Presented at the DLSU Research Congress 2019
De La Salle University, Manila, Philippines
June 19 to 21, 2019

Markovian Transition of Candlesticks in Stock Markets

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Abstract: Technical analysis of financial markets rely on charts that contain four key information about price movement during a trading period. The open, close, highest and lowest prices are all contained in a chart element called the candlestick. The direction of price movement within a trading period are represented through the color of the candlestick, while the difference between open and closing prices are exhibited as the body of the candlestick. Information about the highest and lowest prices are contained in the upper and lower shadows, respectively. Relative sizes of the body and the shadows as well as the color of the stick are used in this study to classify the candlesticks into eight types. Transition of candlestick types can be described by a Markov process, with the transition matrix elements being the conditional probability $P(S_n|S_{n-1})$ that candlestick type S_n at day n appears if candlestick type at day $n-1$ is S_{n-1}. The conditional probabilities are determined empirically through cross tabulation of successive-day candlestick types for ten stock market indices using 20-year data. It is found that candlestick transition depends more on the form rather than the color of the candlestick. The transitions are similar across all but one markets, the exception being the Philippine stock exchange index. As the transition depends only on information about the immediate past, information about an initial state is totally washed off within five trading days. The most commonly occuring candlestick is found to be those with short upper and lower shadows, and the least common are those with short lower but long upper shadow.

Key Words: stock market; Markov process; Japanese candlestick

1. INTRODUCTION

Candlesticks are chart elements that are used to visualize movement of prices in financial markets during a trading period. (Mahmoodzadeh et al, 2007). A candlestick consists of a body and two shadows, the upper and the lower. The length of the body is the difference between opening and closing prices. If closing is higher than opening, the body is light-colored. If closing is lower than opening, the body is colored dark. The length of the upper shadow is the difference between the highest price and the closing or opening price, whichever is higher. Thus, if the body is light, the upper shadow is the difference between the highest price and the closing price. If the body is dark, the upper shadow is the difference between the highest price and the opening price. The lower shadow is the difference between the lowest price and the closing or opening price, whichever is lower.

Candlesticks serve as the basic elements for technical analysis of the market (Grimes et al, 2012). Techniques such as price action look at the

patterns of candlestick as signals for subsequent movement of prices in the market (see for example Austin, 2004). These techniques are generally based on patterns formed by the candlesticks, as seen from their movement as well as changes in their forms. Candlesticks can be classified into eight different types (Roleda, 2019) based on the relative sizes of their bodies and shadows as shown in Figure 1. In this paper, we studied the changes of candlestick form across trading days in ten stock market indices over a 20-year period. Knowledge of the likelihood of each type of transition can provide information that may be useful in developing empirically-based techniques for predicting market movement.

2. METHODOLOGY.

In this study, candlesticks are classified according to the relative sizes of their bodies and shadows. It is found in another study that association between candlestick type and price movement is best found if the ratio between shadow length and body length that is used to categorize shadows as long or short is set at the value of 1 (Roleda, 2019), and is therefore the selector value used in this study. Shadows are considered long if their length relative to the body length is greater or equal to 1, and the eight types of candlesticks are classified according to the presence of long or short shadows, as shown in Table 1 and Figure 1.

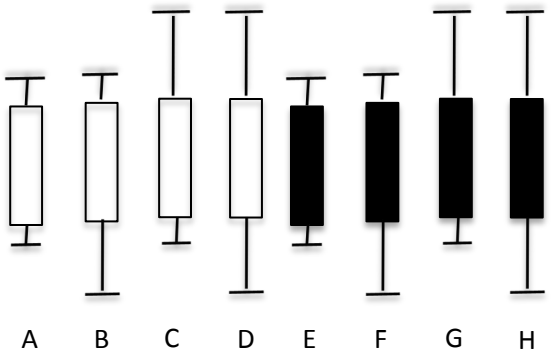

Figure 1. Classification of Candlestick Types

Table 1. Classification scheme for candlestick charts.

C Type	Body	Upper Shadow	Lower Shadow
A	Light	Short	Short
B	Light	Short	Long
C	Light	Long	Short
D	Light	Long	Long
E	Dark	Short	Short
F	Dark	Short	Long
G	Dark	Long	Short
H	Dark	Long	Long

The transition of candlesticks may be described by the matrix equation

$$S = MQ \qquad \text{(Eq. 1)}$$

where S and Q are d-dimensional column matrices with the final and initial candlestick types, respectively as their elements, and M is a $d \times d$ transition matrix with elements

$$M_{sq} = P(S|Q) \qquad \text{(Eq. 2)}$$

The conditional probabilities are evaluated through

$$P(S|Q) = \frac{P(S \cap Q)}{P(Q)} = \frac{N(S \cap Q)}{\sum_S N(S \cap Q)} \qquad \text{(Eq. 3)}$$

where $N(S \cap Q)$ is the number of times a type S candlestick appeared a trading day after a candestick type Q appeared from data obtained over a 20-year period from September 28, 1998 to September 26, 2018 in ten stock market indices:

(1) Dow Jones Industrial Average (DJI)
(2) Standard &Poor's 500 (GSPC)
(3) NASDAQ composite (IXIC)
(4) DAX Performance Index (GDAXI)
(5) CAC 40 (FCHI)
(6) Nikkei 225 (N225)
(7) KOSPI Composite Index (KS11)
(8) Hang Seng Index (HSI)
(9) SSE Composite Index (SSEC)
(10) Philippine Stock Exchange Index (PSEI)

The financial data were obtained online from finance.yahoo.com.

3. TRANSITION MATRICES FOR COLORED CANDLESTICKS.

Using cross-tabulation between succeeding candlestick states, and through eqn. 3, the elements of transition matrices for each of the markets are shown in Tables 2 to 11. It can be seen that with the exception of PSEI, the transition matrices for the various markets do not differ too much from each other. This implies that the transition of candlesticks is stable across most markets and could be considered as a characteristic of a candlestick type. The average for the nine markets excluding PSEI are shown in Table 12. We can see for example that a candlestick of type C in general has a 35% likelihood of being followed by a type E.

Table 2. Transition matrix elements for the Dow Jones Industrial Average. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.24	0.28	0.24	0.26	0.26	0.26	0.29	0.28
B	0.05	0.05	0.05	0.06	0.08	0.11	0.07	0.05
C	0.06	0.03	0.04	0.05	0.04	0.04	0.04	0.04
D	0.09	0.08	0.04	0.11	0.11	0.08	0.12	0.09
E	0.34	0.33	0.39	0.33	0.30	0.33	0.30	0.33
F	0.07	0.06	0.07	0.07	0.06	0.06	0.04	0.06
G	0.06	0.08	0.07	0.05	0.05	0.04	0.06	0.05
H	0.09	0.08	0.10	0.07	0.10	0.07	0.09	0.10

Table 3. Transition matrix elements for the Standard and Poor's 500. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.24	0.26	0.26	0.27	0.25	0.34	0.29	0.29
B	0.05	0.07	0.07	0.05	0.08	0.08	0.07	0.06
C	0.05	0.04	0.02	0.05	0.04	0.03	0.05	0.05
D	0.10	0.08	0.05	0.08	0.11	0.09	0.12	0.08
E	0.34	0.36	0.35	0.38	0.30	0.31	0.28	0.33
F	0.08	0.05	0.09	0.05	0.07	0.04	0.06	0.08
G	0.04	0.07	0.08	0.05	0.05	0.03	0.05	0.03
H	0.09	0.06	0.08	0.08	0.10	0.09	0.09	0.07

Table 4. Transition matrix elements for the NASDAQ Composite. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.27	0.25	0.26	0.27	0.27	0.30	0.27	0.31
B	0.07	0.08	0.06	0.04	0.06	0.06	0.06	0.06
C	0.04	0.04	0.05	0.04	0.05	0.02	0.05	0.04
D	0.08	0.07	0.05	0.10	0.09	0.10	0.07	0.06
E	0.33	0.32	0.39	0.38	0.31	0.34	0.33	0.35
F	0.08	0.08	0.08	0.05	0.07	0.10	0.07	0.07
G	0.03	0.05	0.02	0.04	0.04	0.02	0.04	0.04
H	0.09	0.11	0.09	0.08	0.10	0.06	0.10	0.08

Table 5. Transition matrix elements for the German DAX Performance Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.24	0.24	0.31	0.29	0.27	0.25	0.24	0.27
B	0.07	0.06	0.07	0.05	0.07	0.09	0.10	0.07
C	0.05	0.04	0.04	0.03	0.04	0.04	0.03	0.03
D	0.11	0.11	0.07	0.11	0.11	0.11	0.10	0.09
E	0.30	0.30	0.34	0.31	0.28	0.33	0.28	0.30
F	0.07	0.07	0.06	0.05	0.05	0.04	0.10	0.07
G	0.05	0.06	0.04	0.06	0.05	0.04	0.05	0.04
H	0.10	0.11	0.07	0.10	0.12	0.09	0.11	0.13

Table 6. Transition matrix elements for the French CAC40. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.27	0.26	0.31	0.27	0.29	0.27	0.30	0.32
B	0.06	0.06	0.06	0.05	0.07	0.09	0.09	0.07
C	0.04	0.04	0.04	0.06	0.04	0.04	0.05	0.03
D	0.09	0.09	0.09	0.11	0.11	0.08	0.08	0.11
E	0.29	0.35	0.29	0.31	0.27	0.29	0.31	0.26
F	0.06	0.05	0.09	0.06	0.07	0.06	0.07	0.07
G	0.07	0.04	0.04	0.04	0.04	0.06	0.02	0.04
H	0.12	0.09	0.08	0.10	0.11	0.10	0.08	0.11

Table 7. Transition matrix elements for the Japanese Nikkei 225. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.25	0.29	0.29	0.34	0.29	0.32	0.34	0.32
B	0.06	0.07	0.07	0.05	0.08	0.07	0.07	0.08
C	0.05	0.05	0.06	0.06	0.06	0.05	0.04	0.05
D	0.11	0.08	0.08	0.07	0.10	0.06	0.11	0.09
E	0.32	0.32	0.34	0.30	0.25	0.30	0.25	0.28
F	0.05	0.04	0.07	0.04	0.06	0.05	0.06	0.07
G	0.06	0.07	0.03	0.07	0.06	0.06	0.05	0.04
H	0.09	0.08	0.07	0.07	0.11	0.10	0.07	0.07

Table 8. Transition matrix elements for the Korean KOSPI Composite Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.25	0.35	0.29	0.33	0.30	0.32	0.24	0.30
B	0.07	0.07	0.06	0.05	0.09	0.07	0.08	0.10
C	0.04	0.03	0.02	0.04	0.05	0.06	0.03	0.04
D	0.10	0.11	0.10	0.11	0.10	0.10	0.10	0.07
E	0.33	0.27	0.33	0.27	0.25	0.26	0.33	0.26
F	0.08	0.07	0.11	0.08	0.07	0.07	0.05	0.09
G	0.04	0.04	0.01	0.03	0.04	0.04	0.05	0.04
H	0.10	0.06	0.07	0.10	0.10	0.09	0.11	0.09

Table 9. Transition matrix elements for Hong Kong's Hang Seng Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.28	0.29	0.30	0.29	0.31	0.29	0.26	0.30
B	0.07	0.07	0.09	0.08	0.08	0.09	0.08	0.08
C	0.04	0.04	0.01	0.04	0.04	0.05	0.03	0.04
D	0.11	0.10	0.10	0.06	0.10	0.13	0.10	0.10
E	0.28	0.27	0.32	0.31	0.24	0.27	0.33	0.26
F	0.07	0.06	0.05	0.07	0.06	0.05	0.06	0.06
G	0.05	0.04	0.04	0.05	0.05	0.03	0.04	0.04
H	0.11	0.13	0.10	0.11	0.11	0.10	0.10	0.12

Table 10. Transition matrix elements for the Shanghai Stock Exchange Composite Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.25	0.26	0.29	0.28	0.25	0.33	0.28	0.31
B	0.04	0.05	0.05	0.07	0.06	0.06	0.06	0.05
C	0.03	0.05	0.03	0.04	0.04	0.06	0.03	0.04
D	0.09	0.09	0.08	0.09	0.13	0.12	0.07	0.07
E	0.34	0.33	0.37	0.31	0.31	0.27	0.34	0.31
F	0.10	0.06	0.07	0.08	0.09	0.06	0.11	0.09
G	0.03	0.05	0.03	0.02	0.03	0.04	0.04	0.02
H	0.11	0.10	0.07	0.10	0.10	0.06	0.07	0.11

Table 11. Transition matrix elements for the Philippine Stock Exchange Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.37	0.37	0.34	0.37	0.26	0.26	0.31	0.39
B	0.08	0.09	0.07	0.07	0.07	0.06	0.06	0.08
C	0.04	0.03	0.06	0.04	0.04	0.03	0.03	0.06
D	0.06	0.05	0.08	0.08	0.07	0.06	0.05	0.05
E	0.30	0.31	0.29	0.29	0.40	0.38	0.38	0.29
F	0.05	0.07	0.03	0.06	0.05	0.09	0.04	0.04
G	0.05	0.04	0.03	0.05	0.06	0.06	0.08	0.05
H	0.05	0.04	0.08	0.04	0.05	0.05	0.05	0.05

Table 12. Average transition matrix elements for nine markets excluding the Philippine Stock Exchange Index. Row corresponds to the final state while Column the initial state.

	A	B	C	D	E	F	G	H
A	0.25	0.28	0.28	0.29	0.28	0.30	0.28	0.30
B	0.06	0.06	0.06	0.05	0.07	0.08	0.07	0.07
C	0.05	0.04	0.03	0.04	0.04	0.04	0.04	0.04
D	0.10	0.09	0.07	0.09	0.11	0.10	0.10	0.09
E	0.32	0.32	0.35	0.32	0.28	0.30	0.30	0.30
F	0.07	0.06	0.08	0.06	0.07	0.06	0.07	0.07
G	0.05	0.06	0.04	0.05	0.05	0.04	0.05	0.04
H	0.10	0.09	0.08	0.09	0.11	0.08	0.09	0.10

We now note that if S_1 is the candlestick state on day 1, S_2 the candlestick state on day 2, and so on,

$$\begin{aligned} S_2 &= MS_1 \\ S_3 &= M^2 S_1 \\ &\vdots \\ S_{n+1} &= M^n S_1 \end{aligned} \qquad \text{(Eq. 4)}$$

For Markov processes where the transition matrices are irreducible and ergodic (Bamberg and Sternberg, 1988; Ross, 1983)

$$\lim_{n\to\infty} M^n \to E \qquad \text{(Eq. 5)}$$

where

$$E = \begin{pmatrix} P(C_1) & \cdots & P(C_1) \\ P(C_2) & & P(C_2) \\ \vdots & & \vdots \\ P(C_d) & & P(C_d) \end{pmatrix} \qquad \text{(Eq. 6)}$$

and $P(C_k)$ is the probability for the occurrence of candlestick type C_k. This is indeed found to be true for all ten markets, where M^n reached its asymptotic

limit up to four significant figures at $n = 5$. Elements of the equlibrium probability states for each of the ten markets are shown in Table 13. It can be gleaned from the table that candlestick type E has the highest probability of occurrence followed by A, D, H, B, F, G, then C. It is notable that E and A differ only in color, and so do D and H, B and F, and G and C. This indicates that the dynamics of candlestick types may be indifferent to color. Thus, by ignoring color, a simpler analysis of candlestick transition may be possible without sacrificing too much refinement.

Table 13. Probability of occurrence for each candlestick type in each of the markets considered.

MARKET	CANDLESTICK TYPE							
	A	B	C	D	E	F	G	H
DJI	0.26	0.07	0.04	0.10	0.32	0.06	0.05	0.09
GSPC	0.26	0.07	0.04	0.10	0.33	0.07	0.05	0.09
IXIC	0.28	0.06	0.04	0.08	0.33	0.07	0.04	0.09
GDAXI	0.26	0.07	0.04	0.10	0.30	0.06	0.05	0.11
FCHI	0.29	0.07	0.04	0.10	0.29	0.06	0.05	0.11
N225	0.29	0.07	0.06	0.10	0.29	0.05	0.06	0.09
KS11	0.29	0.08	0.04	0.10	0.28	0.08	0.04	0.10
HSI	0.29	0.08	0.04	0.10	0.27	0.06	0.04	0.11
SSEC	0.27	0.05	0.04	0.10	0.32	0.09	0.03	0.10
PSEI	0.32	0.08	0.04	0.06	0.34	0.06	0.05	0.05

4. TRANSITION MATRICES – UNCOLORED CANDLESTICKS.

Ignoring color, candlesticks of types A and E may both be reclassified as uncolored A, B and F as uncolored B, C and G as uncolored C, and D and H as uncolored D. The corresponding transition matrices for each of the market are:

$$M_{DJI} = \begin{pmatrix} 0.5676 & 0.6025 & 0.6028 & 0.6032 \\ 0.1305 & 0.1464 & 0.1138 & 0.1211 \\ 0.1031 & 0.0971 & 0.1018 & 0.0895 \\ 0.1988 & 0.1541 & 0.1816 & 0.1863 \end{pmatrix} \quad \text{(Eq. 7)}$$

$$M_{GSPC} = \begin{pmatrix} 0.5642 & 0.6322 & 0.5876 & 0.6344 \\ 0.1402 & 0.1256 & 0.1397 & 0.1211 \\ 0.0905 & 0.0812 & 0.0953 & 0.0903 \\ 0.2051 & 0.1610 & 0.1774 & 0.1541 \end{pmatrix} \quad \text{(Eq. 8)}$$

$$M_{IXIC} = \begin{pmatrix} 0.5935 & 0.6061 & 0.6290 & 0.6510 \\ 0.1422 & 0.1558 & 0.1351 & 0.1091 \\ 0.0846 & 0.0707 & 0.0835 & 0.0758 \\ 0.1797 & 0.1674 & 0.1523 & 0.1642 \end{pmatrix} \quad \text{(Eq. 9)}$$

$$M_{GDAX} = \begin{pmatrix} 0.5450 & 0.5623 & 0.5736 & 0.5831 \\ 0.1340 & 0.1320 & 0.1626 & 0.1186 \\ 0.0924 & 0.0935 & 0.0813 & 0.0836 \\ 0.2286 & 0.2122 & 0.1824 & 0.2147 \end{pmatrix} \quad \text{(Eq. 10)}$$

$$M_{FCHI} = \begin{pmatrix} 0.5621 & 0.5910 & 0.6048 & 0.5755 \\ 0.1270 & 0.1338 & 0.1550 & 0.1255 \\ 0.0945 & 0.0932 & 0.0742 & 0.0811 \\ 0.2164 & 0.1820 & 0.1659 & 0.2179 \end{pmatrix} \quad \text{(Eq. 11)}$$

$$M_{N225} = \begin{pmatrix} 0.5550 & 0.6119 & 0.6116 & 0.6192 \\ 0.1257 & 0.1128 & 0.1325 & 0.1159 \\ 0.1159 & 0.1111 & 0.0926 & 0.1126 \\ 0.2034 & 0.1642 & 0.1633 & 0.1523 \end{pmatrix} \quad \text{(Eqn. 12)}$$

$$M_{KS11} = \begin{pmatrix} 0.5604 & 0.5981 & 0.5955 & 0.5754 \\ 0.1546 & 0.1375 & 0.1533 & 0.1561 \\ 0.0821 & 0.0868 & 0.0603 & 0.0801 \\ 0.2029 & 0.1776 & 0.1910 & 0.1883 \end{pmatrix} \quad \text{(Eqn. 13)}$$

$$M_{HSI} = \begin{pmatrix} 0.5561 & 0.5586 & 0.6089 & 0.5724 \\ 0.1434 & 0.1357 & 0.1361 & 0.1448 \\ 0.0870 & 0.0771 & 0.0569 & 0.0825 \\ 0.2135 & 0.2286 & 0.1980 & 0.2004 \end{pmatrix} \quad \text{(Eqn. 14)}$$

$$M_{SSEC} = \begin{pmatrix} 0.5700 & 0.5984 & 0.6426 & 0.6096 \\ 0.1459 & 0.1147 & 0.1441 & 0.1436 \\ 0.0704 & 0.1023 & 0.0661 & 0.0614 \\ 0.2137 & 0.1845 & 0.1471 & 0.1853 \end{pmatrix} \quad \text{(Eqn. 15)}$$

$$M_{PSEI} = \begin{pmatrix} 0.6618 & 0.6625 & 0.6667 & 0.6685 \\ 0.1313 & 0.1602 & 0.1047 & 0.1262 \\ 0.0982 & 0.0778 & 0.1026 & 0.0979 \\ 0.1087 & 0.0995 & 0.1261 & 0.1073 \end{pmatrix} \quad \text{(Eqn. 16)}$$

Just as in the case for colored candlesticks, successive transitions approach an asymptotic limit described in eqns. (5) and (6) at $n = 5$ for elements with four significant figures. The probability for each candlestick type is shown in Table 14.

Table 14. Probability of occurrence for each uncolored candlestick type in each of the markets considered.

MARKET	UNCOLORED CANDLESTICK TYPE			
	A	B	C	D
DJI	0.5823	0.1291	0.0996	0.1889
GSPC	0.5886	0.1346	0.0897	0.1871
IXIC	0.6080	0.1377	0.0811	0.1731
GDAXI	0.5582	0.1330	0.0896	0.2192
FCHI	0.5725	0.1301	0.0897	0.2077
N225	0.5802	0.1231	0.1121	0.1846
KS11	0.5719	0.1522	0.0807	0.1952
HSI	0.5642	0.1420	0.0822	0.2116
SSEC	0.5872	0.1410	0.0728	0.1991
PSEI	0.6631	0.1320	0.0959	0.1090

The most commonly occuring uncolored candlestick type is A, followed by D, then B and C. The transition matrices for most markets are similar, with the exception of the the Philippine market, which exhibited probabilities that are significantly higher than other markets for candlestick type A and significantly lower for candlestick type D.

5. CONCLUSION

In this paper, we studied that transition of candlesticks across trading days and found that the transition is generally similar across markets. Candlesticks with short upper and lower shadows are the most common type, followed by those with long upper and lower shadows. The least common type of candlestick are those with short lower but long upper shadows. It is important to note that the least common candlestick is found in another study to deliver signal for upward price movement (Roleda, 2019).

The Markovian characteristic of the candlestick transitions is quite strong. At four significant figures, asymptotic limit is reached after five transitions. This implies that traces of the original state is washed out after only five trading days.

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