Funkcje skrótu - hash functions

Do realizacji zadania wykorzystano WSL1 na systemie Windows 2019 server.
Dystrybucja uruchomiona pod systemem WSL to Ubuntu 22.04.4 LTS
Do włączenia legacy providera w OpenSSL wykorzystano poniższy tutorial:
https://lindevs.com/enable-openssl-legacy-provider-on-ubuntu

Zadanie 1

Treść Zadania:
Informacje dotyczące używania programu openssl dostępne są po wydaniu polecenia man openssl lub na stronie pod adresem : https://wiki.openssl.org/index.php/Manual:Dgst(1)
Krok1 : Stwórz plik tekstowy z wiadomością np. „This is a trial message to test digest functions!” i zapisz w pliku msg
Krok 2: Zapisz polecenie obliczające skrót tej wiadomości używając kolejno funkcji: MD5, SHA1, SHA-256.
Krok 3: Wykonaj obliczenia skrótu a wyniki zapisz w plikach MD5dgst, SHA1dgst, SHA256dgst.
Krok 4: Zmodyfikuj wiadomość msg poprzez skasowanie jednego znaku np. znaku !
Krok 5: Ponownie oblicz, wykorzystując w/w funkcje, skrót wiadomości msg po modyfikacji
Krok 6: Porównaj skróty wiadomości msg przed i po modyfikacji.

Realizacja

```
root@WSL:lab5_pliki> ls
'Lab5 - PI zaoczne - funkcje skrótu.pdf'  'Lab5 - funkcja skrótu.pdf'   iha1
iha1.c
root@WSL:lab5_pliki> echo "This is a trial message to test digest
functions!" > msg
root@WSL:lab5_pliki> openssl dgst -md5 msg
MD5(msg)= 5f554df44e51b0eea071ae49a854223e
root@WSL:lab5_pliki> openssl dgst -sha1 msg
SHA1(msg)= fdc68fd28db0c992b376a3edf36727ea66d2d391
root@WSL:lab5_pliki> openssl dgst -sha256 msg
SHA2-256(msg)=
a2636d4da000f8b9174e3e1135c6ccd70a098b1e7e3843c3505e54361a572b44
root@WSL:lab5_pliki> openssl dgst -md5 msg > MD5dgst
root@WSL:lab5_pliki> openssl dgst -sha1 msg > SHA1dgst
root@WSL:lab5_pliki> openssl dgst -sha256 msg > SHA256dgst
root@WSL:lab5_pliki> sed 's/!//' msg > msg_mod
root@WSL:lab5_pliki> mv msg_mod msg
root@WSL:lab5_pliki> openssl dgst -md5 msg > MD5dgst_mod
root@WSL:lab5_pliki> openssl dgst -sha1 msg > SHA1dgst_mod
root@WSL:lab5_pliki> openssl dgst -sha256 msg > SHA256dgst_mod
root@WSL:lab5_pliki> diff MD5dgst MD5dgst_mod
1c1
```

```
< MD5(msg)= 5f554df44e51b0eea071ae49a854223e
---
> MD5(msg)= 946e2d2c199b85da32acfd9177bf562c
root@WSL:lab5_pliki> diff SHA1dgst SHA1dgst_mod
1c1
< SHA1(msg)= fdc68fd28db0c992b376a3edf36727ea66d2d391
---
> SHA1(msg)= 5fcb355462f783d439712044e720091c2b6c8dbb
root@WSL:lab5_pliki> diff SHA256dgst SHA256dgst_mod
1c1
< SHA2-256(msg)=
a2636d4da000f8b9174e3e1135c6ccd70a098b1e7e3843c3505e54361a572b44
---
> SHA2-256(msg)=
cea38c49da18b7b1c2fee0cccbb51f48355b39cb3cd68588eba81a9f3f30ed97
root@WSL:lab5_pliki>
```

Pytania

Co można powiedzieć po porównaniu tych skrótów?

Po porównaniu skrótów wiadomości przed i po modyfikacji można zauważyć, że nawet drobna zmiana (np. usunięcie pojedynczego znaku) prowadzi do całkowicie innego wyniku funkcji skrótu. Jest to cecha charakterystyczna funkcji skrótu zwana efektem lawiny, która zapewnia, że zmiana choćby jednego bitu danych wejściowych znacznie zmienia wartość skrótu.

Jakiej długości (wyrażonej w bitach) są poszczególne skróty?

- MD5: 128 bitów (16 bajtów)
- SHA1: 160 bitów (20 bajtów)
- SHA-256: 256 bitów (32 bajty)

Każda funkcja skrótu zawsze generuje wynik o ustalonej długości niezależnie od długości danych wejściowych.

Zadanie 2

Treść Zadania:
W tym zadaniu wykorzystywany jest przykładowy algorytm skrótu zaimplementowany w języku C (program iha1.c) Algorytm nazywa się IHA1 (Insecure Hash Agorithm) i działa na zasadzie funkcji XOR wykonywanej bitowo, a wynikiem jest liczba reprezentowana na 4 bitach (jedna cyfra w zapisie hexadecymalnym).
Krok 1: Dokonaj kompilacji pliku iha1.c poprzez wydanie polecenia:

```
gcc iha1.c -o iha1
```

Krok 2: Przygotuj plik z tekstem jawnym np. „This is a test message”.
Krok 3: Użyj funkcji iha1 do obliczenia skrótu wiadomości zapisanej w w/w pliku.
Składnia wywołania jest następująca:

```
iha1 nazwa_pliku
```

Przykładowy wynik działania programu iha1:

```
root@kali:~/lab11/support> ./iha1 message
    iha1(message) = A
```

Krok 4: Spróbuj znaleźć kolizję (stwórz inną wiadomość jawną która będzie miała taki sam skrót co wiadomość stworzona w tym zadaniu). W tym celu wykonaj 160 prób, w każdej próbie podając na wejście funkcji skrótu inną wartość.

Realizacja

```
root@WSL:lab5_pliki> ls
'Lab5 - PI zaoczne - funkcje skrótu.pdf'  'Lab5 - funkcja skrótu.pdf'
MD5dgst   MD5dgst_mod   SHA1dgst   SHA1dgst_mod   SHA256dgst
SHA256dgst_mod   iha1.c   msg
root@WSL:lab5_pliki> gcc iha1.c -o iha1
root@WSL:lab5_pliki> echo "This is a test message" > message
root@WSL:lab5_pliki> ./iha1 message
iha1(message) = A
root@WSL:lab5_pliki> cat > script.sh
mkdir collisions
cd collisions

for i in $(seq 1 160); do
echo "Test message number $i" > test_$i.txt
../iha1 test_$i.txt >> results.txt
done

^C
root@WSL:lab5_pliki> chmod +x script.sh
root@WSL:lab5_pliki> ./script.sh
root@WSL:lab5_pliki> ls
'Lab5 - PI zaoczne - funkcje skrótu.pdf'   MD5dgst       SHA1dgst
SHA256dgst       collisions   iha1.c    msg
'Lab5 - funkcja skrótu.pdf'                MD5dgst_mod   SHA1dgst_mod
SHA256dgst_mod   iha1         message   script.sh
root@WSL:lab5_pliki> cd collisions/
root@WSL:collisions> ls
results.txt  test_11.txt  test_121.txt test_133.txt test_145.txt
test_157.txt
```

```
[...]
test_35.txt  test_47.txt  test_59.txt  test_70.txt  test_82.txt  test_94.txt
root@WSL:collisions> cat results.txt | grep '= A'
iha1(test_68.txt) = A
iha1(test_79.txt) = A
iha1(test_86.txt) = A
iha1(test_97.txt) = A
root@WSL:collisions>
```

Pytania

Ile średnio potrzebnych jest operacji, żeby znaleźć kolizję dla wyżej opisanego przypadku? Odpowiedź uzasadnij.

Algorytm IHA1 zwraca wynik skrótu reprezentowany jako jedna cyfra szesnastkowa, co oznacza że wynik może przyjąć jedną z 16 wartości (od 0 do F, czyli $2^4 = 16$ możliwych wyników).

Zgodnie z teorią prawdopodobieństwa oraz tzw. paradoksem urodzin, średnia liczba operacji potrzebna do znalezienia kolizji dla funkcji skrótu o n możliwych wartościach wynosi około: $$\sqrt{\frac{\pi n}{2}} \approx 1.253 \cdot \sqrt{n}$$ Dla $n = 16$: $$\sqrt{\frac{\pi \cdot 16}{2}} \approx \sqrt{8\pi} \approx 5.01$$

Zatem średnio potrzeba około 5 różnych wiadomości (czyli 4–5 prób), aby z dużym prawdopodobieństwem znaleźć kolizję dla funkcji skrótu zwracającej 4-bitowy wynik. W najgorszym przypadku może to być do 16 prób, jednak statystycznie znacznie szybciej znajdziemy kolizję.

Zadanie 3

Treść Zadania:
Krok 1: Na maszynie A przygotuj wiadomość zapisaną w pliku np. „This is a test message used to calculate a keyed digest”.
Krok 2: Na maszynie A przygotuj klucz i zapisz go w pliku.
Krok 3: Zapisz i wykonaj polecenie openssl, które pozwoli na obliczenie funkcji HMAC na przygotowanej wiadomości z kluczem zapisanym w pliku z użyciem algorytmu MD5.
Krok 4: Zapisz i wykonaj polecenie openssl, które pozwoli na weryfikację poprawności obliczonej funkcji HMAC na podstawie znanej wiadomości oraz znanego klucza.

Realizacja

```
root@WSL:lab5_pliki> ls
'Lab5 - PI zaoczne - funkcje skrótu.pdf'   MD5dgst       SHA1dgst
SHA256dgst       collisions   iha1.c    msg
'Lab5 - funkcja skrótu.pdf'                MD5dgst_mod   SHA1dgst_mod
SHA256dgst_mod   iha1         message   script.sh
```

```
root@WSL:lab5_pliki> echo "This is a test message used to calculate a keyed
digest" > message.txt
root@WSL:lab5_pliki> echo "secretkey123" > key.txt
root@WSL:lab5_pliki> chmod 600 key.txt
root@WSL:lab5_pliki> openssl dgst -md5 -mac HMAC -macopt key:file:key.txt
message.txt > hmac.md5
root@WSL:lab5_pliki> openssl dgst -md5 -mac HMAC -macopt key:file:key.txt
message.txt
HMAC-MD5(message.txt)= b6e3401fc3288777c285655aabd5d6d6
root@WSL:lab5_pliki> cat hmac.md5
HMAC-MD5(message.txt)= b6e3401fc3288777c285655aabd5d6d6
root@WSL:lab5_pliki>
```

Pytania

Co musi wiedzieć użytkownik maszyny B jeżeli chce zweryfikować prawdziwość skrótu HMAC z kluczem? Odpowiedź uzasadnij.

Użytkownik maszyny B musi znać dokładnie ten sam klucz symetryczny, który został użyty przez maszynę A do obliczenia funkcji HMAC. Jest to niezbędne, ponieważ funkcja HMAC wykorzystuje klucz nie tylko do skrócenia wiadomości, ale do generowania unikalnego podpisu kryptograficznego. Bez znajomości tego klucza niemożliwe jest odtworzenie tego samego HMAC i tym samym jego weryfikacja.

Jakie operacje musi wykonać użytkownik maszyny B jeżeli chce zweryfikować prawdziwość wiadomości i skrótu otrzymanych od użytkownika maszyny A? Odpowiedź uzasadnij.

Aby zweryfikować prawdziwość wiadomości i skrótu HMAC, użytkownik maszyny B musi:

1. Otrzymać wiadomość i oryginalny HMAC od użytkownika maszyny A.
2. Upewnić się, że posiada ten sam klucz, który został użyty do wygenerowania HMAC.
3. Obliczyć lokalnie nowy HMAC z otrzymanej wiadomości, używając tego samego algorytmu (MD5) i klucza.
4. Porównać wynik z otrzymanym HMAC.

Jeśli oba skróty są identyczne, oznacza to, że wiadomość nie została zmodyfikowana oraz że HMAC został wygenerowany z właściwego klucza. W przeciwnym razie wiadomość mogła zostać zmieniona lub klucz jest niepoprawny.

Zadanie 4

Treść Zadania: Dokonaj oceny wydajności algorytmów obliczających skrót wiadomości. Wypełnij Tabelę 1 wpisując wartość średnią czasu obliczania funkcji skrótu obliczoną z 12 pomiarów. Stwórz

pliki o rozmiarach: 100kB, 1MB, 10MB, 100MB. Do tego celu można użyć poniższej komendy:

```
openssl rand -out nazwa_pliku.txt rozmiar_pliku_w_bajtach
```

Do sprawdzenia czasu wykonywania operacji obliczania skrótu można wykorzystać komendę 'time':

```
time polecenie_obliczające_skrót
```

Przykładowy wynik polecenia: time

```
real 0m5.126s
user 0m0.004s
sys 0m0.012s
```

Wpisz przedziały ufności obliczone dla poziomu ufności równego 95%. Wyniki przedstaw również w postaci wykresu. W sprawozdaniu umieść analizę wyników wydajności obliczania funkcji skrótu (sprawdź wyniki – uzyskane czasy dla różnych rozmiarów wiadomości wejściowych oraz dla różnych rozmiarów funkcji skrótu).

Realizacja

```
root@WSL:lab5_pliki> ls
'Lab5 - PI zaoczne - funkcje skrótu.pdf'   MD5dgst       SHA1dgst
SHA256dgst       collisions   iha1     key.txt   message.txt   script.sh
'Lab5 - funkcja skrótu.pdf'                MD5dgst_mod   SHA1dgst_mod
SHA256dgst_mod   hmac.md5     iha1.c   message   msg
root@WSL:lab5_pliki> openssl rand -out file_100KB.txt 102400
root@WSL:lab5_pliki> openssl rand -out file_1MB.txt 1048576
root@WSL:lab5_pliki> openssl rand -out file_10MB.txt 10485760
root@WSL:lab5_pliki> openssl rand -out file_100MB.txt 104857600
root@WSL:lab5_pliki> ls -lah file_*
-rwxrwxrwx 1 root root 100K May  4 12:01 file_100KB.txt
-rwxrwxrwx 1 root root 100M May  4 12:02 file_100MB.txt
-rwxrwxrwx 1 root root  10M May  4 12:02 file_10MB.txt
-rwxrwxrwx 1 root root 1.0M May  4 12:01 file_1MB.txt
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -md5
file_100KB.txt; done
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.024s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.019s
user    0m0.016s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5
```

```
real    0m0.015s
user    0m0.016s
sys     0m0.000s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.013s
user    0m0.000s
sys     0m0.000s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.015s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.016s
user    0m0.000s
sys     0m0.000s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.013s
user    0m0.000s
sys     0m0.000s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.013s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.013s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.015s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.013s
user    0m0.000s
sys     0m0.016s
MD5(file_100KB.txt)= 4f03d8f7e57ee31b3c17495e0ce06af5

real    0m0.022s
user    0m0.000s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -md5
file_1MB.txt; done
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48
```

```
real    0m0.030s
user    0m0.000s
sys     0m0.016s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.027s
user    0m0.000s
sys     0m0.016s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.020s
user    0m0.000s
sys     0m0.031s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.015s
user    0m0.000s
sys     0m0.000s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.018s
user    0m0.016s
sys     0m0.000s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.017s
user    0m0.016s
sys     0m0.000s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.019s
user    0m0.016s
sys     0m0.000s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.018s
user    0m0.000s
sys     0m0.016s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.019s
user    0m0.000s
sys     0m0.016s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.017s
user    0m0.000s
sys     0m0.016s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48
```

```
real    0m0.017s
user    0m0.016s
sys     0m0.000s
MD5(file_1MB.txt)= ea593a12c931984a6264a4de0927fd48

real    0m0.018s
user    0m0.000s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -md5
file_10MB.txt; done
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.064s
user    0m0.031s
sys     0m0.047s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.074s
user    0m0.047s
sys     0m0.016s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.063s
user    0m0.016s
sys     0m0.047s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.046s
user    0m0.031s
sys     0m0.031s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.054s
user    0m0.016s
sys     0m0.031s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.047s
user    0m0.031s
sys     0m0.016s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.046s
user    0m0.000s
sys     0m0.047s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.048s
user    0m0.031s
sys     0m0.016s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48
```

```
real    0m0.049s
user    0m0.000s
sys     0m0.047s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.052s
user    0m0.047s
sys     0m0.000s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.053s
user    0m0.016s
sys     0m0.047s
MD5(file_10MB.txt)= 677b6469023155d6a9b3990ebeb53a48

real    0m0.049s
user    0m0.000s
sys     0m0.031s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -md5
file_100MB.txt; done
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.377s
user    0m0.156s
sys     0m0.219s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.329s
user    0m0.250s
sys     0m0.078s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.328s
user    0m0.172s
sys     0m0.156s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.344s
user    0m0.234s
sys     0m0.109s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.320s
user    0m0.219s
sys     0m0.094s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.327s
user    0m0.188s
sys     0m0.125s
```

```
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.378s
user    0m0.156s
sys     0m0.203s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.459s
user    0m0.234s
sys     0m0.156s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.383s
user    0m0.109s
sys     0m0.234s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.361s
user    0m0.203s
sys     0m0.156s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.325s
user    0m0.141s
sys     0m0.188s
MD5(file_100MB.txt)= e302cb832b2a2531ac1b656e01bb4dc0

real    0m0.331s
user    0m0.219s
sys     0m0.109s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha1
file_100KB.txt; done
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.024s
user    0m0.016s
sys     0m0.031s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.022s
user    0m0.000s
sys     0m0.016s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.016s
user    0m0.000s
sys     0m0.016s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.019s
user    0m0.016s
```

```
sys     0m0.016s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.017s
user    0m0.000s
sys     0m0.016s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.020s
user    0m0.016s
sys     0m0.000s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.037s
user    0m0.000s
sys     0m0.031s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.025s
user    0m0.000s
sys     0m0.031s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.025s
user    0m0.000s
sys     0m0.031s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.023s
user    0m0.016s
sys     0m0.000s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.021s
user    0m0.016s
sys     0m0.000s
SHA1(file_100KB.txt)= 43d90d029d1ad2c22d1f8aad9aad67c3ab938ab9

real    0m0.024s
user    0m0.000s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha1
file_1MB.txt; done
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.032s
user    0m0.000s
sys     0m0.031s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.025s
```

```
user    0m0.031s
sys     0m0.000s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.017s
user    0m0.016s
sys     0m0.000s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.018s
user    0m0.016s
sys     0m0.000s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.017s
user    0m0.016s
sys     0m0.000s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.019s
user    0m0.000s
sys     0m0.016s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.020s
user    0m0.000s
sys     0m0.016s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.016s
user    0m0.016s
sys     0m0.000s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.019s
user    0m0.000s
sys     0m0.016s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.018s
user    0m0.000s
sys     0m0.016s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.019s
user    0m0.000s
sys     0m0.016s
SHA1(file_1MB.txt)= a09e312fddb0f0be72dd3285d979fe32744fa59a

real    0m0.019s
user    0m0.000s
```

```
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha1
file_10MB.txt; done
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.065s
user    0m0.031s
sys     0m0.031s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.048s
user    0m0.047s
sys     0m0.000s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.055s
user    0m0.016s
sys     0m0.031s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.051s
user    0m0.047s
sys     0m0.000s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.048s
user    0m0.016s
sys     0m0.031s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.050s
user    0m0.000s
sys     0m0.047s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.049s
user    0m0.000s
sys     0m0.047s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.046s
user    0m0.031s
sys     0m0.016s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.047s
user    0m0.031s
sys     0m0.000s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.051s
```

```
user    0m0.031s
sys     0m0.031s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.053s
user    0m0.031s
sys     0m0.016s
SHA1(file_10MB.txt)= 9152bc8e13eb8c17e56e51ba15d71aaaa39a2fe1

real    0m0.059s
user    0m0.016s
sys     0m0.047s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha1
file_100MB.txt; done
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.357s
user    0m0.203s
sys     0m0.141s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.313s
user    0m0.203s
sys     0m0.109s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.312s
user    0m0.141s
sys     0m0.172s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.344s
user    0m0.172s
sys     0m0.156s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.313s
user    0m0.203s
sys     0m0.109s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.306s
user    0m0.172s
sys     0m0.141s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.306s
user    0m0.188s
sys     0m0.109s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d
```

```
real    0m0.343s
user    0m0.172s
sys     0m0.156s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.318s
user    0m0.141s
sys     0m0.172s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.463s
user    0m0.188s
sys     0m0.188s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.438s
user    0m0.188s
sys     0m0.234s
SHA1(file_100MB.txt)= ca0386620ae9dc54e7d8c79d829c61ca7e4a586d

real    0m0.370s
user    0m0.109s
sys     0m0.234s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -ripemd160
file_100KB.txt; done
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.029s
user    0m0.000s
sys     0m0.031s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.027s
user    0m0.016s
sys     0m0.031s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.021s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.013s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.016s
user    0m0.000s
sys     0m0.000s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8
```

```
real    0m0.017s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.015s
user    0m0.000s
sys     0m0.031s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.017s
user    0m0.000s
sys     0m0.000s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.016s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.016s
user    0m0.016s
sys     0m0.000s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.016s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_100KB.txt)= 07401aa0d95727840474b7b898c3aa2d760211d8

real    0m0.014s
user    0m0.000s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -ripemd160
file_1MB.txt; done
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.033s
user    0m0.016s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.027s
user    0m0.016s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.022s
user    0m0.000s
sys     0m0.016s
```

```
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.022s
user    0m0.016s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.021s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.019s
user    0m0.016s
sys     0m0.000s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.021s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.022s
user    0m0.016s
sys     0m0.000s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.023s
user    0m0.016s
sys     0m0.000s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.021s
user    0m0.016s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.024s
user    0m0.000s
sys     0m0.016s
RIPEMD-160(file_1MB.txt)= 2dcbca141d6acce6526201ded225b2c6fd3109bb

real    0m0.023s
user    0m0.016s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -ripemd160
file_10MB.txt; done
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.091s
user    0m0.078s
```

```
sys     0m0.016s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.072s
user    0m0.063s
sys     0m0.016s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.084s
user    0m0.047s
sys     0m0.031s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.074s
user    0m0.063s
sys     0m0.016s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.083s
user    0m0.063s
sys     0m0.016s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.101s
user    0m0.047s
sys     0m0.063s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.082s
user    0m0.031s
sys     0m0.047s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.078s
user    0m0.047s
sys     0m0.031s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.075s
user    0m0.047s
sys     0m0.031s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.081s
user    0m0.078s
sys     0m0.000s
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.074s
user    0m0.063s
sys     0m0.016s
```

```
RIPEMD-160(file_10MB.txt)= 97b4b834657a6a54e3a4eb8817ba9673c7574b20

real    0m0.077s
user    0m0.078s
sys     0m0.000s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -ripemd160
file_100MB.txt; done
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.590s
user    0m0.391s
sys     0m0.156s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.602s
user    0m0.438s
sys     0m0.156s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.598s
user    0m0.375s
sys     0m0.203s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.579s
user    0m0.500s
sys     0m0.063s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.599s
user    0m0.484s
sys     0m0.125s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.578s
user    0m0.453s
sys     0m0.125s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.613s
user    0m0.438s
sys     0m0.156s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.738s
user    0m0.484s
sys     0m0.125s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.642s
user    0m0.406s
```

```
sys     0m0.203s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.598s
user    0m0.422s
sys     0m0.172s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.583s
user    0m0.406s
sys     0m0.172s
RIPEMD-160(file_100MB.txt)= dd1d60985cb5d1fe4ca74e4bfe67eff81a3fc6b0

real    0m0.599s
user    0m0.516s
sys     0m0.078s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha256
file_100KB.txt; done
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.028s
user    0m0.016s
sys     0m0.016s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.020s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.019s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.014s
user    0m0.016s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.014s
user    0m0.000s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6
```

```
real    0m0.014s
user    0m0.000s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.013s
user    0m0.000s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.020s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.015s
user    0m0.000s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.017s
user    0m0.016s
sys     0m0.000s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.016s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_100KB.txt)=
b358773a3fabeb9d5b89d6b0ac2488c9f87dc0b2f079c49d9c9505f71a7a4fb6

real    0m0.018s
user    0m0.016s
sys     0m0.000s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha256
file_1MB.txt; done
SHA2-256(file_1MB.txt)=
d04a5db034681193806928f8db7765b9062b1ee2168c3726868f076e8a2523a1

real    0m0.066s
user    0m0.016s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db034681193806928f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.022s
```

```
user    0m0.000s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.018s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.025s
user    0m0.016s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.023s
user    0m0.000s
sys     0m0.000s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.023s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.025s
user    0m0.000s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.025s
user    0m0.016s
sys     0m0.000s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.026s
user    0m0.016s
sys     0m0.016s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.027s
user    0m0.000s
sys     0m0.031s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
```

```
168c3726868f076e8a2523a1

real    0m0.025s
user    0m0.016s
sys     0m0.000s
SHA2-256(file_1MB.txt)= d04a5db0346811938069 28f8db7765b9062b1ee2
168c3726868f076e8a2523a1

real    0m0.026s
user    0m0.000s
sys     0m0.031s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha256
file_10MB.txt; done
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.118s
user    0m0.078s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.067s
user    0m0.016s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.070s
user    0m0.031s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.066s
user    0m0.000s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.088s
user    0m0.016s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.092s
user    0m0.031s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485
```

```
real    0m0.211s
user    0m0.078s
sys     0m0.000s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.101s
user    0m0.047s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.084s
user    0m0.031s
sys     0m0.047s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.096s
user    0m0.047s
sys     0m0.031s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.101s
user    0m0.078s
sys     0m0.031s
SHA2-256(file_10MB.txt)=
957e2f7928c80e45c8985425fb233c8931999554174630b5988a2c8eb9654485

real    0m0.119s
user    0m0.063s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha256
file_100MB.txt; done
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.547s
user    0m0.375s
sys     0m0.172s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.498s
user    0m0.406s
sys     0m0.094s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044
```

```
real    0m0.664s
user    0m0.453s
sys     0m0.109s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.596s
user    0m0.344s
sys     0m0.188s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.528s
user    0m0.406s
sys     0m0.125s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.493s
user    0m0.344s
sys     0m0.156s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.531s
user    0m0.359s
sys     0m0.156s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.502s
user    0m0.359s
sys     0m0.141s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.517s
user    0m0.391s
sys     0m0.125s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.499s
user    0m0.391s
sys     0m0.109s
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.516s
user    0m0.344s
sys     0m0.172s
```

```
SHA2-256(file_100MB.txt)=
fc9fcb2f436d19bb7c10e31417877562d376cdba9b3849f6febeb2b70e42c044

real    0m0.535s
user    0m0.422s
sys     0m0.109s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha512
file_100KB.txt; done
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.350s
user    0m0.000s
sys     0m0.031s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.030s
user    0m0.000s
sys     0m0.031s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.022s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.022s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.018s
user    0m0.016s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.018s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
```

```
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.016s
user    0m0.016s
sys     0m0.000s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.016s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.016s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.015s
user    0m0.000s
sys     0m0.000s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.016s
user    0m0.016s
sys     0m0.000s
SHA2-512(file_100KB.txt)=
5dcf54ef21315def5e4000c6cb2cf6af6f7bd870be26a4ca326cce4e608d5c17
154f3b0d1cbe4da54ff4894a82e88efddb6649a5b4aea14eb13e944d4c1d76f1

real    0m0.015s
user    0m0.016s
sys     0m0.000s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha512
file_1MB.txt; done
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.021s
user    0m0.016s
sys     0m0.000s
SHA2-512(file_1MB.txt)=
```

```
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.028s
user    0m0.016s
sys     0m0.000s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.024s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.023s
user    0m0.016s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.023s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.019s
user    0m0.016s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.018s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.020s
user    0m0.016s
sys     0m0.000s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2
```

```
real    0m0.022s
user    0m0.000s
sys     0m0.031s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.024s
user    0m0.000s
sys     0m0.000s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.017s
user    0m0.000s
sys     0m0.016s
SHA2-512(file_1MB.txt)=
89ae34f1f88b0e8dc68145ec2cd8e3b4b71110b776a614a223cde0cd0ee28190
5d1027d29bba21ea8818f3ab21255c3f0fe97ec72a7a31612e9815585341ddc2

real    0m0.021s
user    0m0.000s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha512
file_10MB.txt; done
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.083s
user    0m0.031s
sys     0m0.047s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.057s
user    0m0.047s
sys     0m0.000s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.062s
user    0m0.016s
sys     0m0.047s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867
```

```
real    0m0.055s
user    0m0.047s
sys     0m0.016s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.059s
user    0m0.016s
sys     0m0.047s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.086s
user    0m0.047s
sys     0m0.016s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.112s
user    0m0.078s
sys     0m0.016s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.214s
user    0m0.078s
sys     0m0.016s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.085s
user    0m0.047s
sys     0m0.031s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.081s
user    0m0.063s
sys     0m0.016s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.084s
```

```
user    0m0.016s
sys     0m0.047s
SHA2-512(file_10MB.txt)=
de1c89088577ccc89bd7fae0859577d4598385d4d71f0f49effcaecd9bda1d6f94da5395d163
b368c2887badc1f98749d49e6b659831d3616db62c086cf96867

real    0m0.085s
user    0m0.063s
sys     0m0.016s
root@WSL:lab5_pliki> for i in {1..12}; do time openssl dgst -sha512
file_100MB.txt; done
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.416s
user    0m0.281s
sys     0m0.125s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.390s
user    0m0.219s
sys     0m0.172s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.433s
user    0m0.266s
sys     0m0.172s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.663s
user    0m0.344s
sys     0m0.125s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.587s
user    0m0.375s
sys     0m0.188s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.452s
```

```
user    0m0.266s
sys     0m0.172s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.425s
user    0m0.313s
sys     0m0.109s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.394s
user    0m0.250s
sys     0m0.141s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.411s
user    0m0.266s
sys     0m0.125s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.422s
user    0m0.266s
sys     0m0.156s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.398s
user    0m0.250s
sys     0m0.141s
SHA2-512(file_100MB.txt)=
a36f6a029dcf6195926179cdd260e6133e8638a300f83eeaf74589ff639b267837f846108dcf
fb85734da58037dd274013f5a649c1d0107b13f8a0872f909a1e

real    0m0.429s
user    0m0.297s
sys     0m0.141s
root@WSL:lab5_pliki>
```

Analiza wydajności dla każdego algorytmu

Poniżej zestawiono średnie czasy „real” (w sekundach) i 95% przedziały ufności dla 12 pomiarów

każdego algorytmu i rozmiaru pliku. Wspólny współczynnik t-Studenta dla 11 stopni swobody: $t_{0.975,11}\approx2.201$.

Wzory obliczeniowe

Średnia arytmetyczna

$$\bar{x} \;=\;\frac{1}{n}\sum_{i=1}^{n}x_i$$

- **x_i** wartość i-tego pomiaru czasu,
- **n** liczba pomiarów (w naszym przypadku $n=12$),
- **$\bar{x}$** średnia arytmetyczna zestawu pomiarów.

Odchylenie standardowe próbki

$$s \;=\;\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

- **x_i** wartość i-tego pomiaru,
- **$\bar{x}$** średnia arytmetyczna pomiarów,
- **n** liczba pomiarów,
- **s** odchylenie standardowe obliczone dla próby.

Przedział ufności 95%

$$\bar{x} \;\pm\; t_{\alpha/2,\;n-1}\,\frac{s}{\sqrt{n}}$$

- **$\bar{x}$** średnia arytmetyczna pomiarów,
- **s** odchylenie standardowe próby,
- **n** liczba pomiarów,
- **α** poziom istotności (tutaj $\alpha=0{,}05$ dla 95% ufności),
- **$t_{\alpha/2,\;n-1}$** wartość statystyki t-Studenta dla rozkładu o $n-1$ stopniach swobody (tutaj $t_{0{,}975,11}\approx2{,}201$),
- **$\displaystyle\frac{s}{\sqrt{n}}$** błąd standardowy średniej.

MD5

100 kB

- Czasy (s): 0.024, 0.019, 0.015, 0.013, 0.015, 0.016, 0.013, 0.013, 0.013, 0.015, 0.013, 0.022
- Średnia: $\bar{x}=0.01592$, odchylenie standardowe: $s=0.00378$
- Przedział ufności 95%: $[0.01352,\;0.01832]$

1 MB

- Czasy (s): 0.030, 0.027, 0.020, 0.015, 0.018, 0.017, 0.019, 0.018, 0.019, 0.017, 0.017, 0.018
- Średnia: $\bar{x}=0.01958$, odchylenie standardowe: $s=0.00440$
- Przedział ufności 95%: $[0.01679,\;0.02238]$

10 MB

- Czasy (s): 0.064, 0.074, 0.063, 0.046, 0.054, 0.047, 0.046, 0.048, 0.049, 0.052, 0.053, 0.049
- Średnia: $\bar{x}=0.05375$, odchylenie standardowe: $s=0.00878$
- Przedział ufności 95%: $[0.04817,\;0.05933]$

100 MB

- Czasy (s): 0.377, 0.329, 0.328, 0.344, 0.320, 0.327, 0.378, 0.459, 0.383, 0.361, 0.325, 0.331
- Średnia: $\bar{x}=0.35517$, odchylenie standardowe: $s=0.04007$
- Przedział ufności 95%: $[0.32971,\;0.38063]$

SHA-1

100 kB

- Czasy (s): 0.024, 0.022, 0.016, 0.019, 0.017, 0.020, 0.037, 0.025, 0.025, 0.023, 0.021, 0.024
- Średnia: $\bar{x}=0.02275$, odchylenie standardowe: $s=0.00540$
- Przedział ufności 95%: $[0.01932,\;0.02618]$

1 MB

- Czasy (s): 0.032, 0.025, 0.017, 0.018, 0.017, 0.019, 0.020, 0.016, 0.019, 0.018, 0.019, 0.019
- Średnia: $\bar{x}=0.01992$, odchylenie standardowe: $s=0.00442$
- Przedział ufności 95%: $[0.01711,\;0.02273]$

10 MB

- Czasy (s): 0.065, 0.048, 0.055, 0.051, 0.048, 0.050, 0.049, 0.046, 0.047, 0.051, 0.053, 0.059
- Średnia: $\bar{x}=0.05183$, odchylenie standardowe: $s=0.00552$
- Przedział ufności 95%: $[0.04832,\;0.05534]$

100 MB

- Czasy (s): 0.357, 0.313, 0.312, 0.344, 0.313, 0.306, 0.306, 0.343, 0.318, 0.463, 0.438, 0.370
- Średnia: $\bar{x}=0.34858$, odchylenie standardowe: $s=0.05231$
- Przedział ufności 95%: $[0.31535,\;0.38182]$

RIPEMD-160

100 kB

- Czasy (s): 0.029, 0.027, 0.021, 0.013, 0.016, 0.017, 0.015, 0.017, 0.016, 0.016, 0.016, 0.014
- Średnia: $\bar{x}=0.01808$, odchylenie standardowe: $s=0.00504$
- Przedział ufności 95%: $[0.01488,\;0.02128]$

1 MB

- Czasy (s): 0.033, 0.027, 0.022, 0.022, 0.021, 0.019, 0.021, 0.022, 0.023, 0.021, 0.024, 0.023
- Średnia: $\bar{x}=0.02317$, odchylenie standardowe: $s=0.00419$
- Przedział ufności 95%: $[0.02045,\;0.02589]$

10 MB

- Czasy (s): 0.091, 0.072, 0.084, 0.074, 0.083, 0.101, 0.082, 0.078, 0.075, 0.081, 0.074, 0.077
- Średnia: $\bar{x}=0.08158$, odchylenie standardowe: $s=0.00870$
- Przedział ufności 95%: $[0.07639,\;0.08678]$

100 MB

- Czasy (s): 0.590, 0.602, 0.598, 0.579, 0.599, 0.578, 0.613, 0.738, 0.642, 0.598, 0.583, 0.599
- Średnia: $\bar{x}=0.61450$, odchylenie standardowe: $s=0.04909$
- Przedział ufności 95%: $[0.58439,\;0.64461]$

SHA-256

100 kB

- Czasy (s): 0.028, 0.020, 0.019, 0.014, 0.014, 0.014, 0.013, 0.020, 0.015, 0.017, 0.016, 0.018
- Średnia: $\bar{x}=0.01775$, odchylenie standardowe: $s=0.00425$
- Przedział ufności 95%: $[0.01511,\;0.02039]$

1 MB

- Czasy (s): 0.066, 0.022, 0.018, 0.025, 0.023, 0.023, 0.025, 0.025, 0.026, 0.027, 0.025, 0.026
- Średnia: $\bar{x}=0.02483$, odchylenie standardowe: $s=0.01327$
- Przedział ufności 95%: $[0.01893,\;0.03074]$

10 MB

- Czasy (s): 0.118, 0.067, 0.070, 0.066, 0.088, 0.092, 0.211, 0.101, 0.084, 0.096, 0.101, 0.119

- Średnia: $\bar{x}=0.10167$, odchylenie standardowe: $s=0.03507$
- Przedział ufności 95%: $[0.07639,\;0.12695]$

100 MB

- Czasy (s): 0.547, 0.498, 0.664, 0.596, 0.528, 0.493, 0.531, 0.502, 0.517, 0.499, 0.516, 0.535
- Średnia: $\bar{x}=0.53550$, odchylenie standardowe: $s=0.04933$
- Przedział ufności 95%: $[0.50416,\;0.56684]$

SHA-512

100 kB

- Czasy (s): 0.350, 0.030, 0.022, 0.022, 0.018, 0.018, 0.016, 0.016, 0.016, 0.016, 0.015, 0.016
- Średnia: $\bar{x}=0.04625$, odchylenie standardowe: $s=0.09575$

1 MB

- Czasy (s): 0.021, 0.028, 0.024, 0.023, 0.023, 0.019, 0.018, 0.020, 0.022, 0.024, 0.017, 0.021
- Średnia: $\bar{x}=0.02167$, odchylenie standardowe: $s=0.00303$
- Przedział ufności 95%: $[0.01974,\;0.02359]$

10 MB

- Czasy (s): 0.083, 0.057, 0.062, 0.055, 0.059, 0.086, 0.112, 0.214, 0.085, 0.081, 0.084, 0.085
- Średnia: $\bar{x}=0.08858$, odchylenie standardowe: $s=0.04278$
- Przedział ufności 95%: $[0.06141,\;0.11576]$

100 MB

- Czasy (s): 0.416, 0.390, 0.433, 0.663, 0.587, 0.452, 0.425, 0.394, 0.411, 0.422, 0.398, 0.429
- Średnia: $\bar{x}=0.45167$, odchylenie standardowe: $s=0.08440$
- Przedział ufności 95%: $[0.39804,\;0.50529]$

Wykres

graph_hash.py

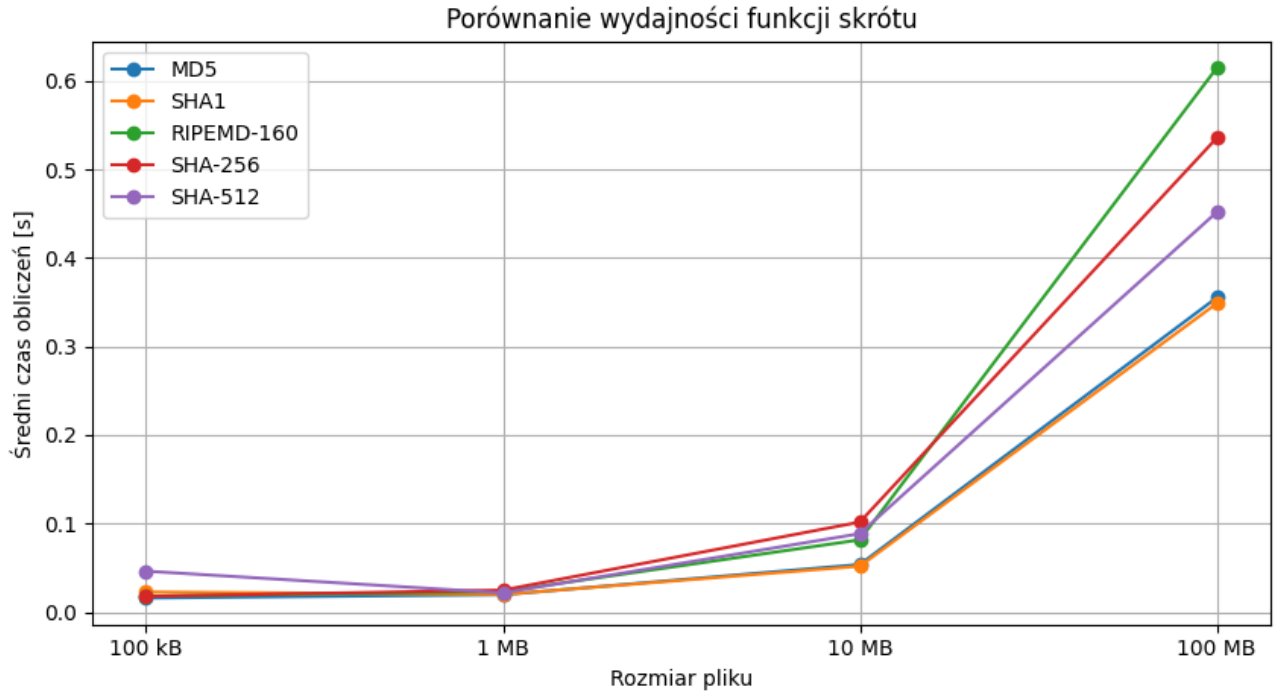
```python
import matplotlib.pyplot as plt

# Average times (in seconds) for each algorithm and file size
file_sizes = ["100 kB", "1 MB", "10 MB", "100 MB"]
md5_times = [0.01592, 0.01958, 0.05375, 0.35517]
sha1_times = [0.02275, 0.01992, 0.05183, 0.34858]
```

```
ripemd160_times = [0.01808, 0.02317, 0.08158, 0.61450]
sha256_times = [0.01775, 0.02483, 0.10167, 0.53550]
sha512_times = [0.04625, 0.02167, 0.08858, 0.45167]

plt.figure()
plt.plot(file_sizes, md5_times, marker='o', label='MD5')
plt.plot(file_sizes, sha1_times, marker='o', label='SHA1')
plt.plot(file_sizes, ripemd160_times, marker='o', label='RIPEMD-160')
plt.plot(file_sizes, sha256_times, marker='o', label='SHA-256')
plt.plot(file_sizes, sha512_times, marker='o', label='SHA-512')

plt.xlabel("Rozmiar pliku")
plt.ylabel("Sredni czas obliczen [s]")
plt.title("Porównanie wydajności funkcji skrótu")
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
```



Wykres porównujący wydajność funkcji skrótu

Tabela

Wydajność obliczania funkcji skrótu (średni czas „real” w sekundach z 12 pomiarów)

	100 kB	**1 MB**	**10 MB**	**100 MB**
MD5	0.0159	0.0196	0.0538	0.3552

	100 kB	**1 MB**	**10 MB**	**100 MB**
SHA1	0.0228	0.0199	0.0518	0.3486
RMD160	0.0181	0.0232	0.0816	0.6145
SHA256	0.0178	0.0248	0.1017	0.5355
SHA512	0.0463	0.0217	0.0886	0.4517