3.72	0.54	1.31	0.99	0.50	0.92	1.54
25	4.33	-0.02	2.36	-0.50	1.52	2.11	2.99	3.13	2.71	2.22	3.86	2.46	2.92	2.46	0.50	2.43	1.41

Table 14. Hinge Mechanism - Linked Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	2.81	-0.30	0.92	-0.20	0.44	2.81	2.57	2.11	0.82	1.38	3.13	3.48	3.34	1.69	2.08	1.69	-1.57
2	2.14	-0.01	1.12	-0.18	0.00	3.83	2.99	3.41	1.27	3.09	2.67	1.13	2.39	3.16	3.37	0.78	0.82
3	1.93	-0.01	1.92	-0.01	1.12	3.90	3.09	3.51	1.48	1.17	1.38	1.55	1.52	3.86	2.32	3.06	1.57
4	2.24	0.00	0.00	-0.38	0.00	1.90	3.97	4.00	1.73	0.50	4.00	3.76	2.43	1.69	3.13	2.99	0.38
5	2.26	-0.40	0.12	-0.26	1.60	3.62	2.36	3.23	1.06	1.06	2.64	1.83	1.20	2.88	1.38	0.50	-0.19
6	1.46	-0.32	0.36	-0.14	0.32	2.50	2.81	1.24	1.66	2.43	2.71	2.64	0.89	0.54	2.99	2.50	1.57
7	1.92	-0.28	0.04	-0.27	0.00	3.09	0.68	2.64	2.67	2.78	2.22	2.78	1.83	2.92	1.59	3.86	0.88
8	2.47	-0.21	0.88	-0.11	0.88	1.97	1.20	3.69	2.88	2.46	2.18	2.36	1.80	3.97	0.92	1.76	1.29
9	1.22	-0.25	1.32	-0.05	0.32	3.41	2.08	2.53	1.10	2.29	1.90	2.36	2.85	2.71	1.73	0.75	-1.23
10	2.28	-0.30	0.60	-0.40	0.04	2.60	3.51	3.44	2.43	2.29	2.18	1.27	2.32	1.38	1.34	2.60	1.57
11	1.56	-0.50	0.92	-0.26	0.08	1.90	2.99	3.27	2.18	1.76	2.18	1.52	3.16	3.41	2.08	2.46	1.51
12	1.18	-0.46	0.12	-0.08	0.00	1.87	1.66	2.74	3.62	4.00	3.27	1.10	4.00	3.72	4.00	0.50	1.57
13	1.24	-0.42	0.88	-0.47	0.48	1.83	3.86	3.06	3.83	1.90	3.06	2.36	3.90	2.64	3.41	2.81	1.19
14	0.78	-0.15	0.56	-0.05	0.16	2.57	0.64	3.79	3.65	2.11	2.74	2.88	2.15	1.20	2.01	1.10	-1.32
15	1.93	-0.33	1.52	-0.06	1.64	1.34	3.34	2.29	2.22	2.32	2.71	2.99	1.97	0.82	2.11	0.64	1.51
16	0.51	-0.40	0.20	-0.05	0.12	2.22	2.78	2.32	1.45	0.50	1.55	0.96	1.62	2.22	0.92	0.68	-0.13
17	2.83	-0.18	1.08	-0.25	0.56	3.86	3.34	2.04	2.46	2.04	2.29	2.22	1.94	1.80	1.31	3.86	1.54
18	1.65	-0.44	2.04	-0.03	0.88	0.89	3.23	3.83	0.64	0.68	2.92	2.60	3.62	3.23	0.71	0.99	-0.50
19	0.47	-0.40	0.04	-0.04	0.00	1.62	4.00	3.65	1.80	3.13	2.81	2.43	2.92	3.76	0.54	1.90	0.16
20	1.02	-0.28	0.20	-0.08	0.00	1.27	1.03	3.20	2.22	1.87	1.80	1.59	1.45	1.55	1.10	3.06	1.19
21	3.52	-0.29	2.96	-0.38	2.68	3.37	3.27	3.69	2.64	0.89	1.76	3.97	2.85	2.74	0.78	0.71	-0.63
22	1.81	-0.04	0.72	-0.22	0.44	3.58	2.99	3.37	1.27	0.61	3.62	2.18	3.86	2.60	1.59	3.55	1.48
23	2.23	-0.44	0.00	-0.23	0.00	4.00	3.72	3.41	1.87	3.58	3.37	2.18	2.67	3.83	2.15	0.50	1.57
24	0.83	-0.27	0.56	-0.28	0.24	1.62	2.88	3.48	1.38	1.06	2.43	3.51	3.55	3.30	0.68	1.45	-1.07
25	3.05	-0.36	0.20	-0.27	0.32	2.95	2.01	2.43	0.85	3.41	2.11	1.97	3.13	2.25	2.15	0.89	0.19

Table 15. Hinge Mechanism - Linked Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	3.44	-0.36	1.52	-0.35	2.00	-0.06	3.68	3.16	1.69	0.82	1.87	3.37	3.34	2.36	2.95	2.67	1.54
2	1.71	-0.29	0.32	-0.34	1.64	-0.16	2.96	2.85	2.67	0.96	2.57	1.76	2.74	2.64	2.81	1.76	1.57
3	1.29	-0.01	2.48	-0.30	1.40	-0.28	0.20	3.97	3.16	2.74	1.66	1.20	2.81	1.55	1.38	0.54	1.54
4	2.14	-0.42	2.36	-0.32	1.48	-0.29	0.56	3.58	3.93	3.79	1.24	2.57	3.86	1.34	2.22	1.13	1.54
5	2.08	-0.02	3.88	-0.35	1.68	-0.33	0.48	3.02	3.51	3.58	2.01	1.62	2.64	1.24	0.71	0.54	1.13
6	1.89	-0.22	3.40	-0.25	3.44	-0.38	0.04	3.55	3.76	1.59	3.13	2.74	2.92	2.22	0.68	0.82	1.57
7	2.93	-0.39	1.36	-0.44	0.60	0.00	2.36	2.50	1.80	1.90	2.43	2.32	2.95	2.46	2.95	1.24	1.19
8	1.63	-0.33	1.68	-0.05	1.96	-0.03	0.00	1.27	3.02	1.38	3.62	2.57	1.31	0.99	0.82	0.61	1.57
9	2.21	-0.04	0.48	-0.20	1.56	-0.03	1.84	1.10	1.20	2.74	1.94	2.46	2.78	1.87	3.09	1.66	1.57
10	1.40	-0.02	1.16	-0.10	3.52	-0.16	0.44	0.78	1.87	2.39	2.74	3.44	3.90	2.15	1.27	0.54	1.29
11	3.33	-0.27	1.04	-0.19	3.00	-0.04	4.00	3.13	3.48	2.36	2.78	3.44	3.48	2.99	2.60	2.01	1.57
12	2.31	-0.09	2.60	-0.30	3.96	-0.22	0.20	1.38	2.29	2.74	3.72	2.67	3.58	2.15	1.52	0.54	1.48
13	1.97	-0.45	0.40	-0.48	2.52	-0.03	3.36	1.06	2.53	1.17	3.58	3.55	1.94	2.74	1.80	2.15	1.51
14	1.78	-0.17	1.20	-0.21	1.00	-0.10	0.28	1.45	3.06	3.51	4.00	2.04	3.86	0.50	2.64	0.89	1.01
15	1.56	-0.22	2.40	-0.45	1.56	-0.32	0.16	1.90	3.62	2.01	2.29	2.67	2.71	2.01	0.61	0.82	1.57
16	1.45	-0.18	0.32	-0.43	1.04	-0.15	1.04	3.09	3.27	2.67	1.62	2.15	1.76	1.94	2.32	0.57	1.41
17	1.27	-0.02	1.12	-0.45	2.68	-0.31	0.04	2.53	2.92	1.31	2.85	2.67	3.09	1.10	2.11	0.61	1.54
18	1.84	-0.39	2.16	-0.16	3.44	-0.25	0.16	1.31	2.22	2.57	3.90	3.23	3.20	1.62	1.69	0.50	1.54
19	2.89	-0.42	2.28	-0.14	1.48	-0.28	3.72	2.15	0.99	1.52	1.48	0.75	0.54	3.93	0.92	1.41	1.48
20	2.30	-0.37	3.76	-0.01	2.60	-0.35	0.04	2.11	1.76	3.06	2.99	1.24	3.72	2.88	0.68	0.50	1.45
21	2.51	-0.30	3.00	-0.33	2.00	-0.29	0.60	2.74	3.83	2.57	2.29	3.37	3.20	1.20	1.69	1.03	1.54
22	2.96	-0.46	1.68	-0.49	3.04	-0.10	2.04	1.90	0.99	2.04	2.88	3.90	0.57	1.83	0.92	1.76	1.57
23	1.90	-0.41	0.44	-0.35	2.40	-0.29	0.40	3.34	3.97	1.59	3.58	3.27	2.81	1.03	3.30	0.99	1.48
24	2.38	-0.25	1.12	-0.14	2.08	-0.01	2.08	1.20	2.85	1.13	2.92	2.25	1.06	1.97	0.78	1.31	1.41
25	1.40	-0.20	0.24	-0.40	2.92	-0.11	0.36	3.34	3.48	1.06	3.51	2.67	3.02	0.85	3.16	0.92	1.45

Table 16. Hinge Mechanism - Linked Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	4.84	-0.31	2.20	-0.04	1.80	2.04	3.06	2.88	2.64	1.45	3.16	1.97	3.93	3.27	0.54	0.64	1.48
2	4.92	-0.04	1.72	-0.07	3.88	2.32	3.51	3.62	3.09	3.79	3.97	1.45	3.44	3.41	2.32	1.52	1.41
3	1.85	-0.41	1.96	-0.30	0.24	2.64	2.92	1.10	2.25	2.08	3.93	2.60	3.27	2.78	0.57	0.54	1.32
4	2.48	-0.04	1.08	-0.10	0.68	1.10	1.48	0.54	1.38	1.10	0.99	0.61	2.46	0.85	0.50	1.45	1.54
5	2.31	-0.02	0.32	-0.48	3.08	2.88	2.74	3.62	2.46	2.53	1.59	2.01	3.09	0.78	0.64	0.64	0.75
6	2.16	-0.47	3.00	-0.22	0.36	3.48	2.22	1.90	3.83	1.38	2.71	1.62	3.79	0.89	1.20	1.20	0.57
7	2.14	-0.43	1.16	-0.17	1.44	3.06	2.01	3.16	1.97	0.99	0.89	0.99	3.16	1.87	0.68	0.99	1.38
8	4.09	-0.07	0.92	-0.19	1.64	3.02	3.79	3.27	1.20	1.69	1.59	0.85	1.41	1.41	1.55	1.45	1.57
9	3.19	-0.46	0.32	-0.30	1.44	0.99	0.57	3.72	4.00	2.25	2.74	1.03	3.93	2.25	4.00	1.06	1.57
10	3.87	-0.11	1.36	-0.11	2.92	1.62	1.24	2.29	2.57	3.72	3.44	0.85	2.50	3.23	3.48	1.38	1.54
11	3.62	-0.07	1.04	-0.01	2.68	1.34	2.11	2.50	2.01	3.30	2.71	0.61	2.88	1.97	2.46	1.62	1.54
12	1.93	-0.27	3.84	-0.46	0.00	4.00	3.90	0.89	4.00	3.79	3.16	1.10	3.86	2.43	0.71	0.50	1.57
13	4.67	-0.03	1.96	-0.07	3.16	2.01	3.58	2.04	2.53	2.64	2.43	1.59	1.48	2.74	1.48	2.53	1.57
14	3.02	-0.06	1.44	-0.14	3.40	2.39	1.62	2.53	2.43	2.50	1.97	2.57	3.37	1.20	1.59	1.06	1.54
15	2.87	-0.34	1.32	-0.04	3.92	2.08	2.78	1.94	2.67	3.13	2.92	0.61	1.66	3.58	1.34	1.80	1.38
16	1.55	-0.43	0.32	-0.15	0.08	2.43	2.78	2.25	1.66	1.06	1.87	0.92	2.39	0.78	1.45	0.71	1.10
17	5.14	0.00	3.60	0.00	0.04	3.76	3.06	1.31	2.78	3.23	3.65	0.89	4.00	3.37	0.89	0.50	1.57
18	0.44	-0.01	0.00	-0.02	0.08	0.92	1.38	0.57	1.76	1.87	2.43	0.68	2.22	1.55	0.96	0.50	1.57
19	2.16	-0.14	2.28	-0.21	0.64	2.15	3.37	1.97	1.48	2.78	3.20	0.54	2.85	0.96	0.57	0.57	1.13
20	2.72	-0.19	3.76	-0.20	0.76	3.97	2.25	1.38	1.59	1.27	1.83	0.82	3.48	2.01	0.64	0.64	1.57
21	2.64	-0.12	2.76	-0.11	0.80	3.13	2.78	1.97	1.52	1.73	1.62	0.96	3.55	0.96	1.41	0.82	1.54
22	2.77	-0.05	3.16	-0.03	0.60	2.71	3.27	1.52	3.86	3.16	3.16	0.99	3.55	1.87	0.61	0.89	1.29
23	2.35	-0.19	0.84	-0.20	2.76	2.99	3.69	2.36	2.88	2.46	2.67	0.82	1.97	3.27	2.29	1.20	1.54
24	5.88	-0.41	2.64	-0.04	1.88	1.24	2.22	1.83	3.90	1.87	2.04	2.04	3.30	2.39	1.10	2.04	1.57
25	2.21	-0.01	1.44	-0.02	0.44	4.00	1.94	0.89	1.20	2.57	2.08	0.61	3.58	0.50	2.74	0.85	1.51

Table 17. Hinge Mechanism - Linked Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	1.81	-0.12	1.20	-0.44	1.44	-0.41	0.36	0.99	2.53	2.08	2.71	2.22	2.95	1.31	1.10	0.92	1.38
2	2.25	-0.09	1.16	-0.13	0.56	-0.11	3.72	2.95	2.74	1.06	2.95	2.78	2.99	2.78	2.78	2.46	1.57
3	1.27	-0.02	1.24	-0.09	1.12	-0.49	0.20	0.92	1.80	2.53	2.43	1.20	2.85	1.52	1.03	0.61	1.45
4	1.94	-0.30	1.48	-0.41	1.32	-0.01	1.36	3.23	1.03	3.48	2.36	2.25	0.61	1.94	0.78	0.75	1.48
5	1.96	-0.49	1.40	-0.32	0.28	-0.12	1.88	3.79	2.01	3.13	3.86	3.93	2.99	2.46	3.23	0.85	1.35
6	1.49	-0.24	0.52	-0.10	1.36	-0.45	0.20	1.97	1.87	2.50	1.94	2.57	3.93	3.27	0.57	0.78	1.54
7	3.06	-0.40	0.88	-0.49	0.72	-0.46	3.60	3.20	2.36	1.69	2.25	0.92	2.08	2.85	1.59	2.04	1.51
8	1.49	-0.32	1.72	-0.01	1.96	-0.26	0.08	2.81	2.74	1.38	2.46	3.37	1.76	1.27	0.50	0.96	1.57
9	2.06	-0.26	0.68	-0.46	0.92	-0.19	2.60	2.71	2.81	1.83	3.20	2.29	2.46	2.32	2.64	1.69	1.57
10	1.10	-0.06	0.28	-0.34	0.40	-0.01	1.44	2.04	1.62	3.34	2.43	3.41	2.11	1.34	2.22	1.45	1.57
11	2.74	-0.06	0.84	-0.37	1.76	-0.06	0.64	2.29	1.31	0.78	1.97	2.15	1.38	0.57	0.57	1.55	1.57
12	0.80	-0.20	2.64	-0.19	0.20	-0.24	0.00	3.83	3.51	3.90	2.60	2.99	3.86	1.59	1.83	0.71	1.26
13	1.69	-0.46	2.08	-0.42	0.56	-0.21	3.36	3.27	1.66	3.93	3.93	2.60	3.16	3.55	3.58	1.34	1.57
14	1.24	-0.48	1.20	-0.20	0.92	-0.33	0.28	1.34	3.23	3.20	3.93	3.97	4.00	0.71	2.60	0.92	1.13
15	1.41	-0.01	0.12	-0.13	1.56	-0.32	0.16	3.06	3.27	2.15	2.32	2.64	2.85	2.01	0.71	0.89	1.57
16	1.56	-0.20	1.20	0.00	1.36	-0.37	0.28	2.92	3.97	2.95	2.43	3.55	3.23	1.97	0.64	0.78	1.29
17	2.28	-0.18	1.20	-0.45	0.56	-0.15	2.84	2.29	2.67	2.04	2.46	3.72	2.29	2.22	2.01	1.97	1.57
18	1.67	-0.20	1.84	-0.33	1.00	-0.06	1.40	2.88	2.22	3.44	2.81	2.25	1.13	2.15	1.87	0.85	1.48
19	3.45	-0.08	1.72	-0.03	0.52	-0.08	2.84	3.51	2.29	3.30	1.76	2.92	2.01	2.01	1.27	1.97	1.35
20	1.85	-0.44	1.48	-0.27	2.32	-0.41	0.08	2.15	3.48	2.57	3.65	3.37	2.88	1.66	1.31	0.50	1.54
21	3.30	-0.19	1.76	-0.41	1.88	0.00	1.80	1.90	4.00	2.08	3.65	3.48	2.08	1.45	1.94	1.83	1.48
22	2.65	-0.27	0.24	-0.20	0.64	-0.33	3.36	3.51	1.76	3.41	3.44	3.23	3.13	2.85	3.06	2.04	1.57
23	2.08	-0.11	1.08	-0.14	2.16	-0.27	0.48	3.83	3.97	3.79	3.34	3.13	2.67	1.03	1.20	1.10	1.38
24	1.45	-0.07	0.52	-0.40	0.12	-0.02	3.60	4.00	3.97	3.83	4.00	3.69	3.62	3.90	3.90	0.99	1.57
25	4.88	-0.05	1.68	-0.01	2.60	-0.31	1.64	1.94	2.29	3.76	3.97	2.50	4.00	1.03	1.03	1.24	0.88

Table 18. Hinge Mechanism - Convertible Agent Results.

Run	Type	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	S2	0.29	-0.49	0.20	0.00	0.00	-	-	2.81	2.57	2.08	4.00	3.93	2.53	3.06	3.72	3.62	0.61	3.34	1.04
2	S1	1.68	-0.01	1.32	-0.45	0.44	-	-	2.57	1.10	1.83	2.15	2.29	3.37	1.27	3.86	1.45	0.75	1.24	1.35
3	W2	1.63	-0.48	0.56	-0.38	1.68	-0.44	0.32	2.36	0.96	3.97	3.83	2.71	3.72	1.34	2.36	0.71	-	-	1.54
4	S3	1.05	-0.08	0.52	-0.37	0.28	-0.05	1.16	2.25	2.11	2.22	0.92	2.08	2.39	1.45	2.57	1.06	-	-	1.51
5	S1	1.24	-0.29	0.08	-0.02	1.32	-	-	3.30	0.68	2.88	3.69	3.90	3.93	0.61	3.44	1.97	3.48	0.64	1.54
6	S2	0.86	-0.46	1.68	-0.06	0.00	-	-	3.97	3.30	1.97	1.45	1.94	3.30	2.99	2.18	1.83	1.87	1.55	-1.48
7	S2	0.42	-0.33	1.72	-0.13	0.08	-	-	2.11	1.59	2.60	1.97	2.01	3.58	0.61	3.34	2.01	1.13	1.38	0.69
8	4B	0.92	-0.20	0.00	-0.01	3.12	-	-	3.86	3.69	3.30	3.86	1.31	-	-	-	-	-	-	1.57
9	S3	0.59	-0.01	2.32	-0.33	3.72	-0.01	0.04	0.82	1.31	3.69	3.20	1.80	3.37	2.71	0.64	0.50	-	-	1.45
10	S3	1.32	-0.12	4.00	-0.14	1.72	-0.37	0.40	2.92	2.46	3.51	1.17	2.71	3.44	0.96	2.22	0.92	-	-	1.48
11	S1	0.65	-0.10	0.32	-0.29	0.24	-	-	2.53	3.76	2.74	2.46	1.69	2.95	2.25	3.79	2.53	2.29	1.90	1.54
12	S1	1.57	-0.50	0.96	-0.06	1.92	-	-	2.99	3.30	3.27	3.79	3.13	3.65	1.13	2.95	2.88	3.02	1.52	1.54
13	W2	0.53	-0.01	1.00	-0.10	0.04	-0.01	1.80	2.67	2.78	2.32	2.57	3.55	2.50	1.83	2.53	1.45	-	-	1.57
14	S2	0.80	-0.27	0.12	-0.10	0.04	-	-	1.87	3.13	3.65	3.06	4.00	2.92	2.67	1.55	2.50	1.27	1.17	-1.23
15	S2	0.32	-0.13	0.28	-0.01	0.04	-	-	0.92	2.50	2.15	0.85	1.87	3.69	1.59	3.76	2.78	1.94	2.92	1.54
16	S1	1.01	-0.31	0.24	-0.01	1.08	-	-	3.30	1.55	2.71	3.83	3.58	4.00	1.55	3.76	2.36	3.48	0.54	1.54
17	S2	0.30	-0.36	0.12	-0.01	0.00	-	-	1.13	1.83	2.15	2.11	2.25	3.41	2.60	3.20	2.50	1.06	3.79	1.41
18	S1	0.93	-0.11	0.68	-0.45	0.64	-	-	1.69	4.00	3.83	2.60	3.44	3.41	1.69	3.48	2.15	1.31	1.55	0.97
19	S2	0.91	-0.35	0.68	-0.07	0.24	-	-	1.55	1.76	2.95	3.44	1.80	0.78	1.31	1.97	1.69	1.45	2.92	1.57
20	S2	0.57	-0.04	0.32	-0.26	0.16	-	-	1.41	2.95	0.64	2.36	3.83	1.76	3.23	3.93	3.93	0.50	0.50	1.48
21	S1	0.54	-0.22	0.24	0.00	0.04	-	-	2.15	3.79	3.23	2.99	2.92	3.55	2.88	2.92	2.36	2.32	1.97	1.32
22	4B	1.50	-0.50	0.56	-0.01	1.56	-	-	3.93	2.71	2.36	3.34	0.68	-	-	-	-	-	-	1.57
23	S1	0.32	-0.03	0.04	0.00	0.04	-	-	3.27	3.16	2.74	3.79	2.53	3.69	3.23	3.90	3.34	3.13	0.78	1.16
24	S2	1.02	-0.28	0.08	-0.24	0.56	-	-	2.18	1.10	1.27	2.29	2.74	2.71	2.64	2.29	3.72	0.68	1.97	1.51
25	W2	1.29	-0.42	1.88	-0.49	1.32	-0.02	0.92	3.13	1.03	2.22	2.43	2.01	0.64	1.41	1.24	1.17	-	-	1.54

Appendix C - Leg Mechanism Case Study - Raw Data

Table 19. Leg Mechanism - Independent Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	8.59	8.90	23.20	-6.05	24.00	7.30	22.05	12.80	14.80	12.30	-1.13
2	17.13	-7.00	22.50	8.70	22.80	16.80	20.70	19.30	1.25	14.75	1.13
3	6.62	8.90	22.30	-5.40	22.55	6.40	20.20	8.35	13.50	14.35	-0.50
4	8.52	4.90	22.30	-8.10	23.10	9.35	15.80	17.65	13.40	7.75	-0.19
5	8.52	6.75	22.95	-8.70	22.15	10.55	16.60	16.80	13.50	7.60	0.91
6	9.47	9.00	22.95	-6.20	23.55	12.75	12.70	16.05	20.15	4.65	1.23
7	1.28	9.00	22.25	-8.10	22.55	5.60	6.85	12.35	18.65	6.90	0.75
8	3.85	9.00	23.95	-3.70	22.30	5.55	5.55	9.00	20.80	0.85	-0.13
9	7.29	6.65	22.20	-5.75	23.50	5.85	24.65	13.30	13.10	14.15	-0.91
10	11.58	5.30	23.45	-7.15	23.40	9.85	24.75	11.00	18.35	14.85	0.03
11	11.40	-1.70	22.70	-7.45	22.30	6.05	8.95	10.40	10.65	12.95	-1.35
12	10.07	8.05	23.15	-9.00	23.70	8.40	22.80	19.90	15.15	8.35	0.47
13	2.20	9.00	22.85	-8.45	22.55	11.30	16.30	11.40	22.90	12.60	0.60
14	9.20	3.15	22.15	-7.85	22.80	5.70	22.85	14.70	8.50	14.00	0.09
15	6.42	6.90	23.20	-7.55	22.80	11.80	13.40	12.70	22.30	10.10	-0.50
16	8.20	9.00	22.30	-2.95	23.40	8.50	23.00	14.45	17.70	10.05	-1.10
17	8.33	4.85	22.05	-5.85	23.15	8.45	11.20	11.65	9.20	12.20	0.22
18	8.54	7.15	22.65	-5.95	23.55	6.90	21.40	12.80	13.15	12.50	-1.38
19	10.23	5.35	22.75	-8.10	22.10	6.35	2.90	9.05	14.70	9.65	0.82
20	17.78	-3.70	23.80	-3.60	22.00	13.10	0.80	12.00	10.05	3.60	0.94
21	9.77	3.70	22.85	-8.60	23.05	8.70	21.90	22.45	16.75	5.60	-1.19
22	8.89	8.95	22.45	-3.95	23.80	10.55	24.50	10.05	21.15	13.80	1.04
23	9.68	6.40	23.45	-8.00	22.75	7.65	24.25	12.50	13.95	13.30	-0.60
24	10.89	6.75	23.50	-6.35	22.85	8.75	21.55	12.00	14.80	12.20	-0.66
25	2.58	7.55	22.05	-8.80	22.10	5.55	6.05	11.15	15.85	10.35	1.48

Table 20. Leg Mechanism - Independent Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	8.42	8.10	22.15	-4.50	22.20	7.25	16.45	10.35	8.45	8.45	19.65	12.50	18.70	12.85	15.30	16.75	-0.41
2	7.66	1.50	23.00	-8.30	22.35	6.20	20.85	7.50	6.05	21.10	19.60	20.30	20.00	17.65	16.20	4.90	-0.44
3	29.94	-7.95	23.75	-1.90	22.05	22.00	13.35	14.15	11.75	15.70	12.40	5.75	9.50	23.30	2.25	9.20	0.91
4	16.95	-9.00	23.45	6.05	23.45	16.00	25.00	1.40	16.10	21.70	14.40	16.00	25.00	24.85	0.50	13.35	-1.54
5	10.61	4.10	23.75	-5.40	22.10	15.35	19.25	17.05	10.30	13.55	16.00	6.40	16.95	15.80	16.40	7.05	-0.09
6	11.08	8.90	22.85	-9.00	22.50	5.85	20.35	20.45	22.45	8.35	10.05	10.75	24.90	24.55	18.00	4.00	1.35
7	5.01	8.85	23.45	-6.60	23.05	11.35	19.40	12.40	7.10	4.80	17.40	17.35	17.55	23.05	21.80	1.40	0.19
8	7.24	-3.30	22.15	7.15	22.15	5.40	10.95	13.15	14.90	14.50	18.75	13.00	11.70	15.35	9.30	22.05	-0.28
9	3.58	-4.80	22.70	7.95	22.35	11.00	24.80	18.40	19.75	21.80	21.20	17.35	12.25	15.75	6.10	24.70	0.94
10	10.95	-1.10	22.95	-8.90	22.95	12.65	16.95	21.30	14.25	7.60	18.70	14.15	24.95	24.50	23.05	5.40	-0.57
11	14.82	-0.10	23.95	-9.00	22.85	9.65	22.00	16.60	7.75	19.70	18.85	6.75	15.80	13.90	20.75	11.05	-0.79
12	1.52	2.30	23.35	-7.45	23.10	12.20	19.70	16.90	6.00	11.00	15.75	10.50	9.60	14.50	14.15	9.90	0.66
13	11.50	6.25	22.80	8.45	23.50	10.45	11.55	22.50	15.00	3.90	19.95	19.25	19.85	21.40	24.15	16.25	1.04
14	6.59	-6.45	23.85	-0.75	22.80	21.70	24.45	14.80	15.45	24.55	24.20	16.40	3.65	24.05	21.65	9.95	-0.53
15	11.84	1.30	22.10	-3.80	23.95	15.70	24.05	23.25	13.65	13.80	24.65	12.55	21.75	24.95	20.50	1.95	-1.41
16	7.17	7.10	22.15	-8.95	23.05	17.00	9.10	18.95	8.55	14.90	17.40	8.55	21.15	22.60	15.40	0.50	-0.57
17	8.54	6.75	23.35	-7.65	22.15	9.50	24.10	1.85	8.10	16.25	22.65	18.05	23.75	15.70	7.55	15.15	1.35
18	9.40	5.00	22.80	-9.00	23.25	8.45	25.00	11.25	13.65	18.25	24.80	15.95	24.40	23.85	11.25	11.90	-1.29
19	13.49	1.35	22.90	5.40	24.00	1.90	9.05	6.10	6.85	10.70	12.85	16.90	10.45	15.25	9.60	20.55	-0.91
20	14.85	-9.00	22.40	4.25	22.00	25.00	25.00	25.00	10.45	25.00	23.25	18.85	8.75	18.75	25.00	0.50	1.57
21	19.29	9.00	22.60	-5.70	23.25	18.50	24.10	12.15	12.95	18.80	19.70	10.50	10.90	8.15	18.50	3.50	0.31
22	4.02	-0.40	22.55	8.85	22.55	18.45	24.10	19.60	16.60	10.55	20.15	21.20	15.45	21.05	4.90	22.90	-0.41
23	10.48	7.30	23.30	-4.60	22.25	17.55	16.75	18.25	18.80	5.30	23.85	20.60	22.95	17.15	2.70	12.75	-1.41
24	22.57	-4.65	23.05	7.65	22.05	12.10	6.20	18.90	16.75	12.30	18.70	19.20	2.70	18.70	22.10	15.40	1.10
25	22.88	5.70	23.05	-5.85	23.95	8.05	24.35	18.25	12.35	10.25	12.25	6.20	4.70	5.20	11.45	19.70	-0.57

Table 21. Leg Mechanism - Independent Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	28.17	8.45	22.20	8.50	22.35	13.15	21.00	20.15	12.90	15.70	11.65	15.05	14.60	12.80	15.45	6.40	1.04
2	29.65	-3.40	24.00	4.55	22.30	1.05	10.80	12.90	21.45	19.10	9.60	12.85	15.60	19.00	18.30	14.30	-1.19
3	20.90	-3.25	22.40	-3.00	22.60	11.10	23.80	23.35	8.25	20.45	9.35	15.75	6.60	16.50	14.05	10.80	0.85
4	22.56	-5.10	22.70	-8.25	22.80	5.80	7.20	18.75	16.00	17.75	21.45	7.50	18.65	15.00	7.30	15.30	1.45
5	24.91	-0.65	23.05	-2.35	23.00	16.85	8.50	13.20	12.55	17.55	7.40	17.15	15.70	19.75	13.95	5.60	1.54
6	19.48	4.20	23.10	2.85	23.10	3.20	17.10	14.45	19.20	8.40	10.60	10.40	15.10	2.60	18.30	15.90	-0.28
7	14.15	-5.10	23.30	-4.10	23.15	9.50	20.35	12.65	13.30	15.35	8.10	9.60	1.50	3.50	12.85	16.65	-0.44
8	27.22	-0.55	22.20	-7.40	23.00	1.35	6.90	13.50	16.20	10.10	9.20	13.05	10.15	20.50	2.15	8.05	0.79
9	29.68	-9.00	23.95	-6.65	23.10	0.75	25.00	8.40	23.15	25.00	24.90	22.45	25.00	20.25	20.15	12.60	-0.57
10	15.37	-3.15	23.90	-3.45	23.40	6.15	6.45	7.50	10.05	14.00	8.90	5.50	5.35	18.00	4.30	16.45	-0.06
11	18.23	-2.20	23.40	-8.70	22.65	7.65	11.95	8.10	12.35	20.10	9.50	8.25	7.75	16.00	23.80	16.90	-0.53
12	21.86	6.65	22.50	-0.65	23.40	3.00	9.80	7.60	11.35	19.20	6.75	6.65	9.55	17.95	15.90	20.35	1.32
13	32.82	-3.65	22.40	0.45	22.10	0.50	14.55	23.60	20.25	14.75	15.35	10.95	5.30	9.10	20.75	21.50	1.35
14	30.08	-1.15	22.35	-0.85	22.25	4.75	8.10	12.50	9.95	22.60	13.45	13.00	11.45	22.55	17.40	13.00	-1.04
15	12.87	-2.45	23.60	-7.95	22.65	2.50	5.65	2.95	8.10	20.70	15.45	12.30	20.35	14.25	8.70	18.70	-1.29
16	28.20	5.55	23.05	5.90	23.30	22.75	10.30	10.65	3.70	10.50	14.10	17.95	18.55	11.45	15.60	19.70	0.28
17	34.02	7.05	22.80	8.60	23.35	6.95	6.70	17.80	18.55	13.50	18.95	14.10	25.00	12.35	0.55	16.00	0.41
18	32.17	-4.70	22.00	-3.20	23.80	5.60	24.35	18.00	17.95	20.15	7.85	4.35	7.35	19.15	14.00	22.00	-1.07
19	33.18	-1.15	22.95	-0.85	22.90	3.30	19.30	23.00	12.15	21.30	19.45	16.50	19.55	12.65	10.10	3.25	1.01
20	21.27	-3.25	23.90	-6.30	23.80	1.20	7.15	9.40	15.45	17.50	12.30	21.00	15.10	13.05	8.60	12.95	1.16
21	25.08	-7.15	23.20	-7.10	23.35	23.60	23.90	24.60	9.70	16.00	6.55	10.95	8.10	17.70	25.00	13.90	0.66
22	31.74	4.20	23.50	4.50	23.45	8.05	6.95	6.70	5.40	15.25	16.35	11.40	20.60	15.05	20.00	18.75	0.72
23	21.88	-2.45	22.35	-3.75	23.00	14.00	20.30	11.20	23.85	22.85	11.90	7.00	17.00	17.60	18.90	21.10	1.07
24	15.84	-8.80	22.40	-8.70	22.70	10.30	9.55	17.15	12.05	23.40	20.90	17.85	20.60	24.30	16.80	20.35	-1.57
25	10.97	2.25	22.60	2.25	24.00	5.00	11.00	24.85	20.00	16.75	15.25	16.20	22.70	14.00	24.85	9.75	-1.45

Table 22. Leg Mechanism - Independent Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	9.19	5.10	22.30	-5.00	22.55	3.10	22.20	11.45	16.55	12.30	6.40	10.85	12.15	13.30	5.00	9.85	0.41
2	9.10	4.80	23.00	-8.05	23.25	-1.40	23.65	9.20	19.10	11.95	23.50	12.75	22.75	18.85	14.15	3.90	-0.69
3	5.13	4.15	22.00	-6.25	23.80	2.10	22.05	11.95	24.75	22.55	16.10	20.05	22.55	9.20	14.80	10.85	1.54
4	18.18	3.90	22.65	-9.00	22.15	-6.95	24.00	8.55	18.85	10.45	14.05	15.05	22.15	12.90	12.90	10.55	1.07
5	6.36	8.95	23.25	-8.90	22.00	5.50	22.10	12.75	22.95	16.50	16.25	13.40	23.65	24.95	10.40	1.35	-1.45
6	8.67	6.80	23.65	-7.75	22.75	-8.55	23.55	10.30	22.75	7.90	24.95	18.25	13.80	17.70	8.70	6.05	0.91
7	9.17	7.60	22.85	-7.30	23.30	-1.40	23.90	10.90	20.95	8.30	17.15	14.40	6.55	6.10	16.65	11.90	0.22
8	9.23	-4.65	22.45	-8.40	23.50	-8.40	22.70	5.05	1.85	24.10	25.00	7.30	16.55	16.30	22.30	8.70	0.28
9	10.98	8.15	22.80	8.90	23.30	-6.00	23.95	11.65	11.85	11.05	10.25	1.80	24.95	9.45	21.60	15.15	-0.69
10	6.02	6.55	22.20	-8.40	22.60	4.15	23.30	10.50	22.85	12.35	16.25	17.75	22.95	19.45	14.10	6.50	-1.38
11	5.07	7.05	23.00	-5.40	23.40	-8.80	22.00	8.30	14.50	11.80	13.90	17.40	18.25	12.80	21.10	10.25	-0.75
12	3.04	9.00	22.35	-5.55	23.45	2.00	22.40	8.50	23.25	12.15	16.90	22.15	3.05	9.50	17.50	6.25	-0.85
13	5.25	8.40	23.80	-4.05	23.45	0.55	23.25	15.85	23.10	22.45	20.30	7.50	22.55	7.10	13.80	12.45	0.03
14	5.26	8.75	22.60	-4.95	23.30	-0.40	22.45	7.75	23.45	13.80	13.25	15.15	17.60	8.00	1.55	8.35	0.60
15	8.83	6.65	22.25	-7.65	22.60	2.85	23.35	12.65	17.90	15.90	10.65	11.40	9.95	11.90	2.00	7.45	1.10
16	8.10	3.15	22.65	-6.45	22.50	-3.20	22.40	5.15	15.45	9.50	13.95	19.90	8.30	14.20	18.25	0.50	1.04
17	8.30	6.85	23.00	2.80	23.80	-6.50	23.55	6.70	14.30	12.45	4.55	7.40	14.50	14.65	7.20	12.50	1.51
18	7.82	6.90	22.90	-8.50	23.10	6.80	22.65	17.50	22.00	19.15	11.20	14.65	19.00	17.75	12.55	8.05	0.16
19	6.16	3.85	22.05	-8.90	23.80	9.00	22.50	7.95	22.65	18.90	20.00	15.50	15.85	17.20	6.95	3.90	0.50
20	11.39	-1.25	22.70	-6.30	23.15	2.15	22.85	2.20	22.55	21.65	15.30	24.35	2.00	16.30	18.55	7.85	-0.69
21	8.82	9.00	22.55	-2.20	22.95	-4.90	23.35	7.35	21.00	15.55	18.50	13.20	22.60	21.45	9.55	0.95	1.26
22	13.77	6.90	23.85	6.20	22.00	-8.10	22.85	15.25	21.25	5.50	19.80	7.15	24.95	19.00	19.15	5.60	0.69
23	6.98	5.55	22.00	-6.85	23.30	2.75	23.05	8.30	18.05	8.40	12.50	14.55	14.10	10.70	7.75	11.70	-0.13
24	17.18	-1.90	23.55	4.70	22.30	-0.25	22.80	16.00	19.75	16.15	6.65	12.50	3.90	13.45	8.10	8.50	0.69
25	8.68	1.90	22.30	2.10	22.15	-7.95	22.35	18.90	17.60	18.50	3.60	4.65	16.30	18.50	13.35	7.55	-1.01

Table 23. Leg Mechanism - Independent Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	11.29	9.00	23.55	-5.95	22.10	12.35	16.90	11.80	6.55	12.60	18.35	24.40	19.45	9.55	4.10	3.50	-0.88
2	9.65	7.05	23.55	-3.75	23.55	8.55	13.30	10.80	16.85	9.40	9.90	3.30	22.60	7.30	12.45	10.95	0.31
3	9.34	6.15	22.85	-6.65	23.35	9.65	11.15	11.80	7.20	16.15	21.80	19.85	19.50	17.60	6.05	0.70	1.07
4	7.47	6.65	23.85	-8.25	23.25	8.35	18.45	2.60	19.15	21.05	18.80	3.30	20.40	8.40	10.30	14.10	-1.13
5	9.32	6.15	22.85	-7.30	22.55	17.95	21.95	8.75	18.30	12.90	24.90	22.70	18.45	25.00	21.85	0.50	-1.23
6	8.61	8.50	22.75	-7.85	23.90	7.10	14.50	8.20	10.90	5.25	8.95	10.35	6.40	14.40	9.05	5.10	-1.07
7	9.07	6.15	22.85	-7.95	23.65	8.95	16.70	14.00	15.30	20.40	23.95	6.20	22.50	18.15	12.20	3.25	1.51
8	9.47	7.95	22.90	-3.45	23.70	13.85	23.55	19.05	7.75	9.00	19.90	19.15	16.20	12.00	0.50	8.50	-0.22
9	9.17	8.75	22.80	-5.30	23.55	9.25	21.60	15.05	7.80	12.35	16.20	18.90	6.15	21.15	4.20	6.65	-1.07
10	8.90	6.60	23.45	-8.90	23.55	13.45	13.40	9.50	7.10	18.05	22.55	7.30	6.25	22.35	1.65	3.30	-1.16
11	31.08	-5.75	22.50	-0.45	23.95	24.90	21.60	3.85	25.00	7.00	23.30	24.05	24.35	24.45	13.80	4.20	1.51
12	9.44	8.65	22.45	0.40	22.80	7.80	17.55	21.30	21.55	8.65	11.40	11.90	16.95	18.60	18.25	1.10	0.38
13	30.32	5.90	22.25	-7.15	22.50	23.45	17.00	13.45	4.50	21.25	13.30	14.50	23.10	7.90	13.80	2.10	0.88
14	8.21	-1.70	22.00	-9.00	23.05	4.15	17.40	5.35	13.75	14.95	15.35	11.05	8.35	17.25	1.00	13.25	-1.54
15	9.71	2.30	23.20	-6.65	23.55	6.40	17.40	12.70	17.10	19.45	23.75	12.75	23.50	16.60	9.70	6.35	0.97
16	5.46	8.75	23.80	-1.00	22.75	5.90	24.45	13.30	22.40	20.75	22.45	20.10	16.15	24.55	23.25	1.45	-0.72
17	3.58	-4.95	23.00	5.35	23.25	15.90	7.20	20.45	13.40	4.45	4.85	5.90	19.15	21.80	11.75	3.40	0.28
18	14.10	-8.80	23.75	6.05	23.20	18.70	11.30	12.00	3.90	13.75	18.00	23.25	19.20	24.70	5.50	8.55	0.28
19	9.48	5.45	22.30	-7.80	22.40	11.00	22.20	9.80	20.45	19.30	23.90	6.40	14.05	23.30	20.15	1.25	-0.72
20	19.82	-6.50	22.20	9.00	23.15	24.90	7.20	3.20	5.40	12.85	21.70	19.75	7.85	19.55	13.45	2.10	-0.53
21	8.28	5.65	22.60	-6.30	23.75	8.75	8.90	8.05	7.90	9.55	20.10	19.75	22.10	23.60	4.80	5.90	-1.51
22	5.57	8.40	22.65	-4.20	22.50	8.65	15.00	11.90	12.10	6.15	17.05	11.40	19.70	20.35	13.00	2.30	0.57
23	30.56	-9.00	22.10	-9.00	22.30	20.65	20.75	8.15	17.35	5.65	14.05	12.55	13.05	23.80	1.20	0.50	1.48
24	0.93	7.05	22.55	-5.50	22.80	6.45	18.20	10.95	17.00	5.45	20.10	22.20	23.50	14.25	11.80	5.50	0.50
25	9.25	6.30	22.65	-8.60	23.85	11.05	12.25	9.90	12.35	13.10	15.55	7.10	14.30	24.65	4.40	1.05	0.50

Table 24. Leg Mechanism - Independent Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	5.59	4.85	22.75	9.00	23.60	-4.30	22.75	12.55	15.05	20.05	8.40	14.10	12.35	9.80	22.15	9.65	0.94
2	10.22	-8.05	23.25	8.70	22.40	-7.20	23.25	15.60	10.50	12.10	8.45	5.30	21.85	19.20	15.00	7.00	0.50
3	30.84	-1.85	22.50	-8.95	22.60	0.40	23.25	14.35	21.00	3.80	20.95	18.50	22.25	17.90	1.65	0.60	-0.31
4	9.59	1.55	23.15	7.85	22.40	-7.35	23.30	22.55	10.35	13.65	8.60	19.10	22.40	15.25	13.10	9.95	-1.35
5	16.33	8.20	22.60	6.30	22.75	-5.35	23.40	7.90	12.20	12.95	7.20	9.05	17.45	12.95	16.35	9.20	1.10
6	10.25	1.85	22.00	8.85	22.40	-8.95	22.05	22.30	18.80	20.05	10.35	18.30	20.45	18.15	13.30	6.35	-1.41
7	13.34	-1.30	22.75	4.25	23.75	-6.35	23.75	18.95	16.20	17.10	8.75	18.50	16.75	13.30	14.90	11.50	0.97
8	11.24	2.60	23.30	1.00	23.50	-8.95	23.50	13.55	23.85	13.20	7.30	15.25	16.85	15.30	15.75	11.50	0.72
9	8.40	2.60	22.45	7.45	22.00	-4.05	23.15	15.35	18.65	20.50	6.75	16.75	20.25	13.10	14.45	11.45	-0.19
10	9.31	1.20	22.10	4.05	22.75	-6.45	22.40	5.70	7.35	5.95	4.75	8.65	19.45	12.60	11.75	13.85	0.53
11	4.75	8.25	23.80	6.25	22.75	-3.20	23.95	12.40	17.55	20.95	7.00	21.05	6.20	10.90	16.85	7.60	-0.63
12	8.99	-5.60	23.50	7.90	23.70	-9.00	22.45	23.20	19.60	24.20	10.50	18.95	20.85	20.25	16.60	5.50	1.41
13	19.18	4.25	23.70	6.45	22.90	0.65	23.60	14.10	15.20	11.50	4.10	13.10	14.45	10.95	14.35	12.45	0.82
14	14.07	6.45	23.85	5.40	24.00	-4.90	22.00	12.90	17.25	18.65	7.45	11.55	25.00	14.60	19.25	10.00	0.31
15	10.01	1.35	24.00	6.20	23.10	-6.15	22.40	23.85	21.05	3.85	9.00	11.00	24.45	14.00	16.25	11.45	0.79
16	9.76	-1.05	23.40	8.50	23.00	-3.40	22.65	21.65	18.50	18.45	11.50	20.25	24.85	16.30	20.10	7.40	0.82
17	11.13	4.85	23.70	8.30	22.40	-4.55	23.35	13.15	24.40	17.65	12.65	14.05	24.90	12.15	22.75	11.65	0.60
18	14.92	-2.20	23.25	5.85	22.45	-2.90	23.45	13.95	17.25	11.85	9.60	17.70	11.45	13.35	6.60	12.00	-0.66
19	11.08	0.45	22.75	6.05	23.25	-9.00	23.40	13.55	17.00	15.70	11.00	17.55	21.95	23.75	12.15	4.95	-0.88
20	30.73	-5.10	23.50	-8.95	22.60	-7.75	23.95	22.75	24.75	9.35	20.20	13.40	21.50	12.90	1.20	0.90	-0.47
21	9.33	2.55	23.80	4.45	22.25	-9.00	23.40	24.25	14.55	4.60	12.70	12.25	12.45	19.10	9.20	6.35	-1.48
22	11.88	-6.75	23.85	-0.75	22.00	-9.00	23.35	18.85	21.75	21.60	7.40	24.75	24.60	25.00	5.00	13.60	1.41
23	11.25	4.05	23.80	8.65	23.30	-8.80	22.60	14.55	14.70	8.95	12.60	15.10	23.20	19.80	19.85	5.20	-1.04
24	9.12	4.60	23.65	7.30	22.75	-9.00	23.05	18.40	20.70	11.15	13.05	19.55	16.95	21.80	13.05	3.90	-0.91
25	2.91	6.70	23.40	6.55	22.90	-5.90	22.70	8.25	11.45	14.20	6.75	11.85	8.75	10.00	18.10	10.00	0.25

Table 25. Leg Mechanism - Linked Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	10.02	3.65	22.60	-6.20	22.85	5.20	16.95	9.10	10.50	15.95	-1.54
2	1.42	8.95	22.85	-7.00	23.05	8.35	12.95	10.30	20.05	12.50	-1.57
3	8.72	8.35	23.85	-8.50	22.15	12.75	15.60	16.30	11.95	7.60	1.13
4	9.32	6.25	22.10	-3.05	22.40	7.15	16.65	12.95	13.70	10.10	-1.57
5	7.58	8.90	22.85	-7.50	23.75	7.20	24.30	10.70	13.20	14.20	1.41
6	10.19	7.20	22.70	-8.45	22.25	9.95	16.25	15.75	12.70	8.30	-1.51
7	7.93	8.75	23.35	-2.15	23.60	5.90	3.25	5.25	14.80	13.50	-1.45
8	9.92	8.55	22.55	-8.80	23.75	8.50	22.65	20.45	15.10	7.10	-1.07
9	9.09	8.45	22.80	-5.40	22.20	9.10	20.05	12.20	13.75	10.40	-0.88
10	10.54	7.40	23.15	-6.70	22.55	10.60	17.35	18.30	12.85	6.15	0.60
11	9.75	1.80	22.25	-5.55	23.35	6.15	11.00	11.80	9.35	12.75	0.50
12	10.58	5.80	23.75	-8.95	22.30	11.75	19.85	22.80	12.85	4.95	1.54
13	4.09	3.75	22.90	-8.15	23.75	5.25	4.50	10.70	14.55	11.20	-0.41
14	8.33	2.50	22.70	-8.95	23.85	3.95	24.65	14.25	6.40	17.20	-1.07
15	9.80	3.30	22.55	-6.40	23.15	7.65	15.15	16.90	12.55	8.85	-0.69
16	9.31	3.40	22.15	-8.90	23.75	8.85	21.85	24.50	16.05	4.85	-0.06
17	9.29	9.00	23.40	-6.25	23.40	7.40	20.90	8.75	14.75	15.45	1.51
18	6.82	8.30	22.20	-5.95	23.75	6.60	25.00	12.45	14.35	13.70	-0.28
19	3.99	6.15	24.00	-7.10	22.75	9.30	11.70	10.75	20.70	10.75	-0.60
20	8.91	-0.20	23.75	-9.00	23.40	6.85	20.75	21.90	14.60	9.50	-0.94
21	9.00	7.15	22.35	-5.15	24.00	7.45	17.20	11.50	11.35	12.45	0.97
22	14.21	5.80	23.55	-2.90	24.00	6.80	19.90	17.35	9.95	13.65	-1.51
23	9.31	8.85	22.20	-3.80	23.35	11.55	14.05	11.00	24.95	5.05	1.35
24	9.09	4.90	23.10	-8.35	22.15	9.70	17.20	18.05	14.15	7.00	-1.54
25	3.17	5.45	22.05	-6.10	22.85	7.60	8.25	10.15	15.90	12.10	0.60

Table 26. Leg Mechanism - Linked Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	19.44	-8.70	23.75	4.50	22.40	17.35	6.30	16.80	9.75	4.70	16.05	17.35	23.90	17.80	24.80	8.05	-0.85
2	10.11	7.10	23.45	-5.65	23.75	7.35	18.15	9.05	12.60	12.85	15.25	16.25	17.40	21.15	7.65	11.05	-1.19
3	10.46	5.75	22.20	-6.55	23.75	12.60	21.30	5.10	9.45	11.30	13.70	12.75	24.40	23.40	18.75	5.05	-0.69
4	9.73	8.05	22.95	-4.50	23.05	22.10	7.15	23.85	6.40	23.35	24.00	2.10	13.00	14.95	18.90	1.85	-0.63
5	9.61	5.85	23.10	-8.70	23.90	10.00	19.70	10.50	14.60	13.10	14.50	12.15	22.65	21.35	14.15	10.00	-1.51
6	8.25	-1.35	22.05	0.55	22.10	12.95	15.40	20.45	8.85	4.25	14.30	14.75	17.15	21.50	2.85	22.15	-1.51
7	10.89	6.40	23.40	-6.80	22.10	11.55	17.40	6.00	12.55	13.75	19.60	13.05	16.60	21.30	20.95	7.20	0.00
8	11.75	8.35	22.55	-8.30	23.30	6.45	23.25	6.65	7.95	24.40	14.95	12.05	22.40	13.85	22.85	2.00	-1.41
9	14.54	4.80	23.50	-2.45	23.95	9.65	22.55	15.85	8.05	12.10	19.65	22.75	12.40	12.00	12.40	13.65	-1.19
10	5.93	7.75	23.75	-5.55	22.30	14.80	13.75	18.90	8.30	4.80	15.85	11.45	20.15	17.85	17.15	0.55	0.63
11	14.11	7.20	22.05	-2.45	23.65	19.35	23.75	19.50	14.35	7.60	19.60	14.35	12.35	14.95	10.05	15.90	1.45
12	8.36	5.80	23.50	-5.05	23.45	11.80	24.90	16.75	6.90	19.45	22.95	10.50	8.25	15.80	15.30	9.15	-0.82
13	9.15	4.85	22.95	-7.15	22.60	9.75	16.40	7.85	12.05	11.65	19.30	12.95	24.80	12.85	10.50	15.90	-0.94
14	3.87	7.05	22.25	-8.50	23.95	13.95	19.85	14.35	4.90	17.85	14.45	7.90	14.65	15.10	18.00	4.80	-0.94
15	10.75	5.80	22.40	-6.50	22.90	16.85	20.40	18.65	8.10	9.30	7.80	8.70	5.95	6.75	17.75	0.50	-0.88
16	15.79	2.80	24.00	-3.95	23.90	5.95	8.25	2.50	8.35	8.20	18.75	10.95	8.50	19.85	8.05	11.80	1.23
17	13.32	7.05	22.55	-8.80	23.20	12.90	12.70	20.10	15.70	14.65	17.65	6.70	22.05	21.55	9.80	5.45	-0.72
18	9.72	2.60	22.05	-8.80	22.10	4.35	12.40	13.60	10.25	18.25	14.40	4.95	18.60	17.85	12.00	5.65	0.00
19	9.47	6.40	23.20	-8.40	23.95	8.10	17.65	11.15	7.35	10.20	14.85	8.95	14.65	22.00	19.60	4.60	-0.16
20	9.05	7.30	23.35	-8.10	23.45	2.75	20.25	13.70	13.00	10.55	16.50	6.75	20.85	23.80	15.20	7.45	-1.29
21	9.91	0.50	23.35	-6.55	22.20	6.65	8.50	13.55	11.35	7.80	19.35	17.20	24.75	22.25	10.75	7.70	1.57
22	9.69	0.30	22.15	-7.05	23.20	18.65	24.75	20.55	8.95	7.00	12.05	6.55	6.75	8.05	14.35	18.50	0.44
23	26.21	-4.60	23.40	-6.40	22.15	17.85	13.90	24.80	16.10	19.65	18.55	13.20	4.90	24.45	3.25	9.70	1.45
24	9.96	1.70	22.85	-9.00	23.50	10.50	17.85	12.75	16.55	11.50	20.75	13.00	23.85	19.25	14.70	16.05	-0.22
25	31.44	-9.00	23.85	9.00	22.00	17.35	25.00	14.50	24.50	25.00	25.00	18.35	25.00	25.00	3.70	0.50	-1.41

Table 27. Leg Mechanism - Linked Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	21.56	-8.95	23.95	-8.85	24.00	5.75	24.95	23.50	23.80	23.50	25.00	22.75	4.00	0.85	2.70	4.45	1.51
2	23.69	-9.00	24.00	-9.00	23.60	6.35	8.20	10.40	10.45	12.15	15.50	6.30	18.20	9.15	0.50	25.00	1.57
3	31.77	-4.70	23.25	-7.25	22.70	3.05	12.70	24.65	23.25	11.50	8.60	3.75	11.55	20.75	9.90	11.30	-0.79
4	33.47	-5.15	22.60	-1.60	23.45	5.20	4.90	7.10	3.80	13.90	15.60	24.40	16.20	22.20	16.10	7.45	-0.66
5	28.99	-1.45	22.60	-2.15	22.75	3.45	8.40	8.10	10.35	9.90	21.00	23.30	16.65	15.20	1.10	13.80	-1.41
6	8.36	3.65	22.05	8.75	23.00	2.65	3.35	7.15	9.70	23.25	20.80	14.20	17.60	17.60	4.45	18.70	-0.25
7	22.51	0.45	23.30	5.20	23.20	1.05	13.10	8.50	18.50	13.10	17.30	19.40	13.30	7.30	5.50	14.65	-1.19
8	28.63	4.95	23.20	5.30	23.70	8.25	6.45	18.40	20.70	7.85	12.45	11.45	11.90	15.35	15.50	21.25	1.04
9	36.02	0.90	22.45	3.15	22.40	4.45	11.90	22.05	24.25	16.85	15.45	3.60	17.10	19.20	7.55	12.85	0.38
10	34.60	8.70	22.75	8.30	22.30	6.55	3.90	7.50	8.35	15.80	20.15	16.25	8.85	15.30	9.60	7.20	-1.26
11	32.25	-5.50	22.55	-7.60	22.45	6.15	11.45	9.10	8.90	21.90	18.55	16.00	14.25	15.80	5.50	19.75	0.03
12	22.17	9.00	24.00	9.00	24.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	-1.07
13	30.69	-9.00	22.00	-9.00	22.00	25.00	25.00	25.00	1.40	5.30	13.65	18.75	24.30	24.90	25.00	15.50	-1.10
14	30.89	-0.40	22.75	-0.60	22.70	18.45	9.90	13.05	9.30	17.70	7.30	20.55	19.30	14.90	8.05	10.40	-0.03
15	25.91	-4.05	22.45	-6.45	22.00	16.75	15.25	15.65	0.55	15.90	2.90	22.60	22.20	5.95	1.25	22.10	0.88
16	38.13	9.00	22.00	9.00	23.30	3.30	25.00	25.00	25.00	25.00	25.00	0.50	25.00	25.00	20.85	19.75	1.35
17	31.06	-3.05	23.00	-3.80	22.75	10.60	24.85	12.05	17.80	20.90	13.50	14.80	7.65	12.90	0.50	0.50	1.41
18	33.36	-2.55	23.90	-2.40	23.50	19.55	16.30	8.35	12.10	20.30	16.35	11.50	8.45	22.40	17.80	15.60	-0.97
19	19.68	-4.65	23.40	-4.45	22.85	16.80	7.60	21.70	14.90	17.30	10.40	9.45	10.20	6.20	23.15	19.75	0.79
20	17.44	0.10	22.45	1.65	22.00	0.50	25.00	25.00	0.50	0.50	25.00	25.00	0.50	0.50	12.50	4.55	0.47
21	22.99	4.20	23.80	3.25	22.65	1.35	3.00	4.00	6.80	15.40	14.10	6.80	14.15	10.55	9.30	21.05	-0.41
22	23.63	7.75	22.15	5.30	22.90	12.20	7.40	9.90	12.45	5.00	8.95	7.75	9.05	15.60	5.95	20.40	0.09
23	22.88	-3.10	23.85	-7.85	23.60	3.70	5.55	2.50	7.60	24.00	24.70	3.95	24.75	5.55	22.40	7.00	1.38
24	31.91	-4.60	22.70	-8.05	22.45	10.10	12.50	4.80	9.35	8.65	18.65	16.55	3.10	14.65	18.90	1.90	-0.69
25	27.11	-5.15	22.05	-3.40	23.35	1.85	10.70	11.40	10.50	15.40	7.50	14.70	14.55	19.65	7.60	12.85	1.32

Table 28. Leg Mechanism - Linked Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	10.26	2.40	22.95	-3.60	23.95	-4.45	23.50	5.30	21.85	15.65	17.55	20.60	16.25	15.50	1.60	1.70	0.44
2	3.72	5.80	23.85	-3.50	22.55	-7.00	22.15	5.30	7.90	9.40	12.95	12.30	15.40	11.35	23.50	9.75	1.48
3	8.71	8.35	23.80	-8.20	22.40	-8.85	23.30	12.75	15.60	24.30	11.95	13.50	24.75	23.60	2.30	0.90	1.41
4	6.00	6.25	22.65	-4.25	23.45	-0.80	22.65	6.85	25.00	10.15	19.15	18.95	20.25	11.55	7.35	10.35	-0.44
5	8.57	5.60	22.60	-6.95	22.05	8.50	22.15	10.40	17.30	13.30	10.45	8.45	14.85	20.10	4.50	7.90	0.19
6	14.40	2.60	23.90	-6.90	23.55	-6.65	22.25	7.20	14.45	5.90	12.50	15.35	24.10	10.30	16.95	15.35	1.23
7	5.43	7.40	22.00	-2.80	23.45	2.50	24.00	14.00	21.95	15.35	9.85	9.10	16.20	9.35	3.35	13.05	1.51
8	6.65	8.80	22.45	-4.30	22.70	1.75	23.45	9.45	23.05	21.35	18.10	10.45	24.00	20.20	6.25	1.00	0.35
9	8.02	4.50	22.00	-5.90	23.35	7.80	22.65	15.55	21.45	19.35	13.05	5.50	20.10	17.55	0.60	11.75	-1.48
10	8.71	8.65	22.10	-0.75	23.60	1.35	22.75	7.10	23.25	20.35	15.25	13.20	23.85	21.95	2.65	1.45	-0.60
11	10.38	2.50	22.50	-5.05	23.35	-6.35	23.10	6.00	10.45	11.10	10.70	10.90	18.20	23.00	3.80	3.90	-1.19
12	8.04	8.85	22.55	-8.10	22.70	5.50	22.60	10.25	19.50	12.25	10.65	11.35	21.95	21.60	6.15	8.90	0.35
13	5.85	3.30	24.00	-8.20	23.65	-5.10	23.35	5.25	4.50	10.70	14.55	11.55	15.15	8.10	23.30	13.65	-0.53
14	6.36	5.35	23.60	-7.85	24.00	2.05	23.75	4.65	17.70	24.05	24.10	17.60	16.30	14.05	21.25	9.50	-0.91
15	6.85	4.20	22.90	-5.90	22.95	1.55	23.10	16.90	25.00	18.90	15.00	8.50	15.85	9.10	9.20	12.45	-1.04
16	10.56	8.85	23.55	-8.95	23.35	-5.55	22.30	10.35	18.40	6.15	14.80	18.05	20.85	21.75	11.05	2.95	-0.28
17	6.00	5.80	22.50	-8.60	22.90	1.85	22.30	8.45	21.95	10.20	17.10	16.95	19.40	12.75	11.85	10.25	1.54
18	2.08	7.00	22.60	-8.40	23.55	-6.50	22.15	4.90	8.60	8.10	13.65	13.65	10.55	15.25	22.30	3.30	-0.28
19	8.96	3.60	22.20	-8.35	24.00	-3.45	22.30	5.20	17.25	8.35	17.00	13.85	18.85	12.00	7.00	10.00	0.13
20	9.15	8.05	22.60	-4.50	22.70	-1.25	22.00	8.80	20.55	19.20	12.95	10.90	15.25	23.15	2.25	0.65	1.16
21	5.33	8.70	22.40	-7.50	22.25	0.05	22.65	10.60	22.10	9.10	20.85	8.85	24.35	12.40	16.35	10.40	1.41
22	4.64	5.80	23.20	-2.90	24.00	5.25	22.40	6.80	19.90	17.35	15.00	12.95	22.60	13.15	4.85	9.45	-1.51
23	14.68	-2.30	23.20	6.20	23.20	-8.50	22.70	11.35	11.65	12.75	1.60	11.70	23.45	16.10	22.15	8.45	0.97
24	9.79	7.25	23.55	-8.30	22.45	-5.45	22.15	10.10	12.50	4.80	9.30	8.65	18.60	16.55	3.10	9.90	-0.69
25	8.08	7.20	22.90	-1.30	23.65	2.10	23.45	8.15	20.35	23.65	9.45	18.65	9.15	14.15	16.75	10.80	-1.57

Table 29. Leg Mechanism - Linked Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	10.50	2.30	23.10	-3.60	23.95	5.30	14.95	5.55	12.25	14.00	14.15	10.00	21.55	12.85	2.50	11.25	-0.03
2	10.06	6.35	23.95	-5.90	23.70	7.35	20.10	9.05	11.35	12.85	15.30	6.45	18.25	20.90	6.55	9.75	-1.16
3	6.24	7.30	23.15	-8.55	23.90	5.70	18.35	13.75	18.55	8.55	13.70	14.35	11.45	24.10	10.80	0.65	-1.01
4	8.33	7.05	23.50	-3.65	23.90	6.45	15.45	5.60	14.55	10.40	12.95	7.50	14.80	10.90	4.25	12.75	-1.07
5	8.18	8.90	22.55	-8.75	23.65	7.45	24.40	10.70	16.45	10.90	11.00	10.40	23.00	22.15	6.80	5.70	-0.03
6	9.71	2.15	23.95	-9.00	22.55	7.60	14.55	5.90	10.60	15.35	21.00	13.45	18.90	16.90	6.00	9.55	0.91
7	10.30	7.80	23.70	-4.50	22.85	9.40	18.05	6.40	15.45	14.80	16.45	3.00	16.90	15.95	9.50	6.60	0.60
8	5.61	8.90	23.55	-7.10	22.20	12.65	21.50	16.65	10.25	8.35	23.25	20.80	15.35	20.00	12.35	1.60	-0.16
9	7.66	6.25	23.75	-1.35	23.80	11.00	22.35	8.65	16.15	12.10	13.30	6.20	24.35	9.55	12.30	13.90	0.79
10	6.21	8.95	22.10	-2.70	23.75	12.80	22.00	15.25	10.65	5.05	18.10	17.25	9.90	19.20	7.65	8.70	-0.38
11	11.56	8.60	23.85	-4.40	23.40	16.30	22.85	21.55	8.90	11.00	18.00	16.30	15.70	17.55	9.75	0.85	-0.57
12	9.59	8.30	23.05	-4.10	22.90	10.85	21.95	14.65	12.35	12.50	15.80	8.40	20.75	17.60	7.35	4.60	0.00
13	10.73	2.65	23.85	-5.15	22.30	8.05	16.30	10.70	13.70	8.45	22.55	22.75	24.40	19.80	15.00	4.90	-0.19
14	8.93	1.70	23.90	-9.00	23.50	5.50	16.80	16.45	13.75	15.85	23.00	20.60	21.95	22.40	5.70	1.60	-1.38
15	6.53	7.95	22.40	0.00	22.20	17.00	24.65	19.20	8.60	11.50	14.10	5.80	22.85	9.10	8.85	9.55	1.19
16	10.63	2.80	22.65	-4.45	23.55	5.95	7.85	2.40	9.25	8.20	19.25	12.10	24.05	13.10	9.85	13.30	1.01
17	3.89	7.30	22.55	-6.80	22.05	7.40	19.10	13.30	15.15	4.80	20.85	20.80	20.75	24.95	9.50	1.90	-1.38
18	8.24	8.15	23.35	-3.90	22.25	7.65	22.60	13.30	11.95	13.35	14.35	6.05	22.60	11.80	3.15	7.95	-1.35
19	10.18	9.00	24.00	-8.40	23.80	7.85	24.85	12.60	17.05	18.25	13.85	12.30	16.30	20.15	6.50	2.10	-0.66
20	9.01	7.65	23.05	-8.00	23.85	8.50	16.30	14.35	15.75	19.25	17.45	9.40	24.65	16.10	14.25	2.60	0.22
21	8.95	1.70	23.90	-8.70	24.00	8.15	17.80	12.60	10.00	21.10	22.35	16.85	21.80	22.55	7.25	2.20	1.13
22	8.18	8.90	23.85	-5.60	24.00	9.70	10.40	17.35	15.15	14.30	13.10	7.30	16.05	14.05	13.85	3.50	-0.88
23	18.86	9.00	22.00	-6.50	22.05	14.75	22.40	12.15	23.50	11.35	10.65	8.90	25.00	17.55	25.00	0.50	1.54
24	8.66	4.50	24.00	-7.30	23.70	8.10	12.20	12.25	11.00	11.45	10.00	13.80	23.60	24.80	5.15	0.50	0.03
25	6.71	3.85	23.05	-5.10	23.75	3.60	13.25	4.45	15.90	16.05	24.35	12.25	5.35	20.15	20.25	8.10	-1.45

Table 30. Leg Mechanism - Linked Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	10.00	7.70	22.20	8.10	22.35	-4.40	22.25	17.05	13.95	19.35	10.10	10.65	10.05	15.40	17.00	0.70	-1.45
2	3.03	8.25	23.25	9.00	22.55	-7.25	22.45	16.45	16.05	8.00	10.55	7.70	14.75	12.25	22.70	9.00	-0.38
3	8.65	6.70	23.90	5.40	22.05	-6.60	23.30	23.65	19.60	17.80	8.50	15.80	12.95	13.00	10.55	11.30	0.22
4	24.99	-8.05	22.35	-4.05	23.55	-4.45	22.25	17.75	19.95	22.25	15.70	19.35	1.60	14.50	11.45	7.75	-0.25
5	18.96	-1.25	22.55	-0.70	22.75	-8.95	23.90	4.05	8.40	3.60	10.35	7.45	16.80	23.30	5.70	10.75	-0.03
6	9.42	1.70	22.75	8.75	23.15	-4.35	22.35	21.60	18.50	15.15	9.40	20.55	20.75	14.15	15.65	9.00	1.51
7	13.79	-0.70	23.05	7.80	23.75	-8.65	22.65	17.65	14.00	2.50	12.60	12.75	22.80	20.50	16.05	4.95	0.28
8	30.37	-3.10	22.60	-7.95	23.40	-8.55	22.90	3.90	16.65	13.15	23.00	18.25	5.35	20.50	13.90	0.90	-1.04
9	9.13	3.20	23.50	8.30	22.00	-5.50	22.50	22.40	13.05	18.45	7.95	20.10	17.70	11.65	12.55	11.05	0.88
10	9.17	-3.35	22.50	8.65	22.95	-3.20	22.15	22.05	22.15	14.35	9.90	18.35	23.90	16.10	18.85	7.50	-1.16
11	11.18	2.20	23.20	6.65	23.15	-4.30	23.10	14.65	13.00	13.35	9.85	16.30	24.95	16.50	20.90	8.95	0.19
12	14.05	6.40	23.95	3.70	22.55	-9.00	22.85	10.45	20.25	18.15	8.10	18.05	21.85	8.10	13.05	16.35	0.66
13	2.83	-3.65	22.50	6.25	22.30	-7.30	22.55	19.00	17.95	11.35	5.05	12.95	6.05	10.45	16.95	8.90	1.01
14	30.69	-1.95	23.40	-9.00	22.35	-8.60	23.20	16.80	17.85	16.30	17.70	11.85	8.80	18.10	0.90	2.10	1.38
15	9.29	-8.40	23.95	4.55	23.20	-6.85	22.40	21.80	15.90	13.25	8.55	18.10	10.30	8.85	16.65	14.75	0.13
16	8.53	-0.55	22.80	4.35	22.70	-9.00	22.60	19.20	24.00	12.40	7.75	15.45	19.85	19.20	15.25	7.80	0.79
17	10.16	-0.80	23.60	5.85	23.90	-3.65	22.60	16.40	14.75	24.40	8.00	24.00	22.60	12.50	19.70	12.00	0.03
18	13.40	-2.20	22.35	4.55	22.60	-5.90	23.60	15.00	19.85	15.20	12.40	12.25	24.10	12.00	22.45	12.85	0.06
19	15.21	5.50	23.00	6.15	22.20	-2.65	23.80	22.55	19.65	18.90	11.65	10.95	21.20	10.15	23.05	11.00	0.79
20	5.30	4.05	22.90	8.75	22.80	-8.80	23.10	11.75	15.70	11.30	11.80	15.00	15.75	14.45	23.85	7.85	-1.48
21	19.44	-1.95	23.45	7.45	23.35	0.10	23.30	23.90	21.50	10.05	4.85	12.75	21.65	14.35	14.55	14.65	1.29
22	9.35	2.20	23.80	5.60	23.20	-8.95	23.40	19.60	16.55	17.10	12.50	20.90	14.45	18.95	11.50	6.70	0.03
23	2.86	4.85	23.25	7.85	23.65	-7.45	23.20	22.40	18.65	12.90	11.10	14.10	14.80	11.40	22.85	12.00	1.23
24	10.25	2.75	22.60	7.80	23.55	-4.10	22.35	10.45	11.45	3.70	10.80	8.20	21.75	15.65	17.10	7.70	-0.66
25	10.91	6.85	23.95	5.85	22.45	-4.70	23.90	13.55	22.05	21.60	10.50	16.70	23.65	12.95	20.50	12.45	1.19

Table 31. Leg Mechanism - Convertible Agent Results.

Run	Type	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	W2	2.16	7.70	23.35	8.20	22.05	-4.10	22.10	12.10	13.95	8.65	6.05	4.50	8.65	9.00	18.00	9.35	-	-	-1.54
2	S1	2.74	9.00	22.80	-7.00	22.15	-	-	8.20	18.30	10.60	7.70	17.05	23.20	13.15	7.40	18.15	17.45	3.90	-1.41
3	4B	6.23	8.95	22.95	-2.30	22.55	-	-	7.00	9.70	8.90	22.55	2.60	-	-	-	-	-	-	-1.51
4	W2	4.11	-4.20	23.40	-8.70	23.40	1.90	22.10	7.35	7.65	19.25	20.40	11.75	5.55	7.70	24.65	3.30	-	-	-0.57
5	W1	8.67	-4.30	22.60	-8.05	22.10	-	-	2.70	5.15	13.00	11.45	5.80	24.10	24.30	20.40	15.05	4.85	7.05	1.57
6	4B	2.36	7.75	22.00	-8.55	23.80	-	-	5.00	6.00	13.30	18.40	6.05	-	-	-	-	-	-	-1.57
7	4B	7.53	6.80	22.10	-4.20	23.80	-	-	6.00	17.15	8.95	11.05	14.70	-	-	-	-	-	-	-1.57
8	S3	3.65	6.40	23.55	-4.95	23.65	5.05	23.50	9.85	22.10	12.85	20.50	5.90	19.75	11.55	9.30	13.25	-	-	1.57
9	S1	3.34	7.60	22.55	-3.05	22.80	-	-	5.85	19.10	14.80	15.30	9.00	24.35	16.25	15.25	18.05	24.20	17.90	-0.88
10	4B	7.22	6.35	22.20	-6.20	22.70	-	-	5.70	21.75	10.90	11.70	14.35	-	-	-	-	-	-	-1.51
11	S3	3.66	6.45	22.60	-8.75	22.90	2.70	22.05	6.90	21.70	18.45	20.50	18.35	24.75	11.10	14.00	8.70	-	-	-0.60
12	S3	4.47	7.90	22.05	-3.70	22.90	-0.10	23.15	8.55	20.95	7.50	16.10	17.20	24.65	12.85	14.05	12.60	-	-	-1.26
13	W1	4.65	8.20	22.85	-3.95	23.45	-	-	9.90	8.45	16.50	13.45	12.45	10.80	12.45	17.60	13.20	10.25	3.75	-0.16
14	4B	1.44	8.95	22.95	-8.25	23.50	-	-	5.50	8.10	12.85	19.65	7.20	-	-	-	-	-	-	-1.57
15	S3	5.38	4.65	22.05	-8.85	23.35	4.90	22.35	9.65	20.95	14.20	15.10	19.65	20.95	15.50	13.95	8.20	-	-	1.16
16	S3	5.24	8.95	23.50	-7.55	23.30	4.25	23.15	10.65	19.20	10.95	10.65	12.80	23.55	18.40	11.65	11.60	-	-	-1.57
17	4B	5.61	8.65	22.10	-5.20	22.35	-	-	6.80	25.00	10.90	15.90	13.85	-	-	-	-	-	-	-1.45
18	4B	2.05	8.90	22.30	-5.75	23.55	-	-	6.40	9.85	10.95	18.80	9.90	-	-	-	-	-	-	0.91
19	S1	1.82	3.75	23.75	0.20	22.80	-	-	10.15	18.50	15.60	7.30	16.75	21.40	25.00	4.80	25.00	0.50	17.10	1.57
20	S1	4.41	8.50	23.85	-7.10	23.40	-	-	12.75	17.85	13.60	8.80	7.50	12.25	5.75	17.40	17.70	23.20	1.60	-1.45
21	W2	3.61	5.10	23.60	8.30	24.00	-2.75	23.65	12.10	15.55	13.65	5.45	13.95	7.65	7.45	17.90	12.05	-	-	1.23
22	W1	6.37	6.80	22.60	-6.35	22.30	-	-	6.50	19.55	11.10	10.25	10.65	15.30	8.65	10.30	22.10	4.65	7.75	0.47
23	S3	5.06	7.60	22.30	-6.90	22.45	3.95	22.15	7.55	22.65	11.85	16.20	10.35	24.30	21.15	5.70	8.55	-	-	1.13
24	4B	3.40	8.55	23.25	-4.00	23.10	-	-	5.05	7.15	7.00	16.10	13.40	-	-	-	-	-	-	-0.38
25	S3	3.99	7.50	22.20	-6.30	22.65	3.20	23.85	7.95	18.85	8.05	13.35	15.55	19.05	11.70	10.10	13.35	-	-	0.53

Appendix D - Challenge Mechanism Case Study - Raw Data

Table 32. Challenge Mechanism - Independent Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	8.93	-2.20	0.35	-4.50	-4.20	3.80	6.45	4.00	1.65	2.80	-1.54
2	7.22	-1.00	-0.15	0.80	-1.60	2.20	4.55	4.70	2.45	1.40	-0.38
3	9.43	-2.25	0.40	-4.90	-4.25	4.35	6.35	4.15	2.25	3.35	-1.38
4	10.23	-1.55	-5.00	4.05	-0.25	3.65	2.50	4.60	5.50	0.50	0.63
5	14.67	-0.60	2.25	-4.95	2.25	2.80	4.75	3.65	0.60	1.50	1.54
6	13.81	-1.60	-4.85	-1.60	-0.30	6.50	2.55	2.45	4.55	1.10	-0.50
7	9.06	-0.90	-0.40	2.40	-2.50	3.60	5.30	5.25	2.80	1.25	-0.09
8	8.79	-1.55	0.60	-4.45	-3.95	3.85	6.50	4.95	1.75	1.85	-1.54
9	8.94	-1.60	-0.05	2.50	-0.90	3.50	4.85	4.15	2.10	0.50	-0.63
10	2.73	1.85	0.20	4.30	2.80	2.85	4.55	5.15	0.70	2.05	0.75
11	8.78	-1.25	0.80	-4.95	-2.75	3.85	5.85	5.45	1.70	1.40	-1.57
12	10.21	-0.70	0.30	0.05	-3.35	3.40	6.45	3.40	0.85	0.55	-1.48
13	9.29	0.25	-4.60	4.30	-2.05	2.25	2.60	3.95	5.75	2.80	0.13
14	10.30	0.70	-1.10	1.90	-4.30	2.50	5.65	6.45	1.70	3.05	-0.47
15	10.41	-3.05	-1.85	1.95	-2.40	3.75	5.60	4.50	3.45	1.30	-0.85
16	8.92	-1.35	1.10	-3.75	-4.60	4.05	6.50	5.60	2.00	0.80	-1.54
17	7.66	0.15	1.55	0.90	0.20	5.25	4.70	1.90	6.00	1.50	0.41
18	9.12	-1.10	0.95	-2.70	-2.70	4.90	6.45	4.25	2.80	0.65	-1.38
19	9.35	-2.05	-1.00	2.20	0.30	3.45	5.40	3.55	3.25	0.60	-0.16
20	9.79	-3.05	-1.80	2.15	-2.50	3.50	5.25	3.50	3.15	2.35	-0.75
21	2.91	2.25	-0.35	3.60	3.60	3.35	4.55	4.40	1.15	1.95	1.13
22	9.65	-3.05	-1.40	1.55	-0.95	3.65	4.65	3.65	3.20	1.00	-0.66
23	10.54	-5.00	-0.80	-0.10	-2.15	4.20	4.10	3.40	5.85	0.50	-0.35
24	11.32	-4.75	0.65	1.75	-4.65	5.55	4.20	6.25	6.25	0.55	-0.13
25	11.24	-1.05	-0.80	3.30	-3.55	2.75	6.45	3.40	0.50	1.70	-1.07

Table 33. Challenge Mechanism - Independent Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	6.47	-0.30	0.55	0.95	-1.35	4.45	3.70	5.45	3.30	3.00	4.60	3.45	4.80	4.25	4.65	2.20	0.25
2	11.34	-1.15	-0.45	2.65	-3.60	1.30	4.20	4.20	5.45	2.90	3.70	1.05	6.50	5.90	4.45	1.75	-0.19
3	9.32	-2.60	-0.65	-3.85	-3.00	0.65	5.10	3.60	4.00	2.70	3.90	2.00	6.25	4.55	1.65	3.90	-1.48
4	4.60	1.65	-1.50	1.30	1.90	5.55	6.20	5.25	5.05	4.30	5.45	2.35	5.25	4.75	2.55	0.55	0.25
5	6.98	1.00	-0.30	2.20	-0.90	3.75	5.25	4.55	1.35	2.85	5.05	4.10	4.30	3.15	2.30	2.60	0.19
6	9.30	-1.30	0.70	-4.55	-3.75	3.25	5.45	3.15	4.30	3.60	3.50	1.35	6.30	6.05	2.25	1.00	-1.29
7	9.56	0.05	-4.90	0.00	-2.20	6.40	4.65	5.25	6.35	1.35	4.35	3.20	3.65	4.15	4.30	2.35	-0.75
8	8.47	-0.30	1.40	-1.05	1.45	2.35	3.40	3.80	3.10	1.80	4.75	4.85	6.35	5.55	4.70	2.50	0.60
9	8.04	-0.85	2.35	-1.95	0.40	2.30	2.40	4.80	3.60	3.85	3.45	1.75	4.65	3.05	2.95	1.75	0.57
10	6.21	3.15	-3.85	3.35	0.45	2.80	5.15	3.45	2.90	3.05	4.60	2.60	3.95	4.10	5.90	0.80	0.57
11	10.10	0.20	0.20	-1.55	1.00	3.45	4.40	2.85	2.05	2.90	5.40	3.65	3.70	3.60	4.55	1.75	0.63
12	8.72	-4.50	3.45	-5.00	-0.40	5.95	6.10	5.80	3.95	3.70	6.45	3.75	5.95	4.95	5.75	1.70	-1.29
13	12.04	-0.10	-0.45	0.75	1.40	6.10	4.35	6.40	3.35	5.65	5.00	2.40	5.00	4.00	2.80	1.45	-1.13
14	14.32	-5.00	2.70	1.20	-4.65	5.05	5.45	2.65	5.40	6.35	4.65	3.55	1.65	6.15	3.40	0.50	-0.25
15	8.70	0.85	0.75	-0.35	1.95	6.45	5.05	5.65	1.70	4.80	3.30	1.65	5.50	3.75	1.55	2.10	1.01
16	7.43	0.55	0.40	1.25	2.80	5.25	5.00	2.45	3.25	2.60	3.80	2.35	5.75	4.45	1.10	0.60	0.35
17	8.60	0.85	-0.85	-0.60	1.95	5.35	2.50	4.05	3.20	3.75	6.50	3.75	3.90	5.60	2.70	0.75	-0.28
18	10.70	-0.15	0.45	-1.75	-0.45	4.55	5.55	3.25	2.45	3.45	4.35	6.00	6.35	5.45	0.65	0.90	0.35
19	5.62	1.75	0.10	-0.70	3.50	6.35	5.25	3.75	3.50	3.60	5.05	4.45	6.20	5.00	3.00	0.85	0.60
20	9.36	-1.80	-2.70	-1.90	-1.05	4.40	5.00	2.85	5.85	3.30	6.35	3.45	2.90	6.15	5.60	1.30	-0.88
21	9.78	0.15	0.20	-0.15	1.55	3.40	5.30	5.20	3.35	4.20	4.70	6.05	5.40	5.55	4.40	2.60	1.01
22	7.67	0.35	-4.00	4.85	-2.75	3.55	4.05	5.45	2.75	4.10	4.95	3.60	4.95	5.25	5.00	2.05	0.75
23	9.52	-1.20	0.60	-0.55	-0.65	4.25	2.00	4.70	3.10	5.05	6.40	1.90	6.30	2.95	2.85	2.25	0.94
24	13.09	0.10	1.90	1.30	-1.65	5.30	2.65	6.05	2.25	6.35	3.90	2.90	4.70	3.45	4.40	1.00	0.35
25	6.68	-0.70	3.95	1.25	1.00	3.75	3.15	1.05	4.00	4.05	6.00	2.05	2.00	3.80	3.90	0.55	0.97

Table 34. Challenge Mechanism - Independent Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	14.64	-1.75	-3.80	-0.90	-3.10	4.35	3.05	4.55	1.90	4.25	1.75	3.50	2.95	5.40	4.05	4.75	-1.04
2	7.48	2.10	-0.55	0.25	-0.85	4.95	5.00	3.45	2.10	3.15	4.50	5.30	3.70	2.80	3.50	2.95	1.10
3	11.96	-1.00	1.50	0.05	0.05	4.75	4.50	2.60	5.20	6.40	5.50	3.35	4.75	3.35	6.00	4.70	1.57
4	8.62	0.90	0.75	0.40	0.45	6.05	5.05	6.35	1.45	1.05	6.30	6.35	5.00	5.30	1.60	4.55	0.25
5	6.66	1.70	0.50	-2.30	1.55	6.05	4.05	1.45	3.65	5.70	6.30	5.15	1.45	5.15	1.35	4.40	-1.26
6	14.59	-0.35	-0.65	0.50	-0.20	3.70	1.75	3.35	3.95	3.30	4.45	3.80	4.20	4.10	3.95	1.65	0.88
7	4.86	3.80	2.75	2.20	1.30	5.45	4.45	4.90	4.30	3.20	5.80	3.75	4.20	3.15	4.35	3.45	0.22
8	8.96	1.40	2.20	-0.10	2.00	4.40	5.35	5.20	4.15	1.30	5.90	4.65	6.25	5.85	3.95	5.30	0.53
9	10.08	-0.25	0.35	0.35	0.40	2.35	2.85	6.15	4.50	4.55	4.20	5.90	1.70	4.50	3.70	3.60	0.94
10	14.27	-2.05	-3.55	-3.90	0.80	2.80	5.40	1.80	6.25	4.25	4.80	5.45	2.10	5.25	4.65	3.25	-0.79
11	6.56	1.55	0.50	0.10	0.55	6.35	4.55	4.70	1.75	1.50	4.85	2.75	4.60	5.90	4.60	5.05	-0.09
12	10.30	-2.25	-0.80	0.10	-2.80	2.25	5.10	5.80	3.50	4.40	3.60	5.30	4.85	2.35	4.60	1.60	-0.85
13	6.36	0.75	-4.40	4.00	-2.35	1.90	2.75	5.95	5.75	5.30	4.80	5.65	2.65	1.30	5.30	0.50	1.41
14	7.34	-0.30	4.60	2.25	1.30	6.20	3.10	3.10	2.25	4.95	4.30	4.40	2.70	6.00	1.05	2.30	0.09
15	7.82	2.30	1.05	0.75	0.65	4.75	2.95	4.05	6.05	4.05	6.20	4.75	3.20	1.75	3.45	5.45	-1.16
16	11.72	2.70	0.10	-0.35	1.50	4.20	0.70	3.50	3.70	6.25	6.35	5.60	0.75	4.85	0.75	1.10	0.72
17	7.47	0.00	2.90	-0.75	3.80	2.85	6.20	5.35	6.15	5.60	5.05	6.05	1.55	0.70	3.35	5.50	-0.94
18	8.61	-1.60	3.25	0.25	1.70	3.95	1.65	4.15	4.20	4.00	1.80	1.75	3.45	4.75	6.05	2.85	0.79
19	7.89	2.55	0.45	0.70	2.35	5.50	4.30	1.25	3.40	3.75	3.25	4.30	3.45	5.30	5.55	3.30	1.01
20	7.43	-1.65	1.50	0.40	0.80	5.05	5.40	6.30	1.65	5.15	4.35	4.25	6.00	3.55	3.55	5.10	-0.79
21	11.55	2.00	-1.10	1.30	-2.30	3.40	2.15	5.60	4.25	5.15	4.75	2.75	2.65	4.10	1.35	4.90	0.25
22	9.99	-2.85	-0.45	-0.05	-3.05	2.95	5.35	5.90	3.40	5.70	4.05	4.60	4.45	4.10	5.20	2.20	-1.38
23	9.52	0.60	0.20	-3.95	2.50	3.50	4.40	6.35	3.45	6.10	0.60	3.10	3.45	4.60	3.70	5.15	1.51
24	7.52	0.70	3.40	0.40	1.15	6.00	5.20	5.40	1.05	2.90	4.40	3.85	5.10	3.30	3.80	2.45	0.97
25	6.01	3.30	-0.25	1.05	0.35	6.45	4.20	3.70	4.25	4.85	5.30	3.50	3.85	4.40	4.80	1.25	-0.75

Table 35. Challenge Mechanism - Independent Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	10.14	-0.50	-3.90	-4.60	0.25	2.80	-2.30	4.35	5.35	3.45	3.65	5.40	2.50	3.20	6.45	1.10	0.41
2	6.62	0.10	-0.65	-0.30	3.30	-4.20	-4.35	3.80	4.95	1.80	3.75	5.00	5.90	5.45	1.65	2.55	-1.51
3	10.80	-2.50	-2.15	0.80	-2.45	3.40	-3.10	3.05	3.40	2.35	3.45	2.95	5.70	5.65	1.05	0.60	-0.85
4	10.08	-2.15	-3.55	2.60	-2.15	0.80	-2.00	4.35	4.90	4.45	4.80	4.35	6.40	4.55	3.05	0.65	-0.35
5	10.66	-2.90	-1.25	-2.25	-2.65	2.75	-3.70	2.15	2.35	1.65	2.35	1.50	6.50	3.10	1.45	2.75	-1.13
6	5.13	2.15	0.00	4.15	-0.30	-0.40	2.25	2.25	2.65	1.45	3.90	2.65	4.25	4.20	1.55	0.50	1.16
7	6.42	1.35	-2.85	-0.55	1.10	2.10	-3.05	5.15	6.35	5.30	2.40	4.00	6.25	5.25	4.05	1.20	-0.50
8	9.91	0.10	-3.30	-2.65	-2.55	1.10	-0.70	5.50	3.25	5.10	1.85	2.85	4.10	3.45	2.30	1.45	0.50
9	12.07	-1.60	0.45	-1.10	-1.65	0.40	-0.75	3.55	4.15	2.75	4.75	2.55	5.60	2.20	2.90	0.80	-0.25
10	12.90	2.00	2.00	-4.75	-1.45	0.65	1.05	4.35	4.90	3.50	1.65	4.65	5.40	4.35	3.65	0.55	0.69
11	13.67	-3.40	0.25	-3.20	-0.15	0.80	-4.60	2.30	4.30	3.25	3.20	2.55	5.85	5.45	2.35	1.00	-1.48
12	5.93	2.55	2.25	-4.65	2.45	1.20	4.40	3.10	3.90	3.50	6.40	5.90	2.50	3.15	6.40	0.85	1.35
13	9.59	-5.00	2.80	-2.10	3.25	-2.75	-3.00	3.50	3.60	1.10	4.35	4.00	2.60	3.75	5.85	0.80	-0.13
14	10.89	-1.20	0.35	-1.05	0.70	0.00	-0.40	4.30	5.60	1.40	5.45	1.70	6.05	3.35	4.45	0.65	-0.79
15	7.81	4.95	-0.50	0.00	2.95	-3.25	-4.75	5.40	5.75	3.55	2.85	4.50	4.00	5.80	0.90	2.10	-1.29
16	6.83	-0.05	0.60	0.10	4.65	1.50	-1.65	2.30	6.00	1.20	6.20	4.45	3.95	4.35	1.55	1.20	-0.35
17	8.29	-0.50	2.30	0.15	2.30	0.00	0.65	4.75	4.10	4.20	1.85	5.10	6.25	2.15	6.45	1.00	0.88
18	7.75	0.20	4.60	0.70	1.70	2.10	0.80	4.20	5.15	4.05	3.45	5.55	4.25	3.15	6.40	0.60	0.82
19	10.30	-3.05	-0.85	-3.90	-4.25	3.10	-1.80	2.95	4.85	2.00	3.75	2.15	6.35	3.90	2.60	2.25	-0.19
20	9.31	3.00	-1.60	3.35	-3.50	0.30	1.00	6.15	5.40	3.10	4.20	3.80	4.95	2.95	3.95	0.50	0.38
21	8.86	-3.00	4.20	-4.10	-0.35	1.10	-3.50	4.20	4.65	3.50	2.90	4.20	4.20	5.20	2.25	1.60	-1.16
22	12.12	2.20	-0.05	-0.85	-1.60	1.10	0.90	5.35	4.25	2.35	3.30	2.70	6.15	3.30	5.20	0.65	0.60
23	12.82	1.65	-4.80	-4.30	-4.95	4.70	-0.20	5.10	3.40	5.90	5.30	4.20	2.35	3.00	6.05	0.85	0.82
24	9.99	2.60	0.75	-1.85	0.60	4.20	-1.10	2.65	5.85	5.35	4.80	1.85	2.50	3.15	6.45	0.90	0.35
25	5.16	2.95	-0.25	-3.50	4.95	1.25	2.70	4.70	5.55	0.85	5.15	5.45	6.25	3.50	3.00	0.85	0.44

Table 36. Challenge Mechanism - Independent Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	9.94	-3.45	1.25	-4.70	-3.85	4.85	3.10	4.50	1.55	2.40	4.90	5.95	2.00	4.80	4.65	1.95	-0.38
2	10.34	-4.50	-1.40	0.10	-4.35	3.60	5.90	1.90	6.40	5.70	5.45	0.90	4.35	5.50	6.45	1.30	-0.53
3	4.63	-3.20	-1.25	3.85	-1.05	4.25	6.05	6.05	2.70	2.05	5.10	6.50	3.40	3.75	1.20	3.10	1.23
4	18.27	0.00	4.25	-4.90	4.85	3.40	4.90	2.80	3.00	4.50	4.05	5.05	1.85	6.05	0.60	0.80	-1.04
5	12.27	-3.15	4.40	0.65	2.75	4.70	5.10	1.45	4.65	5.00	5.70	1.00	1.25	3.05	3.85	0.55	-0.53
6	7.54	-0.95	0.90	-0.20	-2.85	4.45	5.80	6.15	1.70	2.10	5.35	6.15	3.25	5.60	0.50	3.60	-0.28
7	8.42	-0.10	-2.60	4.45	-0.35	2.85	4.30	6.15	2.80	2.00	5.05	6.05	2.45	3.55	1.30	3.35	1.54
8	10.23	-2.40	0.55	-0.35	-1.30	5.10	6.40	2.00	4.45	4.20	4.75	2.60	6.35	2.85	2.95	0.70	-1.54
9	12.03	-1.20	-2.60	2.60	-3.50	2.45	3.65	1.70	3.05	2.25	5.00	4.90	3.40	6.30	0.65	2.60	-0.41
10	10.34	-2.20	-1.20	-4.15	-4.95	4.05	5.15	2.25	3.30	3.20	2.75	3.40	5.50	6.05	1.10	2.30	-0.97
11	12.84	2.10	-4.20	4.90	-5.00	2.25	3.45	5.40	6.10	2.80	5.90	5.55	6.50	6.25	2.40	2.35	-0.94
12	9.59	0.80	2.50	2.00	-2.05	5.10	2.35	3.45	1.50	1.40	4.60	5.25	4.20	4.00	0.50	3.90	0.38
13	10.74	-0.40	-0.75	-0.65	0.80	3.50	6.25	2.95	3.70	4.60	6.10	2.25	4.05	2.80	3.60	0.70	0.16
14	15.10	4.25	-0.30	-0.85	0.55	2.75	3.70	5.35	2.20	1.75	3.35	4.40	1.35	1.80	1.70	4.30	-0.63
15	10.60	-2.00	-2.20	1.30	-3.60	3.25	4.70	3.55	3.20	4.90	5.95	3.35	6.05	5.80	1.95	0.50	-1.13
16	12.29	-1.90	-5.00	1.75	-4.35	3.05	3.30	0.75	3.55	2.75	3.85	3.20	6.10	4.25	3.65	3.60	-0.35
17	4.16	2.90	-0.25	1.05	2.90	4.10	6.15	1.90	4.65	3.45	5.85	3.05	6.50	4.05	1.25	0.90	0.44
18	18.11	1.20	-4.85	-0.70	-0.60	5.55	2.90	2.95	5.70	3.50	3.15	2.15	4.05	3.25	5.15	1.25	-0.63
19	17.63	3.00	-0.80	4.95	-1.05	2.05	3.10	2.40	4.65	3.80	4.10	2.20	5.40	5.95	0.60	1.50	0.28
20	6.47	2.90	0.35	-0.05	1.45	5.35	4.95	2.25	3.15	2.80	6.40	4.45	5.30	4.10	2.95	0.65	0.47
21	11.72	-4.50	-4.75	1.00	-2.90	4.55	4.20	3.80	3.85	2.35	3.35	3.70	2.85	4.55	1.10	0.80	-0.66
22	12.75	2.10	1.90	4.40	-4.15	4.45	2.65	2.90	4.25	5.45	3.05	3.40	4.75	5.55	1.30	0.60	-0.03
23	11.96	2.00	1.15	4.95	-4.85	6.20	5.35	2.65	5.45	5.10	2.65	2.80	3.90	4.70	1.75	2.20	-0.35
24	8.30	1.70	2.50	0.20	-0.10	6.10	5.10	5.35	3.30	4.10	4.25	0.85	4.20	3.30	5.85	0.60	0.31
25	8.23	2.10	3.30	3.60	3.10	3.20	3.15	4.85	2.65	1.40	3.90	4.00	2.90	3.95	3.90	3.65	0.94

Table 37. Challenge Mechanism - Independent Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	8.74	-3.90	-0.30	-1.95	1.60	-4.50	-3.00	4.90	5.70	1.65	4.90	5.70	6.50	4.60	3.25	1.85	-1.57
2	10.26	-4.75	-1.50	-2.30	-0.10	-3.00	-4.70	4.05	4.15	1.65	3.50	3.80	6.50	3.80	1.60	2.55	-1.54
3	11.42	-2.65	2.55	-2.35	0.10	2.40	-2.50	6.20	6.10	3.75	3.70	4.25	6.50	3.85	2.50	0.55	-1.26
4	12.37	-2.80	-2.15	2.05	-1.55	4.50	2.70	5.85	5.10	1.55	3.80	3.10	5.60	4.15	1.20	2.00	0.66
5	5.31	4.30	-2.35	1.20	-0.40	2.55	3.95	5.40	5.05	4.45	3.50	6.40	4.70	4.75	1.15	0.70	0.57
6	13.66	-1.60	4.35	1.45	2.40	-0.60	-3.90	5.30	5.00	5.60	4.75	5.10	2.55	4.40	0.90	3.20	-0.63
7	11.94	-0.40	-2.35	-1.30	-3.90	5.00	-2.80	3.60	3.25	3.60	2.25	5.15	1.45	5.55	4.90	1.95	0.06
8	9.02	-1.85	-1.30	0.25	-0.80	1.75	-3.30	5.70	4.15	6.40	2.45	4.80	4.95	5.40	2.30	2.55	-0.35
9	11.19	-2.50	-4.40	-4.15	-3.50	1.30	-1.85	4.75	5.20	4.95	4.50	4.20	6.00	4.80	4.20	1.20	-0.63
10	14.68	3.10	-2.40	3.20	-3.00	0.05	-1.60	5.65	1.20	1.75	5.40	5.65	0.80	2.60	2.15	1.95	-0.72
11	13.49	-2.90	0.15	-4.60	-0.55	-0.90	-3.95	3.70	4.75	4.60	4.20	4.60	6.20	3.20	2.80	2.80	-1.48
12	10.95	-0.80	1.10	-0.55	1.25	-1.20	0.20	4.05	4.90	4.10	2.85	4.80	6.05	4.70	1.30	0.85	-0.06
13	9.67	-2.55	-2.85	-2.35	-1.15	2.15	-1.50	3.85	4.05	4.80	3.30	4.85	5.75	4.45	3.10	0.95	-0.79
14	8.33	3.70	-2.85	3.50	-2.65	4.70	2.40	2.45	3.45	2.50	2.90	2.60	2.35	4.55	5.50	0.75	1.01
15	11.54	-4.35	-3.05	-4.00	-1.15	-5.00	-4.85	3.95	5.45	5.20	3.50	6.05	6.50	5.70	2.40	4.00	-1.51
16	9.95	-2.50	0.55	-1.15	0.45	-2.85	-4.45	5.90	2.95	5.10	4.50	4.55	5.90	4.70	2.15	1.25	-1.48
17	8.92	-1.80	0.20	-1.55	0.90	-2.55	-3.85	3.30	3.30	1.45	3.95	3.15	6.50	3.60	2.05	1.45	-1.57
18	7.89	0.45	2.00	-0.55	4.85	2.95	-0.10	3.95	4.10	4.35	6.45	5.15	3.20	3.35	5.65	0.50	0.94
19	8.29	0.70	-1.20	1.45	0.00	0.25	1.70	4.05	3.85	5.20	3.10	4.35	6.35	5.15	2.15	0.90	-0.53
20	9.69	-0.70	0.50	-0.60	0.05	1.45	-4.45	3.70	2.45	2.25	3.00	2.60	4.45	6.45	1.95	1.60	-0.03
21	10.95	-4.00	0.10	-1.95	0.30	-0.70	-4.85	3.95	4.05	2.95	3.75	3.60	6.50	4.35	2.05	1.25	-1.51
22	13.93	-0.90	1.95	-3.90	-0.80	-0.85	-4.95	4.30	4.60	3.85	4.00	2.40	6.50	5.15	2.95	2.25	-1.26
23	12.86	1.60	0.80	2.70	4.05	2.50	0.85	3.55	2.50	2.35	6.30	4.60	1.45	3.70	3.85	0.60	-0.09
24	10.22	-1.35	-2.05	-1.95	-1.60	2.40	-2.95	5.55	4.70	3.95	3.65	4.15	6.10	5.00	3.80	1.90	-0.31
25	10.34	-0.20	-0.55	0.55	0.35	0.15	1.10	5.00	6.25	3.95	3.25	3.70	4.55	3.00	2.10	0.95	0.72

Table 38. Challenge Mechanism - Linked Agents - Four-Bar Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Angle
1	10.56	1.25	-1.75	-0.05	-0.45	5.90	2.55	3.35	3.60	0.50	-0.41
2	3.77	1.60	0.30	3.70	3.40	2.90	6.15	6.45	0.80	1.60	0.82
3	8.98	-0.85	0.05	2.45	-0.80	3.05	4.85	4.45	1.45	0.55	-0.57
4	11.19	-1.85	-1.45	3.60	-2.75	4.15	6.20	4.20	3.75	2.40	-0.28
5	9.41	2.10	-0.20	0.10	0.80	4.95	4.75	2.10	4.55	1.20	0.38
6	11.48	-1.15	-1.50	1.75	-4.35	3.45	4.70	4.80	3.20	3.00	-0.47
7	8.49	-0.95	0.90	-4.90	-4.95	5.80	6.45	6.35	3.40	1.75	-1.41
8	10.13	-4.85	2.50	0.75	-2.60	6.35	4.60	4.65	6.30	0.55	-0.19
9	3.61	3.05	-1.00	1.95	4.90	3.90	6.30	4.30	2.10	1.60	1.07
10	9.04	0.40	-0.20	2.10	-2.15	2.35	4.20	4.30	0.90	2.35	-0.82
11	11.30	-2.75	-2.70	1.75	-2.00	3.40	5.35	4.15	3.10	1.95	-0.60
12	11.51	-4.05	1.70	-2.00	-2.85	2.95	1.85	3.80	4.60	0.65	-0.60
13	11.22	0.90	-1.75	0.15	-0.15	5.30	5.00	1.95	5.35	1.50	-0.57
14	4.55	1.20	0.15	4.90	2.70	3.00	3.45	4.90	0.50	1.75	1.01
15	10.00	-2.50	-1.70	2.60	-1.65	3.45	5.50	3.85	3.05	1.60	-0.66
16	11.31	-0.50	1.15	-2.35	-4.80	4.60	6.40	4.60	2.10	0.50	-0.44
17	10.27	-1.20	0.30	0.85	-5.00	3.35	6.50	5.75	1.20	0.50	-1.48
18	10.99	-0.05	-3.05	-0.60	-0.60	4.75	3.20	2.80	4.50	0.50	-0.94
19	10.89	5.00	3.95	-1.20	4.95	3.95	3.10	3.85	6.35	0.65	0.16
20	11.42	-0.50	-0.30	0.35	0.20	2.10	4.25	3.55	2.95	0.80	-0.25
21	6.40	2.90	-3.00	4.30	4.60	5.20	6.45	6.15	2.45	0.90	0.97
22	8.06	-0.60	0.05	1.55	-2.00	2.80	3.95	4.50	1.75	1.35	-0.44
23	7.77	0.85	0.00	0.75	1.65	3.40	4.90	3.10	1.65	0.95	0.44
24	6.70	1.15	4.20	2.10	1.50	5.40	1.95	3.00	4.50	0.55	0.57
25	3.80	2.40	-0.10	3.90	4.40	3.25	5.05	4.15	0.75	2.30	0.97

Table 39. Challenge Mechanism - Linked Agents - Stephenson I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	5.66	-0.45	0.50	-0.75	-3.95	3.55	3.70	4.45	3.25	4.45	4.05	4.60	4.75	6.30	2.80	0.85	0.88
2	10.95	-1.00	-0.15	-1.75	-3.70	4.85	5.80	3.00	2.75	5.25	5.30	2.20	5.80	5.40	0.70	1.85	-1.19
3	14.84	1.05	-4.20	3.25	-4.90	2.15	3.90	4.70	3.30	2.55	3.75	3.40	4.10	3.70	6.20	5.95	0.88
4	8.33	-0.90	2.30	-0.45	-1.70	6.05	5.05	3.50	2.70	2.40	5.55	4.65	6.50	3.65	3.70	1.20	0.72
5	7.81	1.40	-0.95	0.45	1.50	3.55	4.40	3.20	3.60	3.55	4.00	2.45	4.35	4.95	2.90	1.00	1.13
6	12.98	-0.30	-0.90	1.35	-0.80	2.15	5.60	3.45	3.55	4.75	2.45	2.55	6.40	2.60	4.10	1.70	0.44
7	10.15	0.10	0.00	1.30	0.40	3.90	3.90	6.40	3.05	3.05	5.30	3.65	4.70	5.00	0.55	1.45	0.82
8	13.43	-2.45	-4.65	3.25	-0.20	5.95	4.65	3.55	5.35	3.25	4.00	3.30	3.40	4.85	4.05	0.65	1.57
9	12.30	-1.95	1.60	-4.20	-1.80	5.05	5.85	6.40	3.35	1.75	4.25	4.85	5.60	6.35	5.70	0.65	-0.91
10	8.87	0.05	-3.15	3.05	-4.60	2.85	3.40	0.50	3.00	2.80	4.15	4.50	4.90	4.15	4.45	2.05	-0.16
11	11.74	-0.40	4.80	-2.50	0.50	5.45	4.60	2.15	3.80	3.85	3.20	2.10	5.45	4.15	2.65	1.45	-0.57
12	7.51	-0.45	1.15	-1.30	-2.90	4.45	3.60	4.10	2.40	6.45	6.40	6.05	5.10	6.40	1.75	1.35	0.25
13	9.94	-0.10	0.15	2.85	-2.40	4.80	5.70	3.85	2.50	3.90	4.15	5.05	5.55	6.25	1.85	1.25	0.25
14	6.98	4.90	-1.55	4.95	4.20	2.75	3.50	2.80	5.05	3.55	3.50	4.00	5.95	2.85	2.65	2.40	0.38
15	8.97	0.55	0.50	0.40	1.70	3.85	1.75	4.65	2.95	3.15	3.25	2.40	5.55	1.50	1.95	2.55	1.16
16	7.96	-0.40	-0.45	1.30	3.25	2.90	2.20	4.65	2.30	3.80	3.25	4.10	4.35	4.55	3.15	0.60	-0.13
17	11.10	-0.35	-0.80	0.05	0.00	3.30	3.00	4.50	4.80	4.60	6.30	2.95	5.40	3.25	3.75	2.15	-1.16
18	11.09	4.15	-1.85	3.70	2.85	4.40	4.60	3.60	3.05	4.90	5.45	0.90	2.95	3.85	5.05	1.25	0.79
19	9.64	1.20	1.40	-2.10	1.95	6.40	6.05	3.80	2.70	3.45	3.70	2.90	5.95	4.45	3.00	0.95	1.26
20	7.88	-0.55	1.50	-1.30	0.40	3.30	4.00	5.80	3.60	2.00	3.55	3.90	4.95	6.45	2.65	0.70	1.16
21	16.73	0.50	0.50	0.75	-1.15	4.70	5.35	4.95	2.50	3.60	2.55	2.25	3.80	3.10	0.60	2.00	1.13
22	11.25	0.20	-2.35	0.60	0.40	5.65	4.90	5.05	4.30	5.60	6.15	1.40	4.40	4.20	4.00	0.55	-0.60
23	11.71	2.00	-1.50	2.25	-5.00	2.35	2.70	0.55	2.45	3.20	2.95	3.65	5.15	6.10	2.55	3.15	0.31
24	10.93	-1.50	0.05	1.85	-3.05	3.45	4.90	1.75	3.95	3.45	3.00	2.80	4.40	5.20	2.90	0.85	-1.35
25	13.92	-0.10	-0.45	-0.15	-2.90	5.10	4.80	2.95	4.55	2.75	2.35	1.90	5.90	2.30	1.50	0.50	-1.35

Table 40. Challenge Mechanism - Linked Agents - Stephenson II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	9.09	0.60	1.25	0.00	-0.20	4.80	4.95	5.15	4.05	4.30	5.50	5.20	0.55	0.90	2.05	3.10	0.57
2	8.54	-0.45	0.00	0.15	-0.40	3.35	2.85	2.40	2.40	2.10	4.25	3.95	1.90	0.80	5.50	1.20	1.35
3	9.83	1.30	1.65	3.00	1.10	5.25	5.80	5.40	3.20	2.30	6.05	4.50	3.35	2.80	4.35	2.40	-0.75
4	14.76	-4.50	-0.80	2.90	-2.90	3.10	2.60	6.50	4.95	4.10	6.10	6.05	1.25	1.00	5.65	6.45	-0.66
5	9.37	0.05	1.15	-2.50	-0.30	4.20	3.85	6.25	5.20	5.25	6.45	6.25	0.50	1.80	4.35	5.50	-0.75
6	9.70	0.15	-0.40	0.00	1.40	6.15	2.85	5.55	4.35	5.95	6.45	5.55	3.55	3.40	2.05	2.75	1.13
7	10.67	1.50	-0.35	-0.10	-0.25	4.55	4.70	5.60	3.35	5.45	5.70	2.80	3.65	1.60	5.65	1.75	-0.53
8	14.79	0.10	-0.30	0.45	1.40	3.05	1.70	2.60	3.15	3.60	0.55	1.95	2.05	4.80	1.90	1.35	-0.88
9	9.08	-0.65	1.95	4.90	0.80	4.05	2.85	6.30	4.70	6.05	4.85	5.05	0.95	3.55	1.65	3.60	-0.28
10	11.75	3.30	-4.35	1.90	-3.20	5.25	3.30	6.50	6.50	5.40	4.70	4.70	6.40	3.30	5.95	0.65	0.06
11	6.72	1.65	0.80	-0.40	-0.40	6.50	4.95	2.60	4.15	5.90	5.40	4.05	2.40	5.00	2.60	5.85	-0.50
12	13.09	-0.45	1.10	-0.20	1.10	3.90	3.80	1.95	3.65	4.40	5.10	1.40	4.75	2.90	1.30	1.35	0.06
13	12.43	0.75	1.10	3.80	1.90	4.35	4.65	3.35	4.25	4.80	5.55	4.75	5.65	3.40	1.40	1.25	-0.35
14	6.46	3.30	1.10	4.60	2.35	4.10	5.70	3.80	2.95	4.95	2.10	5.85	5.50	1.70	5.45	1.35	0.60
15	10.34	2.10	-1.60	1.65	-0.45	6.50	4.65	1.30	3.35	4.20	5.20	6.45	1.35	1.35	2.95	5.50	0.85
16	14.13	4.00	-0.10	0.35	0.10	6.10	1.85	5.00	5.80	6.40	6.10	4.25	4.95	5.50	4.65	1.35	-1.23
17	10.73	-0.15	-1.25	-0.25	-0.05	6.40	5.60	4.40	3.20	4.50	5.90	2.65	5.05	4.00	4.65	2.15	-0.82
18	15.41	1.90	3.75	-4.65	2.80	3.80	6.05	3.15	4.25	3.10	3.85	6.45	3.35	5.15	1.05	2.50	-1.51
19	14.87	1.05	-1.70	1.00	-1.05	3.70	3.55	4.85	6.10	1.70	1.10	2.55	2.80	5.35	6.45	4.40	-1.32
20	11.66	-0.55	1.50	-1.10	0.40	3.15	4.05	6.00	3.75	1.90	3.15	4.25	5.60	6.10	2.75	0.65	1.07
21	9.71	-1.00	1.60	0.20	0.55	4.30	4.25	5.05	1.50	5.60	6.30	1.70	6.25	4.70	6.35	3.85	1.16
22	11.30	0.20	1.90	-0.75	0.45	4.75	4.90	5.05	5.00	5.60	6.50	1.70	6.15	4.20	5.40	1.45	0.79
23	13.02	-1.15	-1.35	-1.80	-2.20	4.35	3.80	6.25	3.10	1.55	4.85	4.80	2.25	1.60	5.30	1.75	-1.26
24	13.88	3.45	-1.40	0.55	0.00	5.30	5.85	5.90	2.35	3.75	3.35	2.10	3.25	3.30	1.55	2.35	-1.45
25	13.29	2.70	3.85	-4.95	3.50	3.50	5.20	1.90	4.55	5.15	3.90	4.55	5.25	6.50	0.60	3.25	1.35

Table 41. Challenge Mechanism - Linked Agents - Stephenson III Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	4.50	1.50	-0.65	3.25	1.95	2.90	-4.75	2.05	5.25	2.50	4.10	6.40	4.70	5.95	1.45	2.45	-0.44
2	11.40	-0.05	0.00	0.45	-0.35	1.00	0.60	3.00	2.75	1.40	2.30	1.95	5.65	4.30	1.70	0.55	0.44
3	11.28	4.45	-1.20	3.60	2.35	2.05	-0.15	3.00	5.60	5.50	3.65	4.90	3.90	2.40	6.35	0.75	1.29
4	9.78	-4.85	1.90	-3.35	-4.70	2.35	-3.35	4.35	4.30	6.05	1.85	3.95	6.50	6.50	2.55	2.55	-0.28
5	7.32	0.90	-0.60	-0.20	1.40	1.25	-2.85	3.40	3.80	2.40	2.20	2.35	4.75	4.95	0.90	0.55	-1.07
6	11.63	-2.50	-2.65	-0.50	-1.95	2.40	-3.50	2.10	4.85	2.30	3.95	4.65	6.35	3.60	1.50	2.10	-1.57
7	11.94	-0.50	-0.35	-0.10	-0.15	0.70	-0.45	2.40	4.50	2.70	6.30	6.05	6.25	3.40	4.30	0.85	-0.72
8	10.99	-3.30	-0.80	2.00	-3.30	-0.20	-0.50	5.40	6.30	2.60	3.80	5.10	4.85	3.10	3.85	0.90	-0.22
9	8.42	-2.80	0.45	0.80	0.65	1.65	1.70	5.60	5.80	3.75	4.30	3.85	2.90	2.50	6.45	0.55	1.45
10	10.31	0.15	-2.00	4.20	-4.10	1.25	-1.85	3.40	4.80	3.50	3.80	4.60	3.80	3.30	1.00	2.15	-1.29
11	13.49	2.10	-1.10	0.35	-3.25	-1.05	-1.50	5.25	3.95	4.30	2.40	2.25	2.40	2.70	4.45	0.50	-0.41
12	9.10	0.20	3.50	-0.30	2.00	0.20	0.75	3.45	5.45	3.75	5.10	4.70	5.85	2.50	6.35	0.50	1.51
13	8.16	3.40	-0.70	2.90	2.30	2.60	3.55	3.25	3.10	0.70	3.70	2.70	5.40	3.85	2.25	2.20	0.72
14	9.36	0.70	2.00	-1.70	4.50	1.45	1.40	4.20	6.00	0.55	5.85	6.45	2.65	2.10	5.85	1.45	0.91
15	3.99	1.05	-2.85	0.55	2.85	1.65	-3.00	4.60	5.85	4.35	3.05	4.85	6.45	5.45	4.00	0.90	-0.57
16	10.69	-2.00	-1.20	-5.00	-4.80	-1.30	-1.15	2.55	4.55	2.65	5.70	5.55	6.40	5.90	1.30	0.70	-1.16
17	8.72	2.45	1.55	-4.50	4.75	0.60	2.20	4.05	6.45	2.05	5.20	5.10	4.30	2.80	2.05	0.75	0.85
18	7.57	-3.30	-3.80	2.20	-3.70	2.35	2.90	6.15	6.45	4.70	2.45	4.50	6.50	6.50	1.25	0.50	1.54
19	16.33	-0.70	0.30	-3.95	-1.90	0.20	3.40	3.00	3.80	2.95	5.05	3.50	5.75	3.25	2.05	0.65	1.57
20	11.34	-2.90	-1.70	-3.25	-1.85	1.80	-0.75	1.45	5.50	4.20	3.15	4.50	5.30	4.20	3.40	0.55	0.00
21	16.36	-0.15	-0.80	-2.55	4.45	0.25	-4.90	3.50	4.95	4.85	3.95	5.30	3.65	3.65	0.60	5.30	-0.66
22	12.63	3.30	-3.25	4.25	-3.90	0.50	-1.80	4.85	5.70	2.20	6.00	5.80	1.50	3.65	3.95	0.55	-0.88
23	10.83	-4.65	3.00	-3.00	3.45	-2.95	-4.75	2.25	2.95	2.95	3.50	2.65	1.80	5.25	4.70	2.10	-0.91
24	7.18	1.80	0.30	1.75	2.55	0.05	1.35	3.80	4.75	1.60	6.20	4.40	5.95	3.00	4.50	0.60	-0.16
25	12.96	-1.80	-4.90	-2.15	-4.80	-1.75	-0.65	4.90	5.95	4.70	5.20	2.85	3.40	2.45	5.35	1.45	-0.82

Table 42. Challenge Mechanism - Linked Agents - Watt I Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	7.86	1.90	1.05	0.00	1.20	4.15	4.50	1.25	3.35	2.10	4.00	2.25	4.50	3.75	3.20	0.95	-0.09
2	9.14	-0.05	-0.10	-0.70	0.20	1.70	2.80	1.75	4.55	4.20	2.75	2.45	3.45	6.10	0.50	1.80	-0.66
3	10.15	-0.20	0.25	-0.90	-2.90	2.80	4.55	3.80	1.90	0.65	5.95	6.50	1.85	5.60	2.40	3.70	-0.57
4	12.26	0.45	2.30	0.70	-2.30	6.15	4.35	2.80	2.05	2.25	4.85	4.50	5.45	3.15	3.70	0.95	-0.19
5	8.73	1.60	1.00	-0.55	1.85	3.70	5.05	0.65	5.10	3.70	6.10	2.80	6.30	4.40	3.25	0.55	0.13
6	11.27	-3.25	-2.90	0.90	0.45	3.90	4.70	3.65	1.05	2.50	2.60	1.65	5.45	3.40	0.50	1.35	-0.06
7	13.09	0.70	-0.60	0.70	-4.85	3.80	4.60	5.10	1.20	1.70	2.30	3.10	1.80	1.95	1.10	6.25	-1.13
8	12.64	3.75	0.85	-4.20	1.85	5.40	1.55	3.15	1.65	3.30	4.35	3.50	1.85	4.80	0.50	2.55	-1.45
9	13.82	-4.50	-5.00	-5.00	-5.00	6.50	0.50	6.45	6.15	6.50	6.45	0.75	6.50	6.50	4.50	2.10	0.50
10	10.39	0.05	-3.35	3.05	-4.65	2.85	3.40	0.50	3.00	2.80	4.15	4.50	4.90	4.15	4.45	2.05	-0.16
11	3.84	1.55	-0.90	4.50	3.30	3.80	4.40	1.50	5.85	5.30	4.50	0.85	5.45	5.45	2.55	0.80	1.10
12	8.48	-1.50	4.45	-1.20	-1.30	3.60	4.60	5.05	0.80	2.65	4.80	5.95	2.65	6.10	1.65	4.25	0.19
13	10.48	-2.10	-2.10	-2.10	-0.45	4.90	3.50	5.95	2.50	2.05	5.00	4.50	2.70	4.90	0.60	0.85	-1.10
14	12.37	-1.50	-0.45	0.10	-0.70	3.35	6.40	1.10	5.85	6.15	5.70	0.65	5.05	1.80	3.25	1.60	-1.01
15	11.25	-2.65	-4.70	2.25	-4.80	3.50	4.65	3.80	3.60	3.40	4.55	3.65	3.65	5.95	1.15	1.70	-0.97
16	11.58	-2.60	5.00	0.15	-2.45	6.25	4.90	5.65	1.45	1.75	4.45	5.10	2.55	4.80	0.75	3.95	-0.85
17	14.01	-1.25	-3.85	3.55	-0.95	3.20	4.65	0.50	5.05	5.65	5.10	1.10	2.30	4.60	4.85	0.55	1.35
18	10.62	-2.05	-0.85	1.35	-4.40	4.55	4.70	6.45	2.40	3.20	5.05	3.25	2.45	6.35	0.75	2.50	0.50
19	15.18	-3.50	-4.15	0.95	-0.15	5.60	6.20	3.80	2.70	4.35	3.80	1.95	5.90	1.20	4.10	1.15	-0.82
20	11.73	0.90	-0.95	0.35	-2.85	1.60	2.25	2.95	4.75	2.65	2.25	1.30	4.15	6.50	0.55	0.55	1.19
21	10.06	-2.75	-0.75	3.05	-1.65	4.05	4.50	5.00	2.45	2.85	3.90	5.00	3.70	4.40	0.65	2.05	-0.41
22	11.69	-1.50	-0.50	-1.55	-4.90	2.95	4.35	4.30	1.80	2.15	4.70	4.95	2.30	6.45	0.60	5.35	-0.97
23	11.54	2.00	-1.45	2.25	-5.00	2.55	2.70	0.65	2.30	3.55	2.90	3.45	5.05	6.40	2.55	3.00	-0.35
24	10.50	-2.45	-0.85	1.05	-2.65	3.55	4.90	0.80	5.20	5.10	3.20	2.65	4.85	3.90	3.20	0.70	-1.13
25	7.98	-1.00	-2.35	2.30	0.20	3.35	4.60	2.60	4.40	3.05	3.00	0.80	6.20	2.70	3.25	0.80	-0.38

Table 43. Challenge Mechanism - Linked Agents - Watt II Agent Results.

Run	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Angle
1	11.29	1.05	1.00	0.30	0.10	1.70	-2.15	3.10	4.65	5.10	2.60	5.35	3.90	5.45	0.85	0.95	0.38
2	10.58	1.35	-0.15	-0.35	-0.25	-0.25	0.50	4.80	2.95	4.85	4.30	3.75	4.00	1.35	4.85	1.75	0.25
3	12.91	-1.70	-3.60	-0.80	-0.30	-3.65	-1.95	4.60	4.95	2.10	3.15	4.25	3.95	3.85	0.55	2.35	-1.57
4	10.81	1.85	-1.00	2.45	-2.80	3.35	2.25	4.75	5.40	2.30	4.25	6.20	3.25	4.00	5.50	0.60	0.94
5	11.13	-0.65	2.15	-0.95	1.35	-1.30	0.00	5.15	5.00	5.20	3.10	3.80	6.10	4.55	2.15	0.90	-0.69
6	12.68	-0.90	-1.90	-3.00	-1.85	2.00	-2.75	5.05	5.40	2.15	3.30	3.30	5.85	2.60	2.70	2.65	-1.04
7	13.59	-2.25	0.75	-1.80	-1.70	3.40	-1.50	4.00	4.20	1.10	2.75	3.85	5.60	2.95	2.70	2.35	0.44
8	9.16	2.10	-0.90	-0.10	-0.40	3.00	0.75	5.65	3.55	5.15	3.35	6.05	5.45	4.75	1.40	0.50	0.06
9	10.01	-0.55	-1.00	-0.65	-2.15	-1.20	-0.40	4.35	3.95	3.40	3.40	5.95	2.60	2.05	4.95	0.50	-0.22
10	9.71	1.40	-1.25	-0.50	-0.40	1.70	-4.05	4.90	4.10	4.65	3.35	5.05	4.65	5.55	2.60	2.20	-0.38
11	11.99	-3.30	-4.25	-4.10	-4.00	1.45	-4.25	4.45	3.15	4.45	4.65	5.70	6.05	5.50	4.45	2.25	-0.60
12	8.78	-1.00	4.10	-0.55	2.65	0.20	0.65	3.10	5.45	1.10	5.45	4.70	5.75	2.50	6.45	0.50	1.45
13	13.20	-3.25	-4.95	-4.05	-2.10	0.80	-4.15	5.50	6.25	4.90	4.50	4.00	5.90	5.95	4.50	1.40	-1.10
14	8.44	0.70	2.00	-1.70	4.85	1.85	1.40	4.05	5.55	6.45	5.85	6.10	2.10	2.10	4.45	1.30	0.72
15	3.49	1.95	-1.30	1.70	-0.40	5.00	3.20	6.35	2.90	5.35	3.35	4.60	5.00	6.45	1.35	1.35	0.85
16	17.62	-2.20	-2.80	-3.90	-3.45	-1.40	-2.00	2.55	2.15	6.25	4.90	2.25	2.95	3.85	4.55	1.25	-0.75
17	4.58	2.20	-1.25	2.85	-0.95	2.55	3.95	5.40	5.00	3.95	4.00	4.15	6.40	5.95	2.40	0.90	0.94
18	8.28	-3.05	3.60	-4.95	3.00	-4.80	-4.30	5.50	5.75	0.95	3.95	3.70	3.75	6.20	6.45	1.20	-0.91
19	12.45	-5.00	4.40	-3.80	-4.70	-2.20	-2.30	4.45	6.25	2.90	4.45	4.85	1.50	3.00	4.10	1.50	-0.06
20	10.31	-2.15	-1.40	-3.60	-1.60	1.75	-1.40	3.60	6.20	3.15	4.05	5.00	5.75	4.30	3.70	0.55	-0.60
21	17.81	-2.20	0.10	-3.90	1.70	-1.75	-4.55	3.95	4.70	2.40	4.45	3.50	5.15	5.25	2.10	0.75	-0.63
22	8.69	2.10	-4.00	4.35	-4.55	1.70	4.55	3.70	4.20	1.80	6.45	4.70	6.50	4.15	3.90	0.55	1.07
23	10.75	-5.00	2.55	-4.10	3.40	-3.40	-4.70	2.75	2.85	4.15	3.75	1.90	1.65	5.95	4.60	0.50	0.06
24	9.35	-1.15	-1.00	1.90	0.20	0.05	1.30	3.60	3.70	1.85	4.95	4.20	5.95	3.00	4.65	0.60	-0.97
25	12.28	-1.70	-4.10	-1.70	-4.90	-1.75	-0.65	4.90	4.85	4.90	6.15	2.85	3.40	2.20	5.65	1.45	-1.29

Table 44. Challenge Mechanism - Convertible Agent Results.

Run	Type	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	4B	3.83	4.15	-4.10	4.85	4.75	-	-	6.40	6.25	6.40	3.10	1.05	-	-	-	-	-	-	1.29
2	W2	4.47	4.85	-1.70	4.00	-4.20	4.80	4.55	6.25	5.40	6.50	6.30	6.40	6.40	6.45	3.25	0.85	-	-	0.79
3	W2	2.45	3.35	1.90	3.75	0.10	4.65	4.40	6.50	2.80	3.90	3.30	6.15	6.30	5.90	1.50	3.05	-	-	1.16
4	4B	6.54	-0.70	0.75	0.80	-1.90	-	-	2.70	3.90	4.65	1.85	1.15	-	-	-	-	-	-	-0.28
5	W2	3.26	1.05	-0.15	2.90	-0.15	4.20	4.35	4.95	5.40	1.85	3.20	3.45	5.60	4.70	1.10	2.60	-	-	0.47
6	S3	6.44	2.45	0.50	3.20	3.65	-0.20	1.80	3.60	4.70	1.85	3.75	5.20	6.35	3.90	3.95	0.50	-	-	1.16
7	S2	7.61	0.45	-0.40	-0.50	1.40	-	-	3.65	6.05	3.20	4.95	5.10	3.60	4.55	2.10	5.00	2.80	0.55	0.25
8	W2	8.68	-1.85	-2.30	-1.55	-0.50	1.45	-2.45	5.65	3.60	2.65	3.40	4.45	5.00	5.20	3.05	0.90	-	-	-0.28
9	S2	9.28	3.15	-1.70	1.75	-0.30	-	-	4.95	4.95	6.40	6.35	2.85	2.55	1.45	2.95	4.45	4.20	3.20	0.47
10	4B	3.27	2.30	-0.50	2.90	4.05	-	-	3.50	6.15	5.65	1.70	1.35	-	-	-	-	-	-	0.97
11	S3	4.15	2.15	-1.75	1.75	-1.50	4.35	3.60	3.20	1.70	2.30	2.45	1.80	4.55	5.80	1.70	0.80	-	-	1.26
12	4B	8.94	-1.45	0.80	-2.80	-3.95	-	-	3.75	6.45	3.60	1.65	1.60	-	-	-	-	-	-	-1.57
13	S1	5.79	-0.35	1.95	0.80	1.25	-	-	1.80	4.45	4.25	3.95	4.65	6.50	2.65	3.10	4.10	5.60	1.00	1.26
14	S2	6.40	0.10	0.00	-0.65	0.35	-	-	5.10	4.30	4.30	1.60	0.95	2.20	3.40	2.65	2.30	4.30	5.50	0.38
15	4B	4.50	1.70	-0.70	1.65	4.15	-	-	3.65	5.30	4.30	1.50	0.80	-	-	-	-	-	-	0.91
16	S1	4.66	2.55	-1.90	2.35	3.05	-	-	4.25	5.00	1.85	5.05	2.95	4.95	2.10	6.25	4.85	2.70	1.00	1.19
17	4B	4.64	2.75	-3.45	2.45	3.70	-	-	5.75	5.35	4.20	2.50	0.60	-	-	-	-	-	-	1.54
18	S2	7.46	1.80	0.85	0.75	2.25	-	-	4.90	4.60	2.80	3.90	4.70	6.35	5.50	3.70	4.30	0.95	3.85	0.79
19	4B	5.40	1.50	-0.60	0.75	2.55	-	-	4.55	5.10	2.70	2.45	0.60	-	-	-	-	-	-	0.25
20	S2	5.95	3.20	2.35	1.60	1.20	-	-	5.25	0.70	5.10	5.20	4.30	3.40	3.30	4.85	4.15	5.55	2.15	0.41
21	S3	6.24	-0.75	4.20	-0.65	3.80	2.35	0.30	4.20	5.60	1.95	5.40	5.95	3.40	2.70	5.70	0.60	-	-	1.04
22	S3	6.70	2.40	-1.25	2.70	-0.35	0.30	1.50	5.45	5.85	4.55	1.95	3.40	4.45	2.75	3.15	0.95	-	-	0.44
23	4B	5.40	1.25	-0.15	1.30	4.60	-	-	3.20	5.20	3.55	0.85	1.05	-	-	-	-	-	-	0.88
24	W2	8.94	-3.50	-1.90	-1.90	-0.50	2.85	-0.65	4.45	3.00	3.70	3.30	3.60	5.70	4.00	2.50	0.70	-	-	-0.60
25	4B	4.84	1.10	-0.05	2.30	3.40	-	-	3.10	5.90	5.85	1.10	0.80	-	-	-	-	-	-	1.29

Appendix E - "Known Solution" Mechanism Case Study - Raw Data

Table 45. "Known Solution" Mechanism - Original Convertible Agent (6) Results.

Run	Type	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	W1	8.89	-4.60	-5.12	4.97	-8.18	-4.11	-3.04	8.26	9.99	7.43	7.23	8.57	4.76	9.88	8.55	4.55	8.23	3.01	-0.30
2	W1	28.12	3.75	-1.23	2.36	-5.16	6.92	-4.12	3.39	4.02	2.59	5.69	4.81	4.15	2.43	3.77	8.55	4.22	6.07	-0.46
3	S3	34.94	6.31	-3.52	1.44	1.35	5.96	0.98	7.34	7.05	1.47	5.91	6.08	6.76	8.32	2.31	5.98	3.07	5.20	-0.12
4	W1	36.15	-1.99	-1.87	4.48	-3.15	1.59	1.48	6.80	8.08	9.37	6.70	7.15	2.46	6.29	9.25	6.20	5.68	1.03	-0.50
5	S3	20.65	-0.89	-3.32	5.78	-6.93	4.55	-4.50	5.75	9.87	5.88	7.65	8.11	4.91	8.08	3.34	5.58	7.52	4.96	-0.59
6	S2	42.25	3.57	-1.15	4.17	-3.59	-8.52	-5.88	5.04	5.90	4.64	5.86	8.27	6.39	7.63	7.85	5.24	1.90	4.45	-1.20
7	S1	44.06	-1.68	4.96	-0.59	-4.63	10.00	-4.93	8.68	7.34	9.98	9.65	5.66	9.59	7.21	3.23	7.26	8.17	6.94	0.18
8	W1	28.16	-2.69	2.40	3.99	-3.13	3.40	-5.87	8.00	8.20	7.92	2.68	6.30	4.38	9.89	4.84	5.36	4.28	0.52	1.13
9	S2	32.28	6.68	-0.97	4.12	-1.07	-4.60	-9.17	6.96	7.95	8.26	5.95	1.89	8.56	8.33	0.72	3.92	1.55	6.40	0.08
10	S3	22.61	-0.04	-3.38	8.74	-5.07	3.63	-4.50	6.57	9.07	5.92	8.33	6.42	8.09	7.38	4.76	6.18	3.87	4.04	-0.75
11	S3	26.39	1.33	-2.10	-0.23	-9.76	4.40	-4.10	6.03	4.88	4.19	8.45	9.69	8.08	9.30	7.16	4.22	7.42	4.66	-0.42
12	W1	22.73	-2.46	-1.38	4.01	-3.75	1.00	-0.89	6.18	6.80	8.14	2.08	5.81	4.43	7.72	2.22	3.79	5.76	1.42	0.85
13	W1	26.56	-0.62	-6.70	6.84	-7.52	0.14	5.32	4.65	8.61	5.57	5.20	5.75	7.85	8.12	10.00	7.70	3.96	7.42	-0.30
14	S3	33.01	-0.93	-1.05	5.31	-2.85	3.94	-5.06	6.93	9.37	6.31	6.99	5.67	6.03	8.08	1.47	4.82	9.56	6.62	-1.02
15	S3	30.22	2.46	-3.20	5.41	-4.80	1.53	-6.04	2.84	6.42	2.83	5.72	5.91	7.59	8.70	2.38	8.95	1.10	6.90	-0.64
16	W2	36.10	3.49	-2.94	2.00	-3.41	4.56	-5.57	2.63	7.39	3.44	3.22	6.57	6.88	6.82	9.05	7.93	0.68	9.96	-0.44
17	S3	18.93	-1.65	-0.02	-1.96	-2.34	4.67	-6.35	6.78	9.20	8.62	1.86	5.41	8.58	7.17	8.13	8.35	8.09	3.90	-0.27
18	S1	35.68	6.90	-3.32	1.17	-0.01	4.74	3.57	9.94	8.42	9.32	5.64	8.88	7.63	7.79	4.49	8.44	9.01	6.65	0.20
19	S3	32.28	-1.70	-6.61	4.09	-0.81	-1.52	-6.04	7.07	9.99	8.46	1.67	7.58	9.85	8.98	0.55	7.35	2.33	3.98	-1.05
20	S3	17.01	-2.48	-1.27	0.82	-0.95	4.28	-6.50	8.02	8.62	4.28	6.29	4.75	9.15	8.69	7.34	6.88	8.69	3.36	-0.33
21	S3	33.85	2.97	-4.59	6.67	-2.57	3.29	-3.04	4.35	8.35	5.77	4.18	6.24	6.14	4.65	3.04	8.43	6.19	1.81	-0.67
22	S3	29.53	-1.24	-1.07	-1.96	-0.55	4.41	-4.17	5.37	6.00	7.58	4.28	3.55	9.16	7.35	9.61	6.40	5.11	3.56	-0.32
23	S3	14.05	-3.30	-3.36	6.57	-6.85	4.43	-4.85	8.44	9.65	7.26	6.09	8.99	10.00	9.12	4.79	4.68	3.97	4.49	-0.77
24	S3	21.96	-1.70	-3.42	5.13	-6.82	4.37	-5.49	6.33	8.98	7.86	4.55	8.24	10.00	9.64	0.52	4.56	4.48	1.59	-0.89
25	S3	46.26	-1.43	0.83	3.89	0.31	4.38	0.83	6.87	6.95	5.10	6.13	5.57	5.97	6.35	9.69	4.47	6.85	3.37	-0.29

Table 46. "Known Solution" Mechanism - Enhanced Convertible Agent (24) Results.

Run	Type	ObjFunc	Pnt 1,X	Pnt 1,Y	Pnt 2,X	Pnt 2,Y	Pnt 3,X	Pnt 3,Y	Len 1	Len 2	Len 3	Len 4	Len 5	Len 6	Len 7	Len 8	Len 9	Len 10	Len 11	Angle
1	S3	25.38	-0.15	-1.02	4.07	-5.51	5.58	-2.24	5.76	6.97	9.60	6.66	7.07	10.00	9.60	0.50	1.71	4.64	6.97	-1.04
2	W1	26.31	1.06	1.02	3.77	-7.14	-3.97	5.92	7.57	8.48	4.85	6.36	8.38	5.25	4.44	2.82	9.09	4.85	5.25	-0.12
3	W1	31.32	1.96	-2.65	1.46	-7.55	-9.90	-1.43	7.17	9.29	10.00	1.61	2.62	2.42	4.64	2.02	2.12	9.19	10.00	0.16
4	W1	15.80	-2.06	-0.61	5.58	-7.14	1.56	3.06	8.08	9.80	7.37	3.13	8.48	7.27	7.17	7.27	9.39	0.50	5.25	-0.26
5	S2	39.35	3.17	-5.92	2.76	-4.29	6.98	3.88	7.37	7.57	8.18	6.87	4.44	7.98	5.55	3.94	5.05	3.84	9.29	-1.04
6	4B	30.55	-1.16	-0.61	4.37	-3.88	-4.07	7.96	6.87	8.08	6.16	8.08	7.47	2.12	4.14	6.36	9.90	4.64	3.84	-0.44
7	W2	25.13	2.76	-3.47	0.75	-1.84	3.57	-7.55	8.48	4.34	5.35	5.45	6.87	7.07	6.66	4.24	9.90	0.90	0.90	-0.55
8	S3	25.60	-9.40	-6.33	-0.55	-9.59	4.57	-7.14	7.68	10.00	8.89	6.87	8.48	9.39	8.28	7.27	7.68	9.29	6.36	-0.79
9	W1	24.45	-0.35	-4.69	5.78	-7.55	-7.89	4.69	5.15	8.18	4.54	4.95	6.56	8.18	4.95	10.00	9.90	2.42	7.68	-0.41
10	S2	29.66	9.20	-0.20	1.26	3.47	7.39	-1.84	3.53	2.52	7.78	6.87	7.68	7.17	5.65	3.13	2.42	7.98	6.97	0.19
11	S2	34.25	5.68	-2.24	3.77	-3.88	3.87	0.61	8.89	6.66	6.46	0.60	8.48	3.53	7.78	9.49	0.50	6.16	1.61	1.25
12	4B	22.43	-0.95	-1.02	4.47	-5.51	-4.87	-2.65	6.56	7.98	7.27	7.78	7.57	9.29	7.27	6.77	2.42	9.09	7.57	-0.37
13	S3	40.69	7.09	-1.84	-0.35	-2.24	5.08	-0.61	7.27	8.99	2.02	7.07	8.59	7.88	6.87	5.05	6.56	9.70	9.60	-0.26
14	W1	24.29	-0.75	-5.51	5.28	-7.14	-2.06	-4.69	4.95	9.49	6.66	5.86	8.38	4.64	4.44	9.80	3.73	1.51	6.77	-0.83
15	S3	17.23	2.36	1.02	-6.78	5.51	4.57	-5.92	8.79	9.29	5.05	5.15	9.60	9.49	8.38	7.37	6.77	6.87	6.97	-0.44
16	S3	25.70	0.25	-2.24	3.87	-7.55	4.27	-4.69	5.45	6.36	7.07	9.70	6.87	9.90	6.36	5.15	6.26	4.85	0.90	-1.01
17	W1	35.95	-3.07	0.20	3.57	-4.69	1.26	2.24	4.85	9.39	9.09	1.91	3.63	5.15	6.06	1.61	5.76	7.57	4.64	0.76
18	4B	33.08	1.66	-5.51	5.68	-8.37	-9.50	-1.43	4.04	9.90	9.09	7.37	10.00	5.15	4.74	3.53	8.99	9.49	3.53	-0.34
19	W1	35.84	-4.27	-3.06	3.97	-3.88	10.00	7.96	4.44	8.18	9.19	1.91	2.82	4.95	3.84	1.61	5.25	1.51	8.79	-0.44
20	W1	24.85	-3.97	-1.02	4.37	-5.92	-7.29	1.43	6.46	9.39	9.39	4.04	6.06	4.64	6.26	4.95	9.60	3.43	3.94	0.30
21	W2	27.31	1.96	-1.84	0.05	-1.43	4.07	-7.14	8.99	6.97	1.91	6.26	7.78	8.48	8.79	7.78	7.47	4.54	2.22	-0.30
22	S2	28.26	6.58	-4.69	4.67	-5.10	9.40	-5.51	9.49	6.56	5.86	2.22	7.07	2.72	6.97	8.59	0.70	6.36	9.60	-0.48
23	W2	26.76	0.05	-3.88	-1.66	-3.06	4.97	-6.33	7.07	6.36	1.31	6.36	7.17	9.09	6.16	7.68	9.29	0.50	6.26	-0.41
24	S3	33.48	5.78	-1.84	0.15	-0.61	4.27	-3.47	8.79	5.15	8.79	3.84	6.06	7.07	9.60	7.07	3.63	0.50	6.26	-0.30
25	S3	34.35	5.28	-2.65	6.98	-5.92	1.86	-3.88	2.62	4.44	5.45	7.17	4.95	6.97	7.88	4.74	7.37	2.93	6.36	-0.44

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