

Computer-based Objective Interactive Numismatic System

By

Richard A. Bassett

Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Professional Studies
in Computing

at

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Abstract

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Three overarching findings emerged from the details of this research investigation:

1. The Internet makes a feasible alternative to the palpable examination of rare coins for the purpose of grading: human numismatists accepted the validity of determinations they reached on the basis of images delivered on Web pages, and an automated grading system successfully operated with images of the same resolution as the delivered images.
2. The aggregated interagreement on coin quality among human graders working individually over the Internet was substantially increased when they were furnished with a machine-generated reference point.
3. The development of automated systems for grading coins that work with effectiveness of human experts appears to be a technical possibility based on the successful prototype described herein.

Taken collectively, these findings suggest that coin grading may be done more economically and in a timelier manner than it is done now through the mailing of coins to professional services.

There are two empirical thrusts. One examines the use of machine grades supplied as a grading aid to experienced human graders working over the Internet. The goal was to gain insight into the process of remote coin grading over the Internet. The presence of accurate computer-generated grades improved the human performance. The validity of the grading process was substantiated by significant test-retest reliability on repeated gradings of the same coins.

The other thrust explores the effectiveness of an automated system yielding expert grades on the 70-point Sheldon scale for Lincoln cents. The system matches a coin's histogram of red, green, and blue sub pixel frequencies against histograms in a database of coins rated by human experts. While there is little construct validity for this technique, data confirms that it works well.

Acknowledgments

The process of this dissertation has taken many twists and turns along the way. I evaluated five ideas in some considerable depth before deciding on this one. Even within this idea my initial thought was that this study was about developing an automated coin grader, when in fact the automated coin grader turned out to be a minor component of the overall dissertation.

There are many people to thank who either contributed to the dissertation directly or supported me along the way. My biggest supporter during this journey was my wife, Jennifer Bassett, as she provided love, moral encouragement and made many sacrifices during these past three years. The rest of my family also endured missing my company on many occasions. Accommodating my work on this dissertation has become such a large component of our family life that my 9 year old son now thinks that working on the dissertation is something that I do for fun.

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Table of Contents

Abstract	iii
Acknowledgements	v
Table of Contents	vi
List of Tables	vii
List of Figures	viii
Chapter 1 - Introduction	1
1.1 Statement of problem	1
1.2 Significance of the study	2
1.3 Coin Grading Overview	2
1.4 Research Focus Areas	4
1.5 The COINS Model Defined	5
1.6 Research Approach	7
1.7 Scope and limitation of the study	9
1.8 Rarities and Common Collectibles	11
1.9 The role of objective and subjective components in Grading	16
1.10 Similarity in Grading Concerns between rare collectibles	21
1.11 Summary	24
Chapter 2 – Relevance of Research	25
2.1 Overview of Research	25
2.2 The issues associated with Human Grading	26
2.3 Machine Grading Issues	28
2.4 Human/Machine Collaborative Grading	30
2.5 The Evolution of Grading & Authentication	31
2.6 Summary of what is known and unknown about the research questions	37
2.7 The contribution this study makes	43
Chapter 3 - Methodology	45
3.1 Background	45
3.2 Research Overview	50
3.3 Summarized Research Steps Employed	50
3.4 Experimental Overview – Machine Based Grading Experiments	53
3.5 Machine Research Area #01: Machine Reliability	65
3.6 Experimental Overview – Online Grading Experiments	69
3.7 Online Research Area #01: Experts Acceptance of Advance Grade Knowledge	79
3.8 Online Research Area #02: Perception of Internet based Grading	85
3.9 Online Research Area #03: Grader Consensus	89
3.10 Online Research Area #04: Duplicate Grades	92

Chapter 4 – Results	95
4.1 Machine-based Grading Experiments	95
4.2 Machine Reliability Testing	98
4.3 Online Grading Experiments	107
4.4 Online Research Area #01: Results: Experts Acceptance of Advance Grade Knowledge	113
4.5 Online Research Area #02: Results: Perception of Internet based Grading	119
4.6 Online Research Area #04: Results: Grader Consensus	123
4.7 Online Research Area #05: Results: Duplicate Grades	126
Chapter 5 – Conclusions	130
5.1 Conclusions – Machine-based Experiments	131
5.2 Conclusions – Online Experiments	132
5.3 Future research opportunities in this subject area	138
Appendix A – Forms and Communication	140
• A1 – Postings seeking Expert Graders	141
• A2 – Feedback & Comments from Expert Graders	143
Appendix B – Design Documents	148
• B1 – Design Documents for Online Grading Experiments – 1 st Generation	149
• B2 – Design Document for Online Grading Experiment Software – 2 nd Generation	151
• B3 - Design Document for Machine Based Grading Experiment – 3 rd Generation	156
• B4 – Design Documents for Automated Machine Based Grading	158
Appendix C – Coin Grading Domain Information	166
• C1 - Coinage Terminology	167
• C2 - Standard Grades	189
• C3 - Grading Companies	194
• C4 - Lincoln Cent Features	198
• C5 - Mintmark Locations	199
• C6 – Historical Overview of Coin Collecting and US Coinage	202
Appendix D – Sample coins that were used in all experiments	205
Appendix E – Detailed Results from the Machine Grading Experiments	206
Appendix F – Detailed Results from the Online Grading Experiments	216
• F1 – Summarized Online Grading Results – All Graders & All Coins	217
• F2 – Summarized Online Grading Results by Grades shown to Graders	220
• F3 – Subjective Qualities Considered most important by expert Graders	223
References	224

List of Tables

Table 2.5.2	Current third- party grading services	35
Table 2.6.1	Results of Stujoe Grading Challenge	38
Table 3.7.1	Rotation Order of Grades Presented	81
Table 3.7.2	Detail of Grades Presented	82
Table 4.2.1	Machine-Based Reliability Grading Tests A-C	101
Table 4.2.3	Machine-Based Reliability Grading Tests D	102
Table 4.2.4	Machine-Based Reliability Grading Tests E	103
Table 4.2.5	Machine-Based Reliability Grading Tests A-E	104
Table 4.4.1	The effect of advance grade knowledge on expert graders	115
Table 4.4.3	Experts Acceptance of Machine Grade	116
Table 4.4.4	Advance grade knowledge on expert graders	117
Table 4.4.6	F-Test Variance Analysis	118
Table 4.5.1	Physical verses Online grading test	121
Table 4.6.1	Grader Consensus	124
Table 4.7.1	The Results of Graders grading duplicate coins	127
Table 4.7.2	Stability of Repeated Gradings of the Same Coin	127
Table 5.2.1	Degree of Convergence by Coin Quality	134
Table 5.2.2	Degree of Convergence by Rating's Accuracy	135

List of Figures

Figure 1.8.1	Rarity Contributing Factors	12
Figure 1.10.1	Grading Similarities in Collectibles	21
Figure 2.2.1	Human Visualization Model	28
Figure 2.5.1	A Morgan Silver Dollar Certified as MS65 by PCGS	34
Figure 2.6.2	Grading Challenges for Humans	38
Figure 3.4.1	Machine Grading Screen	55
Figure 3.4.2	Technical Grading Model	55
Figure 3.4.3	Lincoln Cent Varieties	62
Figure 3.6.1	Interactive Online Grading Model	69
Figure 3.6.2	Screen Shot of Online Grading Test #1 of 20	70
Figure 3.6.4	Screen Shot of Online Welcome Screen	71
Figure 3.6.5	Screen Shot of Online Ending Screen	71
Figure 3.7.3	Screen Shot of Online Grading Test #1 of 20	84
Figure 3.7.4	Screen Shot of Online Welcome Screen	84
Figure 4.2.2	Machine Reliability Tests A-C	101
Figure 4.2.6	Machine Reliability Tests A-E	105
Figure 4.3.1	Current Generation Online Grader	109
Figure 4.4.2	Explained Variance & Error Rate – Experts Acceptance Testing	116
Figure 4.4.5	The correlations between the different conditions	118
Figure 4.5.2	Mean Change when regrading Physical Coins	122
Figure 4.7.3	Chi-square computation regarding duplicates	129

Chapter 1 - Introduction

1.1 Statement of problem

Accurately identifying, grading and then determining the authenticity of rare collectible items such as coins, stamps, cards, comic books and artwork is a subjective non-automated process conducted by appraisers or graders. Appraisers and graders are usually experts in their respective fields who draw on large established pools of domain knowledge, opinions of other experts in their field and make comprehensive comparisons to other 'works' in the field to assist them in arriving at their findings. As with many professions the credentials for a person establishing himself or herself as 'an expert' can range from being non-existent to possessing a long list of impressive industry certifications.

There are two empirical thrusts of this research:

One examines the use of machine grades supplied as a grading aid to experienced human graders working over the Internet. The goal was to gain insight into the process of remote coin grading over the Internet. The presence of accurate computer-generated grades improved the human performance. The validity of the grading process was substantiated by significant test-retest reliability on repeated gradings of the same coins.

The other thrust explores the effectiveness of an automated system yielding expert grades on the 70-point Sheldon scale for Lincoln cents. The system matches a coin's histogram of red, green, and blue sub pixel frequencies against histograms in a database of coins rated by human experts. While there is little construct validity for this technique, data confirms that it works well.

1.2 Significance of the study

The Internet has provided a major boon to the rare collectibles marketplace as dealers and auction houses are now able to reach vast numbers of collectors, investors and other potential buyers of their offerings. Collectors accumulate everything from rare coins and stamps to baseball cards, autographs, antiques, posters, comic books, beer cans and artwork. Investors seek to purchase rare collectibles that are appealing to their tastes and will appreciate over time.

The selling of collectible items isn't limited exclusively to dealers and auction houses as collectors are also able to sell their duplicates or extra collectible items by reaching large numbers of other collectors through the Internet. Collectors with wares to sell can access other collectors through auction sites such as eBay.com and Half.com as well as newsgroups, chat rooms, email and their own personal websites.

Ultimately collectors, appraisers, dealers, auction houses, markets and insurance companies are concerned with the value, or worth, of a rare collectible as a basis to determining the proper wholesale and retail pricing.

The substantial increase in buyers, sellers and trading activity that the Internet has generated has magnified the problem of over-graded collectibles and thus has led many to purchase items at improperly inflated valuations.

1.3 Coin Grading Overview

The act of determining the condition of a collectible is known as grading. The assessment of the amount of circulation wear or the level of preservation that a particular coin exhibits, or in the case of uncirculated coins by how closely it resembles its "perfect"

condition when they were newly struck is then referred to as the grade. The grade of a collectible item usually plays a significant role in relationship to the value of the item.

Two types of grading exist within the coin-collecting domain; they are technical and market grading.

- Technical grading implies the strict adherence of certain objective and published grading rules, such as the those by the American Numismatic Association [4] without the inclusion of subjective qualities. Thus arriving at a technical grade involves only evaluating the merits of the coin by assessing the wear and defects that occur after it was struck. Technical grading is based primarily on fact and can be thought of as science in that it represents the undistorted views of a grader, which are free of emotion or personal bias that are based on observable phenomena, appraisal and evidence without the distortion of personal feelings or interpretation.
- Market grading is a grade that takes into account some or all of the technical grading features plus certain subjective features such as strike, luster, die state, and overall eye appeal of a collectible item. Market grading is the judgment exercised by a grader that may be based on that individual's personal impressions, visual observations, and cognitive abilities, past experiences, feelings and opinions rather than strict objective external facts. Market grading is more of an art form as it is largely concerned with the aesthetic appeal and how the market will accept a certain collectible.

Collectors and dealers are often at odds with each other on the issue of whether grading is a science or an art form [33]. This research will attempt to demonstrate that effective grading of collectibles is both science and an art as effectively identifying the technical rules based

features in conjunction with determining where and how a collectible item will be received by the marketplace are both of critical importance. A large part of the confusion is that there is great inconsistency in how grading is done by various graders. Dealers, collectors, casual observers or third-party grading services can all perform the grading of collectibles, dealers and third-party grading services are thought to have the status of expert, or professional, graders. Expert graders are known to use either or both technical or market grading in assessing collectibles. The method of grading, technical or market is usually not obvious nor is it always identified with the grade that is assigned. The values for grades are also not published based on technical or market grades, which also contributes to the subjectivity in pricing.

In order to eliminate the confusion between technical and market grades within this research, grades will be discussed in terms of expert grades and not as technical or market grades. The expert grades are the baseline grades, which represent the output results from the machine-based system of the digitized coin images, which were previously graded by the third party grading services.

1.4 Research Focus Areas

Three overarching findings emerged from the details of this research investigation:

1. The Internet makes a feasible alternative to the palpable examination of rare coins for the purpose of grading: human numismatists accepted the validity of determinations they reached on the basis of images delivered on Web pages, and an automated grading system successfully operated with images of the same resolution as the delivered images.

2. The aggregated interagreement on coin quality among human graders working individually over the Internet was substantially increased when they were furnished with a machine-generated reference point.
3. The development of automated systems for grading coins that work with effectiveness of human experts appears to be a technical possibility based on the successful prototype described herein.

Taken collectively, these findings suggest that coin grading may be done more economically and in a timelier manner than it is done now through the mailing of coins to professional services.

1.5 The COINS (Computer-based Objective Interactive Numismatic System) Model Defined

This research centers on the grading of collectible business strike coins. Business strike coins are the coins that are given only one blow or strike from the dies when they are minted and are intended for normal circulation and use in commerce. Coins that are introduced into commerce, or spent, are identified as circulated while coins, which are withheld from circulation and maintain much of their original luster are identified as mint-state. Circulating coins are graded on the Sheldon 70-point scale [64] with grades ranging 1 to 59 while mint-state coins are graded in the ranges of 60 – 70.

Recognizing the need for objective and subjective assessment of collectibles, a model known as COINS has been developed for this research. COINS is an acronym for Computer-based Objective Interactive Numismatic System. COINS is intended to enhance the ability of graders.

The COINS model is a dual component framework of which the first component is a machine-based system that performs grading through the use of a template-matching

algorithm known as the Histogram Distance Algorithm that is described in detail within Chapter 3 and yields a expert grade as the resultant output. The machine-based component of COINS is a software system that processes scanned images against a stored database of pregraded images and determines the grade of a coin by pattern matching. The second component of the COINS model utilizes the output from the first component as the baseline grade for subjective human/machine evaluation process. This human/machine component utilizes the Internet as a transport vehicle for facilitating on the grading of collectibles by allowing expert grading consultants to performing grading on the digital images of collectibles.

The purpose of COINS is to provide grading experts with a baseline machine generated grade thus allowing the grading experts with a starting point to obtain grades in a narrower grade range than in the absence of guidance. By narrowing the grading ranges, COINS can assist with consensus grading.

The value that COINS would have in a commercial setting is the ability to grade coins quickly, reliably, and inexpensively. The obvious limitation of COINS is that it would have little appeal in the grading of common collectibles or super rare collectibles. Common collectibles normally command low or minimal value and as such, condition doesn't often affect the pricing. Super rare collectibles, which are on the opposite side of the scale, are normally graded in a mode of consensus grading, which is the process of determining the condition of a coin by using multiple graders. Major auction houses attempt to overcome the problem of expert's varied interpretation in grading by securing the opinion of multiple graders when the financial stakes are significant, such as in the case of the 1933 \$20 Gold Double Eagle auctioned off by Sotheby's [5]. Bringing in multiple veteran graders to arrive

at a consensus for an item that sells for several million dollars has obvious return on investment (ROI) benefits, as the stakes are large. The majority of transactions involving rare collectibles cannot muster the justification for multiple graders mulling over the salient points of a collectible for hours on end, as the fees to experts are substantial while the value of the average collectible is considerably smaller. Some third party grading services such as Numitrust [52] offer consensus grading as the cornerstone to their service offering. Third party grading services are discussed in more detail within Chapter 2 of this study.

1.6 Research Approach

The initial development work by a student team from Pace University from January 2002 to May 2002 on an automated grading system offered encouraging evidence that a machine-based system to grade collectibles can be built [8].

Similar endeavors in to the realm of machine-based grading systems were previously attempted by PCGS [33] and CompuGrade [36] in the 1990s but were quickly abandoned due to their lack of commercial success and user acceptance. Both PCGS and CompuGrade attempted to build systems that they anticipated would become commercially viable and profitable. They soon discovered that the development of software could be a long and expensive process, which at times never seems to have a conclusion. In the wake of rising development costs, missed deadlines, ever increasingly complex rule sets the hope of all profitability diminished; therefore, both companies quietly withdrew their systems from the market.

The Pace University effort was unconstrained by the financial obstacles that plagued the earlier systems by PCGS and CompuGrade, as there was no profit incentive and no pressure to get a system to the marketplace. The machine-based system was built to grade

collectibles as an academic research exercise. Thus the development team was free of the typical commercial risks that many software development projects undergo and was able to focus in on just moving the technology forward.

The machine-based component of COINS was able to take a scanned image of a collectible and pattern match the grade of the item under consideration. This was accomplished through a series of Java programs that performed pattern recognition through template matching [60] using the Histogram Distance Algorithm on the images and thus produced baseline grades for the items under scrutiny. While only one algorithm was employed in this research future researchers and developers may wish to consider the employment of additional algorithms. Chapter 3 covers the merits of why the Histogram Distance Algorithm was chosen and which other algorithms were considered.

An initial problem that the machine-based component of COINS ran into was in the area of user acceptance. This problem also overshadowed the efforts of PCGS and CompuGrade. The COINS machine-based system is capable of producing an expert grade. Many domain experts argue that a machine based system is not capable of addressing at least six critical subjective areas which must be considered when market grading a coin [9, 40, 42]. Included in these six subjective areas are: color, toning, planchet quality, strike quality and aesthetic appeal. The difference between what is an acceptable grade, technical and market has been a point of contention in the collecting domain for a long period. Technical grades are compared to science, and market grades are compared to being an art form.

An initial focus of this study was to build a system capable of producing acceptable grades on a consistent basis. While challenging, producing expert grades with a machine-

based system was clearly obtainable as demonstrated by the results of the machine-based experiments within Chapter 4 of this research.

From the onset of this research, it was hypothesized that the machine-based grading system would yield consistent and repeatable results while producing grades on an expert grading level. To verify the reliability of the machine-based system the results were measured against the baseline grades of the coins, which were obtained from the third-party grading services. The reliability of the machine-based system in evaluating the images of coins that were graded by the third-party grading services is documented within Test E of the machine-based reliability tests of Chapter 4.

It is further hypothesized that the larger the database that the machine was working from the better it would perform. This hypothesis is worthy in as much as anomalies could result from the histogram distance measurement algorithm, and such anomalies would detract substantially from the utility of the machine-based system. In the absence of sufficient database representation of the different grade bands, (Good, Very Good, Fine...etc) the machine-based system couldn't possibly yield proper results as the nearest-neighbor pattern match might come from an improper grade band. For instance matching an image with a grade of Good-4 as a grade of Good-6 isn't as much of an anomaly as matching the same image as a grade of Fine-15 as Good-4 and Good-6 are in the same grade band but Good-4 and Fine-15 are not. To ensure closeness in matching, the database had to be populated with images that were representative of all of the major grade bands.

1.7 Scope and limitation of the study

The collectibles market is both dynamic and vast. Dynamic as new issues of collectibles are constantly being produced while the population of previously issued

collectibles decreases in size with attrition over time. Historical significance and market demand change over time, as do the value of items. Most highly collectible type items have weekly wholesale and retail price sheets that are published. The market is vast in that thousands and even millions of current collectibles are turned out each year, some with slight series differences, which may make a single series in a single year in strong demand. Contributing to the vastness is the increased number of collectors and collectable series in the past several years. As previously indicated, the Internet has contributed to the increased number of collectors and has opened the door for other types of previously obscure collectibles items, such as Paint by Numbers sets.

The continuously changing nature and the vastness of the collectibles marketplace makes it extremely difficult for collectors to specialize in more than one collectible as a considerable amount of knowledge is required to efficiently and effectively accumulate and maintain a quality collection. For this reason many collectors tend to specialize in a single collectible type.

This research concentrates on the grading of one area of collectibles, United States business strike coinage. For testing purposes, the focused attention will be placed on the limited series of Lincoln Cents in United States coinage. The technology employed within the machine-based system of COINS was developed in such a way that it could be adaptable with minimal modifications to work with other coin series and other collectibles, although this research did not branch out and test these other areas. The trained database of the COINS framework is made up on 160x160 dpi GIF images of Lincoln Cents, these images could be substituted in future research by images of other series or other collectible items. The resolution of 160x160 dpi was chosen as testing deemed it a high enough resolution to

provide the desired of detail required on the images of the collectible being evaluated while being simultaneously small enough to ensure quick loading while using dial-up connections. Nothing was specifically hard coded into COINS that would force it to work with just this one series. COINS draws on the same stored images for the machine-based pattern matching techniques and the machine-assisted Internet evaluations.

1.8 Rarities and Common Collectibles

Providing discriminating scrutiny to certain collectibles over others is justified in that a limited supply of collectibles are considered rarities and can potentially command considerable values. However, the vast majority of collectibles are common and usually command very little value or attention from collectors. Professional grading and appraisal of collectibles comes with long lead times and has a tendency to be expensive. Thus, it is important to screen out the less sought after collectible items from the rarities when undergoing expensive professional grading.

Numerous factors make a collectible item rare, even though a common misconception is that age alone is the most decisive parameter. Some collectible items such as raw precious metals, i.e. gold and silver, have only to contend with supply and demand when determining value. However, the value of non-commodity type rare collectibles is more difficult to calculate as it is dictated by numerous complex factors such as condition, authenticity, age, number originally produced, estimated surviving population, historical significance, as well as market demand.

Factors that contribute to the value of a rare collectible

- Condition
- Authenticity
- Age
- Number originally produced
- Estimated surviving population
- Historical significance
- Market demand

Figure 1.8.1 – Rarity Contributing Factors

Condition, which is often referred to, as the grade is significant, as the most discriminating collectors prefer their collectible holdings to be in the best condition/grade possible. Prices for perfect and near perfect condition, also known as mint state condition, collectibles tend to be considerably higher than for those in similar worn collectibles.

Determining *authenticity* of a potentially rare collectible is a major concern due to the increased financial incentive to produce counterfeit collectibles and the emergence of the technological capabilities to do so. Counterfeiting rare collectibles dates back to the days that coins were first produced. [69] Counterfeiting can be achieved by producing a near duplicate item from scratch or by altering an existing item in series so that it conforms to the attributes of a rarer and more highly sought after item.

With some collectibles, *age* can be a significant driving factor in determining the value, such as in the case of a 1795 Draped Bust Silver Dollar. The value of collectible antiques is often thought to increase markedly with age. However, with many collectibles, age in itself is insignificant in determining value. For instance, a 1995-W One Dollar Silver Eagle made at West Point is considered a great rarity with a present day value of just over \$2,000 while an uncirculated Silver Dollar made in 1900, which is over 100 years old, is worth just \$50. Another example of age having little influence on the value of a coin is the

Ancient Greek coin identified as Tiberius 14-37 AD. In very good condition, this 1900+-year-old coin can be currently obtained for approximately \$100.

The number or amount of a collectible that was *originally produced* is a value-contributing factor as it helps to give understanding to the largest potential size of the population. The production records for mass-produced items such as stamps, coins, comic books, prints and cards in modern times are quite accurate. The records for custom made items that haven't been mass-produced such as artwork and antiques are not as reliable. Still the population records for both custom and mass-produced items in the non-modern periods tend to be non-available and generally unreliable.

In general terms, the *surviving population* of a collectible item is thought to diminish with time. This surviving population can also be thought of as the supply. As in the case of silver coinage, much of the silver coinage was melted in 1965 and 1980 respectively when the US Government switched over to the clad copper coins for circulation and the Hunt Brothers attempted to corner the world silver market. Many coins are damaged and lost. When the surviving population of a particular appealing collectible is thought to be low, the value or price of that collectible would usually be on the high side. Conversely, when an ample amount of a collectible exists, the value is thought to be low. If the documented surviving population exceeds the number production population, it is quite possible that a sufficient number of counterfeits may exist or that improper production record keeping occurred contributing to the excessive numbers. [78]

A collectible may be an object of historical significance that is tied closely to a period, a person or a special event in history. Often collectible items with historical significance may start as ordinary products. For instance, certain antiques from the Victorian

Period command hefty premiums and are quite sought after as some collectors romanticize and feel nostalgic about this timeframe in history. Barry Bonds 600th homerun ball is an example of an ordinary item. In this case, a mass-produced baseball gained sufficient value by being part of a historical event. Items with historical significance do not always hold their values of time. For instance, a special event in history may shine the light of historical significance on to a collectible series temporarily causing the value to rise while the demand is strong. However, once the collecting public loses interest or the supply catches up to the demand levels, the collectible will drop in value and no longer be considered rare. A classic example of this was Beanie Baby mania that spurred the value of many of these stuffed animals to astonishing high temporarily levels only to have the prices crash back to earth after the market was flooded by these mass-produced items. Short-term demand spikes can occur that temporarily drive up the price of a collectible.

Market demand contributes to value fluxuations as collectible items fall in and out of favor with collectors over time. New hoards can be discovered which increase the supply in the market and thus drive down the demand. Newly revealed low supply numbers can suddenly cause a collectible to enjoy strong demand. Publicity of an item, the artist or production facility can create sudden demand for items. Unexpectedly high prices realized at auctions for similar items may cause a sudden surge in demand for a collectible. The passing of an artist or designer can create the realization that the supply is suddenly finite and thus drive up demand. When demand for a collectible gets stronger, the value of that collectible may rise at exponential rates. By example: In 1995, 4.6 million \$1 Silver Eagles were minted in Philadelphia and 395,000 in San Francisco as normal. [37] These coins were not considered rarities of any great value when they were acquired. However, in the same year

just 30,000 \$1 Silver Eagles were minted at the West Point Mint. These coins were made to celebrate the 10th Anniversary of the Silver Eagle and were essentially given away free with the purchase of the Gold Eagle 4 piece set. The Gold Eagle set had a price of \$995, which was a steep enough price deterrent to cause many would be collectors to pass on purchasing the Gold set just to obtain the \$1 Silver Eagle. The final mintage numbers of the 1995-W \$1 Silver Eagle were released in early 1996, just after the sale of 1995 Gold sets were completed. Demand for the 1995-W \$1 Silver Eagle surged after the mintage numbers were released, as did the value of the coin. At present day, the 1995-W \$1 Silver Eagle has a value in excess of \$2,200 thus demonstrating that a particular series of a collectible can become significantly more valuable than other series that were produced in the same year.

Collectibles that maintain their value and appreciate in the long term usually have several or more of these prime factors in common and are often the most sought after items in their respective categories or series. These items are referred to as rare collectibles. Only the minority of items in a particular collectible category is usually deemed rare and have high values attached to them. Thus, the vast majority of collectibles in a category or series are more readily available and easier to obtain at lower costs; these items are usually referred to as being common.

Condition (grade) and authenticity are the two major factors that sellers can fake, with condition (grade) being by in large the most widely abused factor. The value of a collectible item can be substantially more or less than its true value if the condition or grade of a collectible is improperly represented.

Two examples: